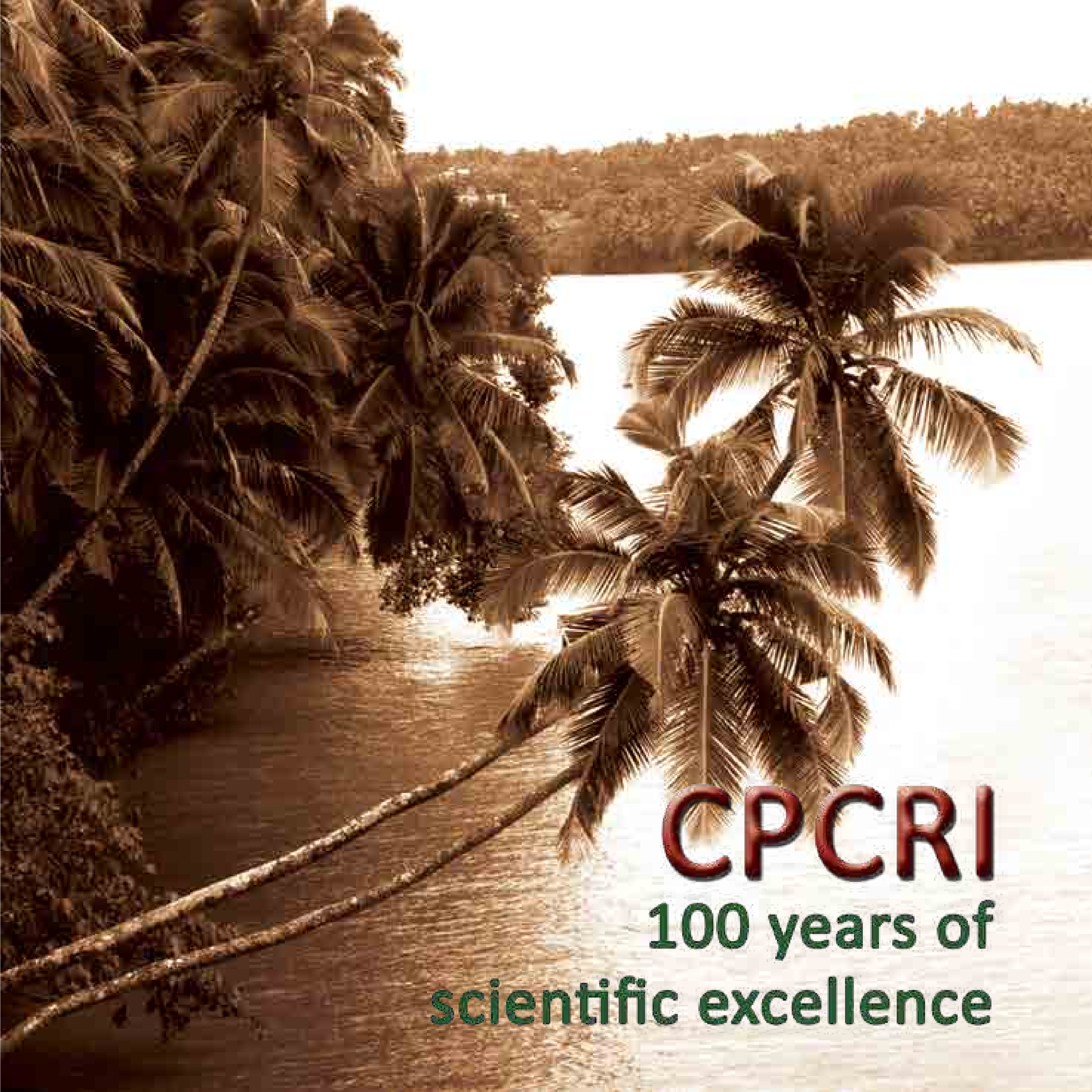

CPCRI

100 years of scientific excellence

CPCRI: 100 Years of Scientific Excellence

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FOREWORD

Plantation crops have a unique role in the national economy of the country. Apart from earning valuable foreign exchange and providing basic raw materials for a number of industries, these crops form the backbone of the agrarian economy of the nation and the lifeline of many states in India.

I am happy to note that ICAR-Central Plantation Crops Research Institute, is bringing out an exemplary book "CPCRI: 100 Years of Scientific Excellence", commemorating the centenary of coconut research in India and 100 glorious years of the institution since its inception in 1916. This book is unique in that it encapsulates history of the CPCRI from its origin, evolution over the years, salient research achievements and a futuristic vision for not only the present mandate crops of the institute (coconut, arecanut and cocoa), but also spices, cashew and oil palm, which were also dealt in the early days.

The story of the origin and early progression of research and development in plantation crops is an episode out of the larger story of the colonial endeavours to introduce and institutionalize agriculture science in India in the early 20th century. ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), the premier research institution in the National Agricultural Research System of India, had a modest origin with its lineage tracing back to the Coconut Research Station started in 1916 at Kudlu village (of present Kasaragod district of Kerala in Southern India) in the South Kanara district of erstwhile Madras presidency. The story of 100 years journey of CPCRI, evolving from the Coconut Station in 1916 to the two Central Coconut Research Stations at Kasaragod and Kayamkulam under the Indian Central Coconut Committee and their eventual merger with the Central Arecanut Research Station along with its sub-stations (under the Indian Central Arecanut Committee) to a unified research institute in 1970, subsequent reorganization in the 1980s leading to delinking of research in spices, cashew and oil palm with the establishment of independent research institutions and the phenomenal growth of all the four research institutions, is really fascinating.

Ever since its inception, CPCRI has served the cause of science and society with distinction through exemplary research, generation of appropriate technologies and reaching out to the farmers. Considering its exemplary achievements, the institute was conferred with almost every award for institutional, team and individual excellence under the ICAR.

I congratulate Director and his team in bringing out such an innovative and inspirational book, showcasing its glorious history and achievements. I wish the institute all the best in its pursuit of excellence in all scientific endeavours.

(Dr. Trilochan Mohapatra)

Secretary, DARE & Director General, ICAR

PREFACE

This book endeavours to open a window to the world of plantation crops in India and most pertinently, ICAR-Central Plantation Crops Research Institute (CPCRI), the epicentre of plantation crops R&D, taking the reader along its 100 years journey from the genesis, through its evolution, achievements, the present day realities in the plantation crops sector and a vision for the future. It was not conceived to be an up-to-date scientific review of voluminous research in plantation crops for over a century or an exhaustive compendium of its massive research achievements. The contents are carefully selected and the style calibrated suitably for a pleasant easy reading.

You will agree with me that crops like coconut, arecanut and spices are not just agricultural or market commodities for us, they are monuments of our own cherished culture and heritage, for we were born, have grown up and evolved with them. The journey down the memory lane begins with select anecdotes of history and vignettes in research accomplishments, not necessarily in the strict chronological order, as objects would appear in a child's kaleidoscope, giving you a mesmerizing reading experience. Next three chapters give you a better perception of the current research activities and most pertinent achievements and glimpses of a futuristic vision in coconut, arecanut and cocoa.

The story of the CPCRI joint-family would not have been complete without an account of the birth and growth of the siblings as well. Hence, next three chapters give an account of the history of the research establishment and the prodigious research achievements in spices, cashew and oil palm, initially under CPCRI and later under the present-day institutions - IISR, Kozhikode, DCR, Puttur and IIOPR, Pedavegi.

Unity in diversity is in our national character. In a geographically and agro-climatically diverse country like India, crops and farming systems are no exception. Location-specific research is key to finding local solutions to local problems. Deservingly, an account of the national network of research stations under the AICRP (Palms) catering to the requirements of location-specific research is given in the last chapter.

As in any account of history, the name and work of a very few key personalities, mostly the pioneers and founding fathers who single handedly changed the course of history, is only specifically mentioned in this account. It does not, in any way, belittle the contributions of hundreds of colleagues past and present, all worthy men and women who have steadfastly served the cause of these crops over the last 100 years.

In this centenary year of coconut research, it has been our endeavour to place CPCRI in the right perspective, for a better understanding of its history and appreciation of its contributions to plantation crops. I hope, a better appreciation of the invaluable contributions of our dedicated and pioneering workers of yester years with limited facilities and manpower then, will inspire the present day researchers, positioned far more advantageously, to greater achievements in their scientific pursuits.

(P. Chowdappa)
Director

100 YEARS IN EVOLUTION: FOUNDATION IN THE COLONIAL AND THE MANSION IN THE INDEPENDENT INDIA

ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), the premier research institution in the National Agricultural Research Systems of India, presently mandated to conduct research in plantations crops (coconut, arecanut and cocoa), had a modest origin with its lineage tracing back to the Coconut Research Station started in 1916 at Kudlu village (of present Kasaragod district of Kerala in Southern India) in the South Kanara district of erstwhile Madras Presidency. Ever since its inception, it has served the cause of science and society with distinction through exemplary research, generation of appropriate technologies and development of skilled human resource.

The story of the origin and early progression of research and development in plantation crops is an episode out of the larger story of the colonial endeavours to introduce and institutionalize agriculture science in India, in general, and Madras Presidency, in particular. Plantation crops, which include perennial crops like tea, cashew, coffee, coconut, arecanut, rubber, cocoa, oil palm and spices such as cardamom, pepper etc. have a unique role in the national economy of the country. Apart from earning valuable foreign exchange, these crops form the backbone of the economy of the nation and the lifeline of many of the southern states, in particular, and provide basic raw materials for a number of industries. Despite the physical dissimilarities in the growth habits and requirements, and an amazing diversity in the nature of the economically useful parts of these plants, there are broad resemblances in problems concerning improvement in their plant type, environments in which they grow, their protection from biological hazards and their post harvest technology. Destinies of about a dozen crops in India are intricately intertwined in this grand epic, with the three crops (coconut, arecanut and cocoa) being the integral part of the storyline.

Organized agricultural research was initiated in the first decade of the 20th century when agricultural colleges and agricultural experimental stations were started in the most important agricultural tracts in the Indian peninsula. The compulsions for exploring new revenue resources must have been enormous for the colonial administrators as the conventional land tax revenue resources were already stretched to the maximum. Equally 'tempting' must have been the enormous opportunities that the vast and most diverse land, blessed with all natural resources, offered for promoting cash-rich horticultural/plantation crops in the empire.

With the increased demand for coconut products in the European markets in the beginning of the 20th century, resulting from the expansion of the European soap and edible oil industry and with the introduction of better road and rail connectivity and increased shipping facilities in India, the export trade in coconut products expanded considerably. This 'economic prospect' must have been the driving force for taking up the cultivation and development of coconut in an organized manner.

Systematic research on coconut had its beginning in the year 1916 with the establishment of four research stations (representing the major soil groups of the coconut belts) in the then South Kanara district of the erstwhile Madras Presidency. Dr. H.C. Sampson, then Deputy Director of Agriculture at Tellicherry and the Economic Botanist at Kew later, is credited with laying the foundation for coconut research at these centres. The work of the Research Station at Kasaragod was actually managed by a farm manager and a field assistant. M. Govinda Kidavu, the son of the soil, succeeds Sampson as Deputy Director of Agriculture, VII Circle in 1921 and continues the good work of his predecessor more or less in the same direction. Then, J S. Patel joined as oilseed specialist in 1930, stationed at Coimbatore, and the coconut stations came under the oilseeds section.

The world trade in copra, coconut oil and other coconut products was seriously disturbed by the outbreak of the first and second World Wars. In the early part of the 20th century, India was in a formidable position in the export trade in copra (about 30,000 tonnes of copra annually) and coconut oil, with the concomitant performance on the production front. However, the price crash in the aftermath of the first World War and the prevailing general economic crisis forced the growers to neglect the cultivation, with the cascading decline in production and the imports gaining momentum. The acute shortage experienced in India in the supply of copra and coconut oil in 1942 was the catalyst for initiating concrete measures for intensifying the production of coconuts to meet the surging demands in the World War II scenario.

The turning point was in 1945, when the Indian Central Coconut Committee was set up to take measures for the improvement and development of Indian coconut sector to serve the entire need of the country. In 1947, the Committee took over the Coconut Research Station, Kasaragod (Kudlu) (out of the four stations started initially) and establishes the Central Coconut Research Station (CCRS), Kasaragod. Shri C.M. John becomes the first Director of CCRS at Kasaragod. Agronomy, Botany, Cytogenetics and Analytical Chemistry sections were established under it for intensive research.

Around this time, the State Department of Agriculture, under the princely state of Travancore, established the State Research Laboratory at Quilon and a field station at Kayamkulam to work on coconut diseases and control of different pests of coconut palm with emphasis on root (wilt) disease. Realizing the importance of tackling diseases in coconut, these two stations were transferred to the Central Coconut Committee in 1947. Later on, the Research Laboratory at Quilon was shifted and merged with Kayamkulam Station in 1949.

Coconut research became an integral part of the national agricultural research system of the country in 1966 when the Government of India abolished the Indian Central Coconut Committee and among the 'twin functionalities of R&D', the coconut research was taken over directly by the Indian Council of Agricultural Research and the development of the crop was entrusted to the Directorate of Coconut Development, which later transformed itself in to the Coconut Development Board in 1981.

There was another parallel storyline taking shape in the immediate neighbourhood. Arecanut industry in India was also passing through a crisis when the second World War broke out. By 1945, representations were made to the Central Board of Revenue regarding its deplorable plight, the heavy cost of cultivation and poor return mainly due to the absence of scientific research to improve cultivation and augment production, the heavy crop loss due to fruit-rot and the ill-developed marketing system in vogue. The unrestricted imports of arecanut at low prices from the East Pakistan (now Bangladesh) in the aftermath of the partition in 1947, further aggravated the problem. There was demand from arecanut farmers for immediate protection in some form or the other for the local industry for its survival.

As a first step towards the improvement of the industry, the Government of India set up an adhoc Committee under the Indian Council of Agricultural Research to formulate coordinated schemes for the purpose. On the recommendations of this committee, the Government of India, constituted the Indian Central Arecanut Committee (ICAC) in May, 1949. On the recommendations of a special sub-committee the ICAC, the Central Arecanut Research Station (CARS) was established at Vittal (in the erstwhile Madras State) in Karnataka in April, 1956, with an area of 6.7 ha of land acquired for the purpose. Dr. G.I. Patel took over as the first Arecanut Specialist in 1957.

The original scheme had only five scientists including an Arecanut Specialist who was the head of the Station. There were three sections *viz*, agronomy, botany and pathology. During 1963-64, two more sections, statistics and soil chemistry were added. Separate sections on entomology and plant physiology were established during 1964-65. The early research efforts were aimed at standardizing nursery techniques, determining various agronomic requirements *viz*., spacing, cultural, manurial and irrigation of the crop, introduction and evaluation of exotic germplasm lines along with promising local ones including dwarf types. Five Regional Arecanut Research Stations (RARS) were established in different agro-climatic regions of the country during 1958-59, one each at Palode, Peechi, Hirehalli, Mohitnagar and Kahikuchi.

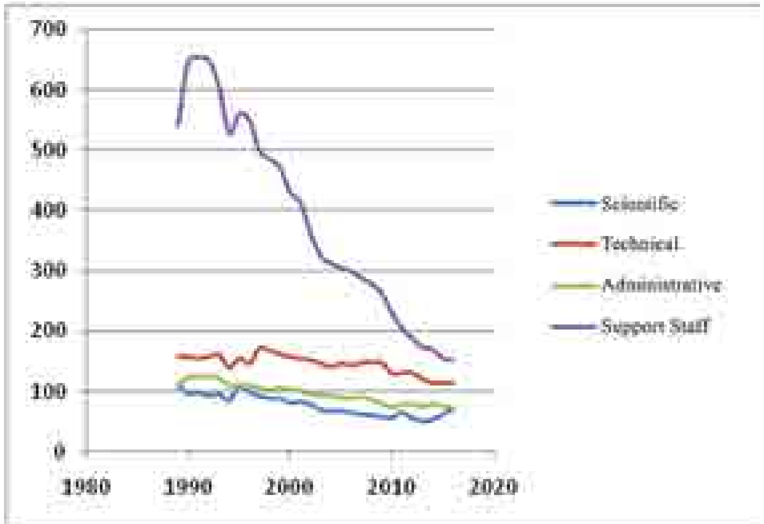
The defining moment in history was in 1970, when lCAR established the Central Plantation Crops Research Institute with headquarters at Kasaragod, by merging the Central Coconut Research Stations at Kasaragod and Kayamkulam and the Central Arecanut Research Station at Vittal along with its five substations at Kannara, Mohitnagar, Kahikuchi, Hirehalli and Palode. Consequent to the establishment of the unified institute, CCRS at Kayamkulam was made a Regional Station to work on pest and diseases of coconut, while the CARS at Vittal was also made a Regional Station of the Institute, with a mandate to carry out research on arecanut and cocoa and the Regional Arecanut Research Stations were converted as Research Centres of CPCRI. Dr. K.V. Ahmed Bavappa took over as the first Director of CPCRI in January 1970. Systematic research on cocoa production technologies was also started during 1970 and the introduction of cocoa as mixed crop under arecanut and coconut has provided sustained production models. For these crops, it is a story of 'parallel evolution' in the early days, the 'co-evolution' and then evolving further as a 'single entity' in the company of one another.

There is lot more to the story of 'kingdom of plantation crops research'. Mandate of the new institute was enlarged with addition of cashew, oil palm, black pepper, cardamom and other spice crops under its responsibility. Establishment of the Seed Farm at Kidu in 1972 and Shantigodu in 1973, both in Karnataka, to produce quality planting materials of mandate crops was another milestone in the organizational evolution. The ICAR Research Complex for Lakshadweep Islands at Minicoy was handed over to CPCRI in 1975. The administrative control of the ICAR Research Complex for Goa was also vested with the institute in 1975, the final act in consolidation of the 'CPCRI empire'. Simultaneously, two All India Coordinated Crop Improvement Projects pertaining to these crops were also initiated so as to coordinate the work done by various agencies in different parts of the country. The All India Co-ordinated Coconut and Arecanut Improvement Project and Cashewnut and Spices Improvement Project came into operation with effect from 1st October 1970 and 2nd December, 1970 respectively. The network was further strengthened in the later years.

In the initial years, the paltry funding for the agriculture department and research stations under it came from the provincial exchequer of the Madras Presidency. Under the dispensation of Central Coconut and Arecanut Committees, limited funding came directly from the government, supplemented with the agricultural commodity cess in part. Paucity of funds was a major problem. The total cess fund for coconut was around ₹ 6 lakhs and of this, around 1 to1.5 lakhs usually were allotted for Kayangulam and 2 to 2.5 lakhs for Kasaragod in the Annual Budget. In the post independent India, science and scientific institutions including agricultural research received prime attention and concomitant funding and in fact the focus during the second five year plan was on agriculture. Pandit Jawahar Lal Nehru, the first Prime Minister of India, is stated to have remarked "Everything else can wait, but not agriculture", which sums up the priority that agriculture received in the early days of independent India.

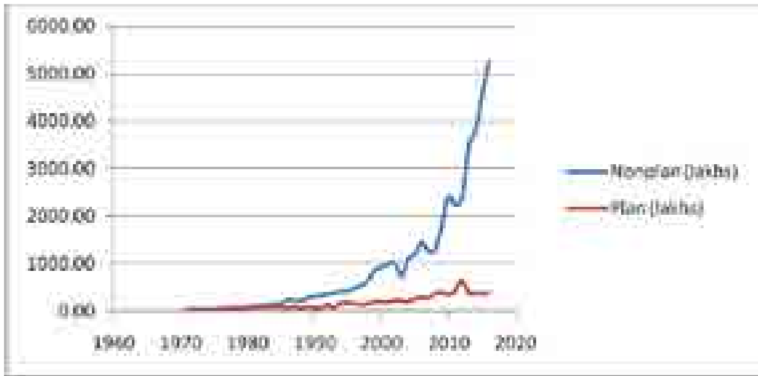
With sustained funding and patronage from the ICAR, the apex body coordinating agricultural research in India, CPCRI grew as one of the large R&D institution in the ICAR system in terms of the large number of mandate crops, its pan India presence with research centres in almost all important cropping tracts (along with AICRP), expansive infrastructure, manpower and financial resources.

When the institute was established in 1970, the total staff strength was 468 (including 90 scientists), which by the end of 1980 got increased to 1,042 with 152 scientists and concomitant increase in all other cadres. By 1986, after the reorganization, the total staff strength in the Institute was 882 comprising of 170 scientists working in 16 disciplines, assisted by a team of 173 technical, 23 auxiliary, 121 administrative and 565 supporting staff. In 2000, the total staff (including KVK) was 866 with 756 in position (including 83 scientific personnel) which by 2010, got further downsized to 640 (including KVKs) with 491 in position (scientific 59) and 411 (including 72 scientists) in position



at present, in accordance with the government policy of outsourcing non-core areas of work and consequent downsizing of permanent workforce.

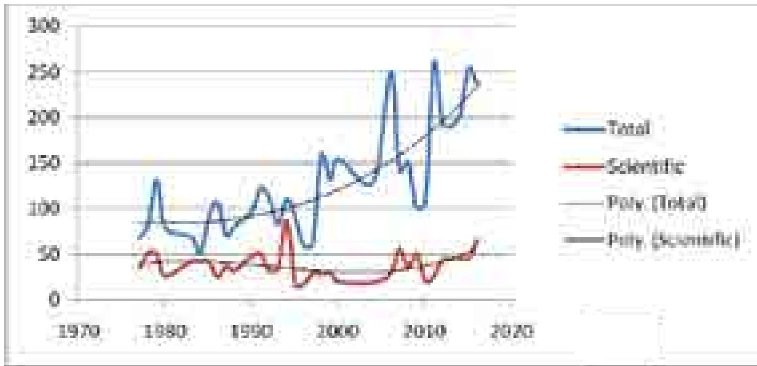
The total expenditure of the institute increased from ₹ 4.6 million in 1970-71 to ₹ 19.0 million in 1980-81, to 27.1 millions in 1984-85, ₹ 31.3 million during 1986-87 (after the reorganization of the institute) and the budget allocation was ₹ 39.4 million in 1991. There was a quantum jump in the funding resources in the beginning of the present century with a budget allocation of 99.33 million under Non-Plan and 18.40 million under Plan, which by 2010, rose to 241.80 million under Non-Plan and 35.0 million under Plan and in 2015-16, 334.33 million under Non-Plan and 40.0 million under Plan. In the first half of the 1980s, apart from the institutional funding from ICAR, the Institute also received substantial financial assistance under Kerala Agricultural Development Project (KADP) and Multi State Cashew Project (MSCP), both funded by the World Bank, for time targeted specific research programmes in coconut, spices and cashewnut and from the Bioversity International (IBPGR then and IPGRI later) for PGR explorations in coconut.



In the early years, research programmes were largely of the conventional intra-mural projects, with a judicious mix of basic and applied aspects. Right from the beginning, there were conscious efforts at fostering linkages and enlisting partnerships in collaborative research programmes, both at national and international levels. As early as 1970, investigations on the bud rot of coconut was in progress under the PL-480 programme of USAID. Strategic research collaborations with premier national and international institutions were struck in key areas like tackling root (wilt) disease of coconut, biological control and enhancement of genetic resources. CPCRI was one of the five ICAR Institutes selected for taking up collaborative research programmes with some of the leading research institutes in U. K. under the Indo-UK Natural Resources Development Programmes. Under this initiative, the on-going research programmes on root (wilt) disease of coconut and yellow leaf disease of arecanut were further strengthened through collaborative work with prestigious institutions like Rothamsted Experimental Station.

In the 1980s and 1990s, it could attract international research projects in partnership with BOVERSITY, COGENT and APCC, with substantial funding from international developmental agencies and financial institutions like DFID, World Bank and ADB. During the last four decades, apart from the research projects with institutional funding, the institute could undertake a large number of projects with external funding (contributing to nearly half of the total research programme at present) from national developmental agencies like CDB, DCCD, DASD for projects oriented to transfer of technologies in the mandate crops, for fundamental/basic research programmes from DBT, DST and DIT and of late, several strategic multi-disciplinary research projects from the plan scheme funds of ICAR awarded on a competitive basis.

Over the years, the institute has accomplished excellent research outputs to its credit, as discernible from the high volume of top-quality research publications with a sizable number in national/international journals with high impact factor and a large number of technologies developed and adopted by the farming community/agri-enterprenuers. Besides, the large number of extension publications targeting the farmers, its principal beneficiary, forms an integral part of this massive output.



As inevitable in history, it went through several events of reorganization, acquisitions and mergers, secessions and consolidations over the years. In the 1980s, CPCRI not only 'gave birth' to new institutions, but 'nurtured' them well in their infancy and 'mentored' them through adolescence to adulthood. Dedicated research institutions for individual crops or group of related crops will undoubtedly promote better R&D, with more functional autonomy, higher financial allocations, better infrastructure and human resources. The policy has paid rich dividends as can be seen from the present stature and R&D achievements of these 'sibling' institutions like the Indian Institute of Spices Research (IISR), Kozhikode, Directorate of Cashew Research, Puttur, Indian Institute of Oil Palm Research, Pedavegi and the Central Coastal Agricultural Research Institute, Goa.

However, CPCRI also bore the brunt of some 'adverse' policy and adhoc administrative decisions. In hindsight, it seems probable that 'loss' of WCGC in the strategic off-shore location of Andaman islands in 2001, Research Centre at Hirehalli located in the Maidan region of Karnataka in 2002 and the pristine lands of Research centre at Kannara, Kerala in the ambience of Western Ghats in 2007 may hurt the long-term interests of the institute considering the interests of the certain agroclimatic regions, requirement of large extent of lands for laying out new field experiments in a perennial tree crop like coconut,arecanut and cocoa and the acute shortage presently being faced in this regard.

At present, the research and frontline extension aspects of these crops are undertaken under five divisions *viz.*, Crop Improvement, Crop Production, Crop Protection, Physiology, Biochemistry and Post Harvest Technology and Social Sciences at the institute. The Regional Station at Kayamkulam (Kerala) is mandated to work on pests and disease problems in coconut, while the Regional Station at Vittal (Karnataka) caters to the R&D in arecanut and cocoa. The three Research Centres - Kahikuchi (Assam), Mohitnagar (West Bengal) and Kidu (Karnataka) are for undertaking location-specific research in these crops while the Minicoy (Lakshadweep) centre has been recently remandated to function as a production and demonstration centre for vegetable and fruits in the Lakshadweep Islands. CPCRI hosts the Distributed Information Sub Centre (Sub-DIC), under the Biotechnology Information System Network (BTISnet) and the Bioinformatics Centre under Agri-Bioinformatics Promotion Centre (ABPC). CPCRI has two Krishi Vigyan Kendras (KVKs), one each at Kasaragod and Kayamkulam, extending farm oriented training and support to farmers in agriculture and rural development. Besides, the Agricultural Technology Information Centre (ATIC) at CPCRI, Kasaragod provides a 'single window' delivery system of service to the farmers.

The new exciting development in the centenary year is the proposal to set up a new Regional Station of CPCRI in the 60 acres of land situated at MR Palem in the fertile belt of East Godavari district, offered by the Govt. of Andhra Pradesh. A formal approval accorded by the Govt. of India is a big step towards establishing this new research station, conceived to be an alternative field gene bank of coconut in the eastern side of peninsular India.

Presently, the mandated crops being limited to coconut, arecanut and cocoa, and the governance much easier with only a handful of research stations under its administrative control, it is now more cohesive and focused as a research unit. The long-term vision is to develop the institute as a technology generation and repository centre, to showcase, demonstrate and compare world-wide technologies in the commodity chains of coconut, arecanut and cocoa to make India the global leader. The mission is to develop technologies that enhance resource use efficiency, profitability and livelihood security of people who depend on plantation crops.

Aligning with the present day realities that the sector presents, the mandate has been redefined as:

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

ICAR-CPCRI and its role in plantation crops research & development in India

Sectoral challenges: An industry at crossroads

The plantation sector in India is dominated by millions of small and marginal farmers and mainly confined to the economically and ecologically vulnerable regions. The changing cropping pattern, climate change concerns and constraints on natural resource use and reduction in profitability in the plantation scenario warrants innovative strategies and approaches to address challenges and promote accelerated growth of the sector.

Coconut, arecanut and cocoa are important plantation crops of India with a profound influence on the rural economy by supporting the livelihoods of 20 million people in the country. However, of late, these crops are facing unprecedented crisis on account of various macro and micro level factors. The productivity of these crops is constrained by the low input use efficiency in conjunction with other biotic and abiotic stresses which are priority areas of research. The aspects of mechanization also demand for adequate importance, considering the scarcity of skilled labour. Above all, the most important facet is value addition, which should be strengthened to address the issues of low profitability of the coconut, arecanut, and cocoa sectors. The relevance of CPCRI arises exactly in this context, wherein the institute strives for technology generation and dissemination to address the challenges and to convert the weaknesses into opportunities, in a concerted and synergized fashion.

Winds of change: Ushering in technologies

Right from its inception, the institute had been sensitive and responsive to the problems at hand and challenges ahead, and had been continually striving to address them in a time-bound fashion, through periodical reviewing and fine-tuning its research programmes accordingly. Some of the most succinct achievements are enumerated here, giving just glimpses of the prolific research achievements accomplished over the years.

The Institute has built up, over the years, a rich repository of genetic resources to provide breeders with required genetic stock to tackle present and future challenges. It is a matter of national pride that it maintains the largest collection of germplasm accessions: coconut (455), arecanut (164) and cocoa (344). International Coconut Genebank for South Asia (ICG-SA) was established under a tripartite agreement among ICAR-FAO-ITPGRFA. The Institute also hosts the National Coconut Gene Bank (NCGB) and serves as the National Active Germplasm Site (NAGS) for coconut, arecanut and cocoa. Recently, DUS (distinctiveness, uniqueness and stability) test centres for coconut, arecanut and cocoa have been started with funding from PPV&FRA, New Delhi. The Institute has facilitated development of the DUS guidelines for coconut and arecanut for effecting plant variety protection mechanism.

The focused breeding efforts have culminated in development and release of several high yielding varieties and hybrids ensuring higher productivity and overall profitability to the farmers. Nineteen improved high yielding varieties (thirteen selections and six hybrids) of coconut, with potential for higher yield and suitable for copra/ tender nut/ biotic and abiotic stress tolerance, have been released for cultivation. Altogether, ten improved varieties of arecanut (eight selections and two dwarf hybrids) with higher yield and seven high yielding varieties in cocoa (three elite clones and four hybrids), with varying processing qualities have also been released. Presently, the emphasis is on developing dwarf varieties and D x T hybrids in coconut and arecanut and dual purpose varieties in coconut, in appreciation of the present day realities in this sector.

The protocol for somatic embryogenesis and plantlet regeneration in arecanut is a major breakthrough for mass multiplication of dwarf hybrids and yellow leaf disease tolerant palms. Coconut embryo culture protocol has been developed for long term storage and easy transport of germplasm during exchange. Techniques have been standardized for cryopreservation of mature coconut zygotic embryos and coconut pollen. Sequence characterized amplified regions (SCAR) markers have been developed for confirming the hybridity at seedling level in both coconut and arecanut.

It is too fool-hardy to keep all 'the eggs in the same basket', like the proverbial milkmaid. In the present scenario of integrated global markets in the post GATT and FTAs, where the slightest disturbance in the production front in one country can have unpredictable impact in the value chain elsewhere in the world, it is all the more prudent that a traditional small-holder farmer should go for as many crops and agri-enterprises as can possibly be integrated seamlessly in to the farming system. Coconut and arecanut based inter/mixed, multi-storied multi-species cropping as well as mixed farming systems have been developed by integrating livestock for increasing total system productivity. The coconut based cropping system using multi species cropping of coconut with pepper, banana, nutmeg, pineapple, ginger, turmeric and elephant foot yam generates a net income of ₹ 3.7 lakhs/ha, nearly one and a half times higher than that of coconut monocrop (₹.1.4 lakhs/ha). A coconut based mixed farming system (CMFS) comprising coconut, pepper, banana, crossbred cows, poultry birds, goat, and pisciculture generated a net return of ₹ 5.5 lakhs, which is nearly three times higher than that of coconut monocrop. Arecanut based cropping system with cocoa, banana and black pepper as component crops generated net returns as high as ₹ 8.8 lakhs per ha, which is more than double compared to that of arecanut monocrop (₹ 3.80 lakhs). Arecanut based mixed farming system (AMFS) with dairying, fresh water aquaculture and fodder grass (Hybrid Napier) components generated net returns up to ₹ 6.6 lakhs per ha, which is quite higher than that of arecanut monocrop.

A versatile technology has been developed to utilize crop wastes (a coconut garden of one hectare area can generate up to eight tonnes of leaf biomass residues every year) for production of mushrooms and vermicompost using the local isolate of *Eudrilus eugeniae*, meeting 50% of the nitrogen requirement of coconut palms. Similarly, arecanut and cocoa gardens generate biomass of 12 and 8.5 tonnes/ ha respectively and these wastes could be effectively utilized for production of vermicompost, oyster mushroom and as livestock feed, meeting the nitrogen and phosphorus requirements of these crops considerably, with consequential savings in the cost of cultivation and additional income from value added products. On farm coir pith composting technology has been developed to produce organic inputs to the plantation as well as soilless medium for crops. Two plant growth promoting rhizobacteria (PGPR) based products (Kera Probio and Cocoa Probio) have been launched recently for promoting clean and green, sustainable cultivation of coconut.

Integrated disease management strategies developed for root (wilt) and leaf rot affected coconut gardens could increase yield by 25-83%, depending on severity of the disease. Phytoplasmal etiology of yellow leaf disease has been established and management of the affected gardens with appropriate nutrient management has been advocated. IPM packages have been developed for managing all major and minor pests in coconut, arecanut and cocoa.

In situ soil and water conservation techniques helps in augmenting the soil moisture availability in coconut plantations having mild slope and could enhance coconut yield up to 60%, besides reducing soil erosion and consequential nutrient loss. Drip irrigation in arecanut, coconut and cocoa has reduced the use of water to the extent of 35-40 per cent with increase in yield by 30-40 per cent. Drip fertigation in these crops has reduced the use of chemical fertilizer from 50 to 75 per cent with increase in yield by 35-40 per cent.

Mechanization of farm operations is the immediate requirement of the farmers to reduce the cost of production and increase the labour efficiency, especially in the context of high labour wages and their nonavailability for timely farm operations. The safety attachment incorporated by CPCRI to the popular model of climbing device has become an effective solution since it could be operated even by women with proper training. Apart from this, manual and power operated coconut husking machines, coconut shell splitting device, de-shelling machine, tender coconut punch and cutter, coconut dryers of varying capacities and using different fuel sources, testa remover, coconut slicing machine, coconut milk expeller, VCO cooker, VCO fermentation tank, copra moisture meter and telescopic sprayers are the other major contributions from the institute.

The nutritional, nutraceutical and health benefits of tender coconut, coconut oil and virgin coconut oil have been elucidated in our efforts to promote coconut as a health-wellness-food crop. Coconut is an excellent source of good fats with medium chain triglycerides and the consumption / topical application of coconut oil is traditionally believed to impart physical, mental and curative health benefits. Tender coconut water is a rich source of essential electrolytes like sodium, potassium, magnesium, calcium and phosphorus. It is also rich in tocopherol, polyphenol and anti-oxidant activity, qualifying it as a pure natural nutritious health drink, truly a nature’s bounty. The presence of lauric acids, polyphenols and anti-oxidants in virgin coconut oil finds a place in cosmetic and overall health care products.

There exists a huge scope for coconut based agri-business in India in order to increase the present 8% level of value addition to 25%. Value added products can thereby became a deciding factor in the price movement of coconut to ensure fair, reasonable and steady price to coconut farmers. In an effort towards value addition, Institute has developed complete ‘technology packages’ for production of virgin coconut oil, coconut chips, coconut honey, jaggery, sugar, ice creams, extruded products and sugar based chocolates and drinking chocolates and sweets. CPCRI has developed ‘Coco-sap Chiller’ for collecting fresh, hygienic and unfermented coconut inflorescence sap called Kalparasa. A bottling technology has been developed for Kalparasa, which can extend its shelf-life up to 45 days under refrigerated condition without adding any preservatives and additives. It has been demonstrated that a farmer tapping 15 coconut palms for Kalparasa could earn, on an average, net profit of ₹ 45,000 a month, while a tapper can earn about ₹ 20,000 per month.

The Institute and its KVKs are acclaimed by stakeholders and developmental and extension agencies as nodal center for coconut, arecanut and cocoa. Socio-economic research has 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. Dissemination of technologies are pursued through on-campus and off-campus training programmes, frontline demonstration of farming systems, INM, IPM, IDM and post-harvest technologies, exposure visit of clientele, diagnostic field visits, Kisan Melas, exhibitions, mass communication media and print media. Research-extension-farmer interface are facilitated through interactive video conferencing.

The consistent research efforts of the institute have greatly contributed towards the overall growth in area, production and productivity of the mandate crops. It is estimated that, in terms of Gross Value Output, coconut contributes ₹ 95,000 million to the national income and arecanut contributes ₹ 45,000 million and cocoa, ₹ 2,000 million. In terms of exports, coconut earns ₹ 21,385 million (including coir products) while the contribution of arecanut is ₹ 300 million. The overall economic impact (per annum) due to the adoption of CPCRI technologies has been estimated to be ₹ 19,000 million.

Ever since its inception, CPCRI with mandate to conduct research and extension activities in the plantation crops (presently confined to coconut, arecanut and cocoa) has always been on the forefront of developing technologies and reaching out to the farmers. Considering its exemplary achievements, CPCRI was awarded with the prestigious Sardar Patel Outstanding Institution award for the best Research Institute under ICAR for the year 2003-04. KVK -

Kasaragod, functioning under this Institute, was adjudged as the best in ICAR in 2002-03. Chowdhary Devi Lal Outstanding AICRP Award for 2014 was conferred on the All India Co-ordinated Research Project on Palms for its contributions in developing and popularizing location-specific technologies. Besides, several scientists have got prestigious recognitions like ICAR award for Interdisciplinary Research in Agriculture, Best Women Scientist award, Young Scientist award and so on.

The challenges ahead

The Indian plantation sector has inherent strength of varied agro-climatic conditions, huge domestic demand, higher productivity, strong research and development network and technology dissemination systems. However, so far, the sector has not effectively utilized the possible linkages between them for increasing the production and marketing efficiencies. Inclusive growth and sustainability of plantation economy could be achieved through integrated development of cultivation and industry coupled with a stable market. The research programmes targeting higher production and better system productivity coupled with optimum input use efficiency and strengthening the technology dissemination programmes with the active participation of beneficiaries along with new 'social engineering' strategies like aggregation of farmers for group activities and creating more skilled labourers for farming, harvesting and processing operations, with the overall objective of triggering production, processing and value addition, will, hopefully, place the coconut, arecanut and cocoa sectors at forefront in the world. Apart from these, since food safety standards are becoming more stringent in the world, and to be competitive in the trade, adequate importance must be given to the Good Management Practices (GMP) in the plantation sector. There is an urgent need to realign the production structure of plantation crops in accordance to the international and domestic price signals. Needless to say, the research and developmental agenda of the R&D institutions should invariably be 'proactive' to keep itself abreast of the latest developments in the sector and to address them effectively. And, ICAR-CPCRI has always been a model institution in plantation crops R&D in India and 100 years of its history stands witness to it.

In retrospect, it is essentially the story of evolution of an institution over one hundred eventful years in history, proud of its creditable achievements and massive contributions to the farming community, cognizant of the multiple challenges ahead and geared up to address them. A journey that began one hundred years ago and at this milestone in its history, it has truly 'miles to go' further and lots of 'promises to keep' indeed!

"The woods are lovely, dark and deep,
But I have promises to keep,
And miles to go before I sleep,
And miles to go before I sleep."
Robert Frost*

**From "Stopping by Woods on a Snowy Evening"*

100 GOLDEN YEARS OF COCONUT RESEARCH IN INDIA: SELECT ANECDOTES FROM HISTORY AND VIGNETTES OF ITS ACHIEVEMENTS

The saga of coconut research in India is essentially a story of unmitigated tears and toils, personal sacrifices of thousands of men and women all along of vision, foresight and perseverance yielding fruitful rewards in the long run, and of an institution taking shape, weathering many a storm, and marching ahead harnessing science and technology for the benefit of the plantation crops sector. Though the coconut palm has been known to exist in India since 3000 years ago, organized efforts to develop the crop have a recorded history of over 100 years only.

Coconut research in colonial times (1916-1946)

1770, 1783, 1876, 1896, 1899 and 1943 CE.... there is only one recurrent theme in the history of British India - **the gory sceptre of famines devastating various parts of the country and millions of hungry people dying....** a stark reminder of the little precedence accorded to agriculture and the meagre investments made in agricultural research and development in colonial India.

Based on the report of the Famine Commission in 1901 (which summarizes its recommendations thus: "*The steady application to agricultural problems of expert research is the crying necessity of the time"*), the Imperial Government of India sets up a Central Department of Agriculture controlled by the Imperial Secretariat and agriculture departments were also set up in the provinces to primarily look after agricultural enquiry, agricultural development and famine relief in the country. However, it was only after 1905 that, with the reorganization of the agriculture department, agriculture research was organized on a more systematic line, realizing the need to explore and develop further income resources from agriculture and for sourcing raw materials for the industrial England on a long term basis. In consideration of the unlimited opportunities that the vast and agro-ecologically diverse empire offered, agricultural experimental stations were started in the most important agricultural tracts.

In line with this development, three separate blocks of vacant land in and around the village of Nileshwar (Nileshwar I (Pilicode), 15 acres), Nileshwar II (20 acres), Nileshwar III (20 acres) and an existing coconut garden in Kudlu Village (26 acres) (all in the present day Kasaragod district of Kerala state, India) were acquired in order to obtain representative soils, on which coconuts were generally cultivated on the West Coast and thus four sub-stations have now been started in the South Kanara district of erstwhile Madras Presidency.

The journey thus began, a journey well-begun!

It is all about building an institution, brick by brick from its modest beginnings in 1916. Soil and sub-soil profile of the new stations were delineated. Preparatory to planting, enclosing the land, laying out roads, sinking of wells and putting up buildings, preliminary operations like ploughing and the digging of planting holes, and raising necessary seedlings in the nursery were all taken up. The annual report of the station (1917-18) reports *"Some 25 acres were planted this year including about 2½ acres of existing gardens at Kasaragod which were under planted". "Six coconut trees out of 1917 plantings in the Coconut Station No. IV, Kasaragod flowered for the first time"* (Annual Report 1923-24), which must have been surely the most memorable occasion for them.

Mother of all experiments to come

For them, there was no time to waste! Since the three blocks out of the four thus acquired were vacant lands and naturally it takes several years for the well-laid experimental plots to be available for laying out new experiments, the standing coconut crop (though not scientifically planted) in the newly acquired Kudlu block (where the present CPCRI is located now) was used for initiating preliminary experiments as a trial-run for collecting valuable data for proper planning of future experiments. *"This station therefore may be looked upon largely as a place where experiment can be made to find out how best to conduct experiments on the other three stations, which are now to be planted up"* (Annual Report 1916-17). Indeed, the "mother of all experiments" to come!

Coconut being a crop fairly unfamiliar to Western science, initial attempts were to study the morphology of the palm, its floral biology, manurial requirements and cultural practices, introduction of varieties etc. By all records, probably, this must be the earliest case of organized systematic research on coconut the worldover.

The seeds were indeed sown early!

One can see the blueprints in these early experiments, on which systematic investigations were conducted in later years. The early observations of palm-to-palm variation in growth and yield, and enumeration of yield contributing characters have led to the concept of pre-potent palms and careful selection of such superior individuals in a population has given most promising rewards in later years. The Investigations on crown morphology elucidating the right hand spiral and left hand spiral arrangement of leaf whorls and the classical study on the coconut root system and its feeding area are phenomenal. The need for collecting good seednuts from select palms and selecting good seedlings at nursery stage based on a set of criteria especially the split leaf were emphasized as early as 1918. A series of manurial experiments were started to understand the nutritional requirements, the absorption pattern and the optimum methods of supplying them. The benefits of growing green manure crops and soil moisture conservation by mulching were recognized in the early years.

A further line of work identified quite early *"is the question of the greater utilization of this tree as a sugar producer and there is scope for improvement in the indigenous manufacturing processes of jaggery. Very little information seems to have been recorded of the capabilities of this tree as a sugar producer"* (Annual Report 1919-20) and in the subsequent year, investigations were started in right earnest, and came out with most valuable information. The Report on the Operations of the Dept. of Agriculture, Madras Presidency (1921) states *"It has also been found possible to prepare brown 'sugar' of good quality from the coconut juice and the yield amounts to 9 ½ percent of the juice treated and the results (in the form of an article) have been published in the Agricultural Journal of India"*. Perusing the reports of the early years, one cannot but be amazed by the vision, sagacity, precision in observation and recording of data and sheer planning in every step.

"Seeing is believing", the central dogma of transfer of technology: Glimpses from the past

Laying out demonstration plots in research stations and farmers' gardens as a way of demonstrating and convincing farmers to adopt technologies is the order of the day in ToT strategies. The Annual Report of the Coconut Stations in Kasaragod (1921) reports *"The advantages of inter cultivation continue to be well marked at the Kasaragod station. Block III, which is purposely left uncultivated as a check and a warning to ryots, steadily declines in yield, while the remaining seven blocks which are being cultivated, are improving"*. The Annual Report (1923-24) further states *"The ryots having realized the superiority of our seedlings are coming forward with their applications not only from the West Coast districts, but also from other parts of the Presidency". "There have been a considerable awakening in the South Kanara district to the possibilities of coconut topes. When the coconut trees were once established, it was the practice to give no further attention to them. The methods adopted at the Kasaragod station, where a large increase in crops has resulted from after treatment, have led to considerable interest and imitation and the district staff stationed in this district have done all in their power to bring our improved methods to the notice of the cultivators"* (Report on the Operations of the Dept. of Agriculture, Madras Presidency 1922).

Twists and turns: the first now and many more to follow

Driven by the economic and political compulsions for strengthening the grip of the colonial administration, there was a shift in focus from the general agricultural set-up, orienting attention to specialized commercial crop groups like cotton, oilseeds etc. The Madras Government created the Oilseeds Section in 1930 with Dr J.S. Patel as head. The four Agricultural Research Stations doing work on coconut are now attached to this Section. Incidentally, this deep-rooted legacy of orientating coconut as an oilseed crop still haunts, notwithstanding the recent efforts to re-brand it as a health-wellness crop.

Hugh Charles Sampson (1878-1952)

Mr. H. C. Sampson, CLE., F.L.S. was educated at Bedford School and graduated at Edinburgh University in 1900. He commenced his career in the Transvaal Department of Agriculture and in 1906 and then entered the Indian Agricultural Service, retiring in 1923 as Director of Agriculture, Madras Presidency. It can truly be said that the coconut research in India started under the leadership of Dr H.C. Sampson, then Deputy Director of Agriculture, Southern Region. He laid the foundation for coconut research by formulating a system of recording observations, guidelines for manurial application and cultural operations, and collection of local variability in coconut. Mr. Sampson was Economic Botanist at Kew for many years since 1927. He was also a specialist on growing cotton, besides coconut. After his retirement, he also worked in Nyasaland for the Empire Cotton Growing Corporation. His major works include the book, "The coconut palm: The science and practice of coconut cultivation" (1923) and "List of the Cultivated Crop Plants of the British Empire" (1936).

The first coconut hybrid is born!

The development of hybrid varieties involving tall and dwarf types possessing prolificity and precocity is a major landmark in the annals of coconut improvement. It was the pioneering work of Dr. J.S. Patel and his team that paved the way for the exploitation of heterosis in coconut. The first hybrid was produced by crossing local West Coast Tall with the Chowghat Dwarf Green and the hybrids were planted at Nileshwar in 1934 for evaluation. That must be an auspicious beginning indeed! Since then, six coconut hybrids have been developed/released from CPCRI, a mammoth achievement in itself, considering that developing and evaluating a new hybrid in a perennial crop like coconut takes about two decades. The demands for hybrid seedlings of coconut have ever been on the increase and now large scale production programmes are in operations to meet the increasing demand.

A hybrid seedling from the first set planted at Nileshwar during 1932 - 34

Post-Independence Period: Reorganization and Consolidation

Transition from imperial to post-independence: Indian Central Coconut Committee (1945-1969)

The second world war created conditions, which meant better prices for the commodity, but Indian coconut industry could not cope with the emerging situation. Under these circumstances, in 1943, the Government of India initiated an enquiry into the production aspects, regulation of import of copra and coconut oil, improvement of quality of copra and better utilisation of shell and fibre. The Enquiry Commission recommended the setting up of a statutory body for coconut with powers and functions similar to those of the Ceylon Coconut Board. The Government of India accepted the recommendation to set up a statutory body, but with somewhat narrower functions than originally proposed. Thus, the Indian Central Coconut Committee (with the Vice-President of the ICAR as president of the ICCC) was set up in February1945 under the "Indian Coconut Committee Act, 1944" to coordinate research and development activities at the national level.

Opposite: Chandrasankara

J. S. Patel

Dr. J. S. Patel had his post-graduate education at Cornell USA and took his doctorate from Edinborough, UK. He served in various capacities as Oil Seeds Specialist in the erstwhile Madras State, Jute Specialist, Principal, Agricultural College, Sabour, Director of Agriculture, Bihar, Agricultural Commissioner to the Government of India, and Vice-Chancellor, Agricultural University, Jabalpur. The development of hybrid varieties involving tall and dwarf types possessing prolificity and precocity is a major landmark in the annals of coconut improvement. It was the pioneering work of Dr. J.S. Patel and his team that paved the way for the exploitation of heterosis in coconut. He authored "The Coconut-A Monograph", published in 1938 by the Government of Madras.

Coconut research had been the responsibility of only the State Departments of Agriculture until then and immediately after taking over, the Committee deputed Shri C.M.John and Dr. K.P.V. Menon to visit all the coconut growing tracts of the country to assess the work being done and to suggest future lines of investigations. In their report, it was suggested that two Coconut Research Stations be set up, one at Kasaragod and the other at Kayamkulam (since the root (wilt) disease had spread nearly the entire Travancore-Cochin belt by this time).

CCRS, Kasaragod and Kayamkulam: 'A Tale of Two Stations'

In 1947, the Indian Central Coconut Committee purchased the Kudlu Station along with its 30 acre farm and renamed it as the Central Coconut Research Station, Kasaragod (while the other three field stations remained with state department of agriculture and later handed over to Kerala Agricultural University in 1972). Under this regime, the activities of the Research Station acquired new momentum with special emphasis on problem and production oriented research.

The Central Coconut Research Station (CCRS) at Kayamkulam was established in 1948 by the Indian Central Coconut Committee. The CCRS had its origin in the erstwhile Agricultural Research Laboratory (Office of the Plant Pathologist) started in 1937, with its headquarters at Kollam and a field station at Kayamkulam mainly to tackle plant protection problems of coconut. Problems relating to breeding, cultivation, manuring etc. were handled at the Research Station at Kasaragod while those pertaining to diseases and pests at the Research Station at Kayamkulam.

Central Coconut Research Station, Kasaragod: In pangs of labour and growing up

The nascent institution had inherited all handicaps, being bereft of all basic amenities like office/ working space, electricity, transport, medical facilities, schools, residential facilities and recreational facility for staff and their families. On being transformed from a field station, it slowly acquires the trappings of a research organization with an administrative set-up. During the

Central Coconut Research Station, Kasaragod

first phase, the area was increased to 100 acres by acquiring additional land. Research was reorganized under four disciplines, namely agronomy, botany, cytogenetics and analytical chemistry. The major experiments in Agronomy were on NPK studies, different cultural practices, permanent observations trial, and evaluation of different nitrogenous fertilizers. In Botany, the main areas of research were on varietal studies, germplasm collection, conservation and evaluation, hybridization for evolving new hybrids, and identification of promising cultivars. Another major activity of the Station was the large-scale production and distribution of superior planting materials of coconut to farmers and government agencies at a subsidized rate.

The next phase of development of CCRS began in 1958 with the implementation of the Second Five Year Plan. The Administrative as well as the Research establishments were shifted to the new building in the early part of 1958. As a part of this development, another 40 acres of land near the beach, and 48 acres of land in the Hill Block were acquired, at times meeting stiff resistance. By early 1960, the activities of the Institute expanded and the staff strength increased along with other infrastructural facilities. During this period, the main thrust was on survey and identification of indigenous germplasm, laying out of large-scale fertilizer trials, crop weather studies, survey of coconut soils of Kerala, cytological and anatomical studies, studies on button shedding and barren nut formation, preliminary studies on irrigation, lime requirement in coconut soils, seednut storage, etc. The achievements made by the CCRS, with the minimum basic facilities and manpower, are stupendous. The significant contributions made towards gathering basic knowledge about the palm and the vast data collected in those days still form the basis of current research programmes.

CCRS, Kayamkulam set up in 1948: Smooth sailing

In contrast, CCRS, Kayamkulam has a much happier tale to tell! For the set up, two gardens of 5 ha were taken on lease by the Travancore Government and another 30 ha of private land was promptly acquired and handed over to it. On the instructions of then Diwan of Travancore, Sir C. P. Ramaswami Aiyer to acquire the land, a notification came in the gazette promptly and no difficulty was faced in acquisition of the land. In the beginning, there were 4

Central Coconut Research Station, Kayamkulam

C. M. John

Shri C. M. John was the first Director of the Central Coconut Research Station, Kasaragod in 1950 (from which he retired in 1955) and later served as Principal of Agricultural Colleges at Bapatla and Coimbatore. He has rendered a yeoman service to coconut research in various capacities as Oil Seeds Specialist and Botanist, before becoming the Director. He also worked as agricultural Advisor to the Potash Scheme and has visited France, West Germany and Switzerland to study the fertilizer use practices there. The contributions of Shri C M John to coconut research are unparalleled. Shri John was responsible for organizing coconut research at the national level and for starting the Central Coconut Research Station at Kasaragod by drawing the technical programme for the first five years. He is also credited with a large number of publications. He has authored the popular publication "Coconut Cultivation" (1952), on realizing that there was considerable need for popular articles on coconut in addition to scientific monographs, which was well received as it has gone into several editions, and was translated into several Indian languages besides English and Hindi.

Dr. K. P. Velukutty Menon

Dr. KPV Menon (Kuttiezhathu Puthanveettil Velukkutty Menon) was an eminent coconut pathologist who devoted his entire life for working on coconut diseases, especially the root (wilt) disease. After graduating from Bombay University, Dr. Menon took his Ph.D. in 1932 from London University under a well known Plant Pathologist, Dr. Brown. Back in India, he started his research career as Personal Research Assistant in the Rust Research Scheme of the ICAR at Agra College from 1935-37. It was Dr. E. J. Butler (Dr. Butler was the first person who worked on coconut diseases in India), who put some speculative questions on the diseases of coconut palm during his Ph.D *viva voce*, which ignited his interest in coconut diseases and later prompted him join as plant pathologist at the erstwhile State Research Laboratory at Quilon in March, 1937. He became the Joint Director and later the Director of CCRS, Kayamkulam. Immediately after his retirement from CCRS in 1963, Dr. Menon was appointed as FAO expert on Coconut Cadang-Cadang disease in the Philippines. Along with Dr K M Pandalai, he authored the monumental book 'Coconut Palm - A Monograph'

major departments attached to the Institute: Plant Physiology under Prof. T.A. Davis, Entomology under Dr. KK. Nirula and Soil Chemistry with Dr.KM. Pandalai and Dr. K.P.V. Menon himself looking after Plant Pathology section. The total scientific strength was 16 with four scientists in each section. There was one Farm Manager and four Fieldmen. The office staff consisted of one Superintendent, one Accountant and four Clerks. There were minimum facilities for living at Krishnapuram including a school and a hospital.

"The stone laying ceremony of Kayangulam Station was my most joyful occasion", recollects Dr. KPV Menon, the then Joint Director of the CCRS Kayamkulam. *"The stone laying ceremony was done by Shri Marthanda Varma, the Elaya Raja of Travancore in 1948 and the building was ready in 1949 in less than eight months without any interference from anyone and we moved from Quilon to Kayangulam".* The long cherished dream has thus come true.

First re-organization of ICAR and its impact in plantation crops research

In 1963, the Ministry of Food and Agriculture appointed the Agricultural Review Team headed by Marion W. Parker of USDA (United States Department of Agriculture), to scrutinize the organization of agricultural research in India. With the first reorganization of ICAR in 1965, as recommended by this review

Dr. K. M. Pandalai

Krishnan Madhusudanan Pandalai, a Fellow of the Royal Institute of Chemists, London, started his career as Assistant Biochemist of Travancore and worked in various capacities as Chemist, Joint Director at CCRS Kayamkulam and retired in 1966 as Director, CCRS, Kasaragod. He has put in 40 years of research service in various branches of chemistry. He was earlier a guest worker at the Rothamsted Experimental Station, Harpenden, Herts. UK and has travelled widely in the United Kingdom, France, West Germany, the Netherlands and Rome.

Coconut Monograph by Menon and Pandalai : the magnum opus

"The Coconut Palm: A monograph" by KPV Menon and KM Pandalai, brought out by the Indian Central Coconut Committee, Ernakulam in 1960 is still the Bible for coconut researchers and farmers alike. Most comprehensive in coverage, it is essentially an update on the earlier works starting from "The coconut" by HC Sampson (1923), "The Coconut" by Copeland (1931) and "The Coconut - A Monograph" by JS Patel (1938).

team, research efforts were consolidated under the ICAR system with all the research institutions under the Department of Food and Agriculture and under the Central Commodity Committees transferred to the administrative control of ICAR. Till then, ICAR was a coordinating body engaged largely in financing selected ad hoc research schemes and its control was limited to these schemes financed by it. The Governing Body of ICAR was reorganized to make it primarily a body of scientists and agriculturists. Institutes like Indian Agricultural Research Institute, National Dairy Research Institute and Indian Veterinary Research Institute were made National Institutes. New research institutions were formed by merging and consolidating related institutions under the various commodity committees.

CPCRI taking shape: the golden age

In line with this development on the national scene, the ICAR took over the administrative control of CCRS at Kasaragod and Kayangulam from 1st April, 1966 following the abolition of the Commodity Committees. Since it was felt that the C.C.R.S. cannot exist by itself at an all India level, the then Director-General, late Dr. B.P. Pal, F.R.S. and the Secretary, ICAR, Dr. K.P.A. Menon visited the C.C.R.S and C.A.R.S. and discussed the pros and cons of amalgamating these two Stations along with the Research Centres of C.A.R.S. into an All India Research Institute for the agricultural plantation crops (excluding tea, coffee and rubber). In fact, a premonition of what is in store was evident in the words of Shri A. D. Pandit, the President of the Coconut Committee, addressing the 31st meeting of the Committee on the 17th January, 1964 at Ernakulam *"that since coconut, arecanut and spices were all grown in more or less the same areas in the country, coordination is possible in several aspects of the working of the Indian Central Coconut Committee, Indian Central Arecanut Committee and the Indian Central Spices and Cashewnut Committee"*.

Thus, the Central Plantation Crops Research Institute (C.P.C.R.I.) came into existence in January, 1970 with its headquarters at Kasaragod. The Central Arecanut Research Station (CARS) Vittal along with the five substations under the Indian Central Arecanut Committee was also merged with the new entity. The CCRS, Kayamkulam and CARS, Vittal were designated as regional stations. Dr. K. V. Ahamed Bavappa took over charge as the first Director of the Institute in January, 1970. The budgetary allocation of the new institute was about ₹ 50.0 lakhs (₹ 30.33 lakhs under Non-Plan and ₹ 19.67 lakhs under Plan) for the financial year 1970-71.

Face- to-face with Western science in post-independence scenario

In 1959, the legendary scientist, the late J.B.S. Haldane published his classical paper entitled "Suggestions for Research on Coconuts". Haldane had earlier visited the Central Coconut Research Station and gained first-hand knowledge of the crop. His paper contained many valuable suggestions for research on the palm. Incidentally, during this visit, he met T.A. Davis, the coconut physiologist, who was so fascinated by his profound knowledge and commitment to fledgling science in post-independent India that joined for research under him at ISI, Kolkata. About this time, S.C. Harland published an interesting paper entitled "Improvement of the coconut palm by breeding and selection" in which he emphasized the need for genetic upgrading of planting material in coconuts through identification and use of pre-potent palms, which greatly influenced subsequent crop improvement programmes in coconut.

Subsequently, the administrative control of the two ICAR Research Complexes in Goa and Lakshadweep were also transferred to CPCRI in 1976. A scheme for initiating research on spices was sanctioned by lCAR during the Fifth Five Year Plan and CPCRl sets up a new Regional Station at Calicut in 1975 with the laboratories at Chelavoor and the farm at Peruvannamuzhi for conducting research on pepper, ginger, turmeric, clove, cinnamon, nutmeg, allspice and vanilla. It was thus entrusted with the responsibility to co-ordinate the research efforts in all important plantation crops like arecanut, oil palm, cashew, cocoa, cardamom, pepper and other spices, besides coconut. Thus, the great 'CPCRI empire' was founded - the golden era - with all the 'princely states' and 'free states' (arecanut, cocoa, cashew, oil palm black pepper, cardamom and other spices etc.) were merged with the 'union' except tea, coffee and rubber.

The All India Co-ordinated Coconut and Arecanut Improvement Project and Cashewnut and Spices Improvement Project came into operation with effect from 1-10-1970 and 2-12.1970 respectively. The network was further strengthened in the later years. The AICRP on Palms has at present 15 centres on coconut, four on arecanut, eight on oil palm and two on palmyrah, covering the important cropping tracts.

A modern township in a rural landscape: A lesson in infrastructure building

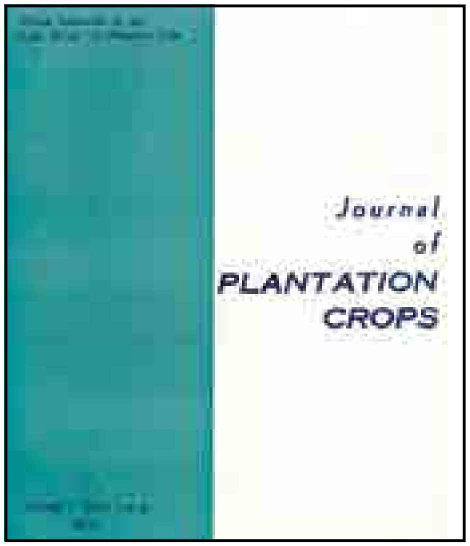
All facilities were built up with a vengeance, perhaps a 'retribution' for the sufferings in the early years - spacious office buildings constructed, modern laboratories with sophisticated instruments set up, a residential complex built up, schooling facilities starting from kinder garten to a Kendriya Vidyalaya started functioning at Kasaragod. Primary health centre with full-time medical officer and para-medical staff, creche, guesthouses, all facilities for a model workplace were institutionalized in a very short span of few years.

Birth of Indian Society for Plantation Crops and Journal of Plantation Crops

With the establishment of Central Plantation Crops Research Institute in 1970, the scattered and isolated units carrying out researches on individual plantation crops were brought together under a single agency of ICAR, with the possible

exception of coffee, rubber and tea (for which separate research institutions were already there in place). Consequent to the inception of the Institute, it was felt that a common forum be established to bring together all scientists working on these crops so as to facilitate free exchange of ideas and experiences.

The Indian Society for Plantation Crops (ISPC), a professional forum devoted to sustainable growth and development of plantation crops sector, was thus established in 1971 with headquarters at Kasaragod and this society has presently metamorphosed into one of the premier scientific societies in India. Its main activities are publication of the Scientific Journal, Journal of Plantation Crops (JPC), holding National and International Symposia and encouraging original research by instituting various awards.



Journal of Plantation Crops the first issue

Journal of Plantation Crops (JPC), as a multidisciplinary journal, aims at dissemination of research findings in plantation crops (coconut, arecanut, cocoa, cashew, oil palm, coffee, tea, rubber, date palm), including cropping systems, as well as various spices. Since its inception in 1973, 42 volumes have been published. The journal is published thrice a year during April, August and December and publication of the articles is subject to peer reviewing and recommendation by experts in the field.

The first 'coconut expedition' in 1981

Survey and collection of coconut germplasm in Pacific Ocean territories was undertaken in 1981 with the financial assistance of US $ 50,000 from IBPGR/ FAO. A scientific team, consisting of Dr. EVV Bhaskara Rao and Dr PK Koshy, was deputed to Solomon Islands, Fiji, American Samoa, Western Samoa, Tonga and French Polynesia during 9 August - 7 October 1981, and they collected 2500 nuts from 23 sites from these countries (except Western Samoa due to the incidence of internally seed-borne disease there). The collection consisted of 20 Tall types and four Dwarfs. These include types known in the literature as 'Rennel Tall', 'Solomon Tall', 'Fiji Tall', 'Samoa Tall', 'Tahiti Tall', 'Rangiroa Tall' and 'Dwarf Yellow' (American Samoa) 'Dwarf Orange' ('Rangiroa', also known as 'Hari Papua') and 'Niu leka' (Dwarf Fiji). Two tall types, 'Bulundrau' (Fiji) and 'Takovs' (Tonga) having large number of small nuts (comparable to 'Laccadive Micro' of India) were also collected. These collections were initially planted at the newly established World Coconut Germplasm Centre in Andamans and subsequently most promising selections from the original collections were relocated to the ICG-SA at the CPCRI Research Centre, Kidu in Karnataka.

Though coconut germplasm was introduced in India from south and southeast Asia several times in the past as early as 1924, this is the first case of a scientific exploration mission to outside India. This mission to the region considered to be the 'original home of coconut' has turned out to be highly rewarding, as these precious collections were the foundation material from which several new

Dr. M.C. Nambiar (1925-2010): the last Director of CCRS

Dr. M.C. Nambiar is the link between the CCRS and CPCRI, as the last director of the CCRS from (1967 to 1970) during the transition period (after the abolition of the Coconut Committee) and as Joint Director of CPCRI in 1970 and later officiating as director for a short period in 1977. In 1971, he was appointed as the Project Coordinator of the All India Coordinated Spices and Cashewnut Improvement Project on its inception. He began his career as a research worker with the Government of Madras in August 1947. In 1951, he joined the Cyto-Anatomy section of the Central Coconut Research Station, Kasaragod and was the Cyto-Anatomist till August 1967, when he took over as Director of the Station.

Dr. K.V. Ahmed Bavappa: The founding Director of CPCRI[20]

Born in 1930, Dr. KVA Bavappa had a brilliant academic career throughout. Commencing his service as a research worker with the Madras Agricultural Department in1951, he joined the services of the Indian Central Arecanut Committee in 1956. Later he worked in the capacities of Agronomist, Botanist and Arecanut Specialist at the Central Arecanut Research Station, Vittal and was instrumental in standardising the selection procedures in arecanut and evolving the popular semi tall, high yielding 'Mangala' variety (VTL-3). When research on plantation crops was unified, he became the first Director of the Central Plantation Crops Research Institute in 1970 and continued in that post till 1977 and later during 1982 to 1987. In between, he was deputed as a Spices Expert under the UNDP/ FAO project in Sri Lanka.

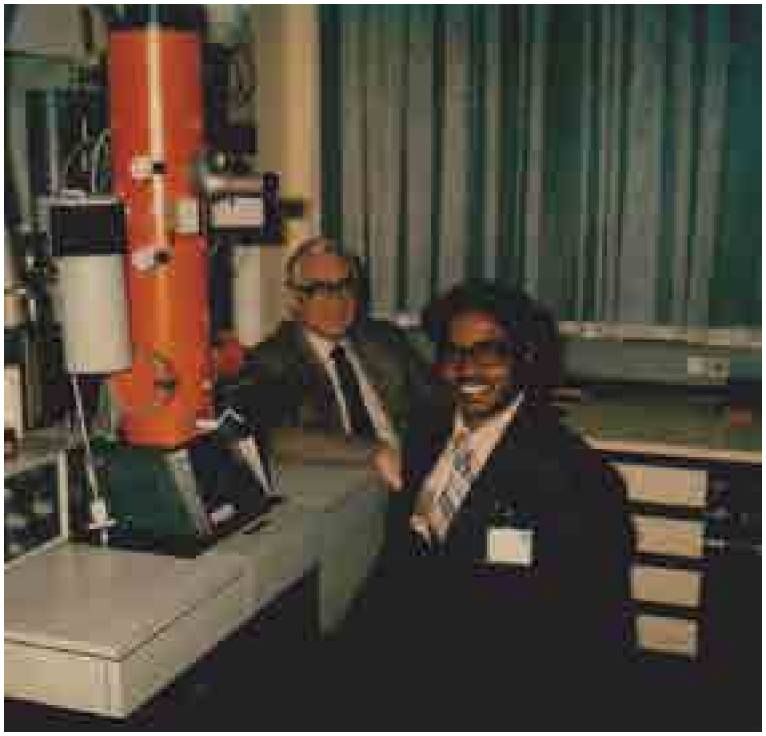
Dr. N.M. Nayar takes over the reins from Dr. Bavappa

Back in India from the Institute of Plant Breeding, University of Gottingen on a prestigious fellowship from the Alexander van Hurnboldt Foundation, Dr. N.M. Nayar begins his stint at CPCRI as the Joint Director of Regional Station Vittal in 1972, from where he moves over to Kasaragod as its Director in 18 July 1977 (consequent on Dr. Bavappa embarking on an FAO deputation) and continues in that position till 8 February 1982. His contributions to development of research and infrastructure like the Plantinum Jubilee Block and the Kendriya Vidyalaya are stupendous. International collaborative programmes for strengthening root (wilt) research under KADP was initiated during his tenure as director. A multi-faceted personality, Dr. Nayar is known for his scholarship, exemplary editorial skills and mentoring his scientific colleagues in developing skills in scientific communication.

hybrids/selections were developed/released in recent times and still more are in the testing line.

'MLOs' as an etiological agent of root (wilt) disease: A breakthrough

A breakthrough in the etiology of root (wilt) disease of coconut was accomplished by Dr. J.J. Solomon and his team in the 1980s in collaboration with Prof. J. Neinhaus of West Germany. Through systematic research, the involvement of fungi, bacteria, virus, viroid, nematodes and soil factors in the incidence of the disease was already ruled out. Mycoplasma Like Organisms (MLOs) were detected under electron microscope in ultra thin sections of developing leaves, unopened inflorescences, root tips, and terminal bud tissues (in the sieve tubes of phloem) in coconut root (wilt) affected palms and were conspicuously absent in samples from healthy palms. No virus-like particles or microorganisms other than MLOs were made out in these ultra thin preparations. Sample preparations and ultra microtomy were performed at the CPCRI Regional Station, Kayangulam and ultra thin sections were examined under electron microscopes at the Christian Medical College, Vellore, the Cotton Technological Research Laboratory, Bombay and the Institute for Plant Diseases, Bonn, West Germany, where the presence of MLOs was observed in disease affected palms.



Butler and the 'Mystery Disease': The enigmatic etiology of coconut root (wilt) disease

Though the history of organized institutional research in coconut in India started only in 1916 with inception of the coconut research stations, individual scientific investigations in coconut dates back to 1908 when Dr. E.J. Butler, the then Imperial Mycologist at the Imperial Agricultural Research Institute at Pusa was deputed to study the incidence of an 'unknown disease' in coconut (which is now known as the root (wilt) disease of coconut), based on vociferous demands from growers in the then Central Travancore area of Kerala State.

Sir Edwin John Butler FRS (1874–1943) was a British mycologist and plant pathologist. In 1905, he became the Imperial Mycologist at the Imperial Agricultural Research Institute at Pusa in India and later the first director of the Imperial Bureau of Mycology (later known as the International Mycological Institute) in England from 1920 to 1935. In 1930, he published the Fungi of India along with Guy Richard Bisby. Interestingly, Butler's tryst with coconut diseases also involved bud rot disease as well.

Dr. Butler in his "Report on Coconut Palm Disease in Travancore" (1908) observed that though no fungus was present in the leaf or stem, but the roots are attacked by a parasitic fungus (*Botryodiplodia theobromae*), and considered this root-rot to be sufficient to account for the disease, even though conclusive infection-experiments were not yet carried out. The report concludes with remarks on the intensity of the attack in different localities, and instructions for checking the disease. Though subsequent investigations also showed constant association of *Rhizoctonia solani, R. bataticola, Cylindrocarpon effusum and Fusarium equiseti* in the roots of disease affected palms, all these pathogens failed to produce the characteristic symptoms of the disease under artificial inoculation studies, thus conclusively ruling out the fungal etiology. It is in fairness of things that, though Dr. Butler could not identify the etiology of the root (wilt) disease or suggest measures for alleviating the malady, his recommendations helped in developing a modern line of approach to the problems of coconut cultivation.

Of course, scientific advancements in later years have resulted in redesignating these 'sub-microscopic non-culturable vascular limited plant pathogenic organisms' more specifically as Phytoplasma, and not MLOs. Successful transmission of the disease by lace bug (*Stephanitis typica*) and plant hopper (*Proutista moesta*) under insect-proof conditions has further established the phytoplasmal etiology. With the advent of polymerase chain reaction (PCR) based detection techniques, molecular characterization in recent years have established the coconut RWD Phytoplasma as belonging to the 16srDNA XI group. Besides, a sensitive, simple and rapid sero-diagnostic test was also developed by the institute to detect the phytoplasma even 6-24 months prior to the expression of visual symptoms. But apart from these, not much progress could be achieved towards finding a curative solution to the root wilt (disease) considering the enormous complexities that every Phytoplasma mediated diseases poses worldwide.

If no cure, then better manage it: Management packages for root (wilt) diseased gardens, the second line of defence

It is sheer prudence that first priority be given to minimizing losses and saving maximum lives and property in any given contingency, where it is nearly impossible to prevent or thwart the occurrence of such an unfortunate eventuality, be it a natural calamity like earthquake, or an epidemic or facing an incurable disease. Fortunately, root (wilt) disease of coconut is only a debilitating disease and not a lethal one and as such the health, and yield of palms can be improved/ maintained through the adoption of integrated management practices consisting of balanced fertilizers, addition of organic matter, raising green manure crops in the basin and its incorporation, weed control, leaf rot control and recycling organic matter. In general, apparently healthy palms and those in the early stage of disease respond better to management practices. For ensuring better economic returns and for a sustainable family farming, farmers are encouraged to adopt integrated cropping/farming systems.

Management of pests of coconut: Evolution from chemical pesticides, biocontrol to IPM

Plant protection in India, and for that matter most of the developing countries in general, was mainly based on the use of chemical pesticides. Chemical control is, off course, one of the effective and quicker method in reducing pest population, where farmer gets spectacular result within a short time. However, over reliance and indiscriminate use of pesticides resulted in a series of problems in the agricultural ecosystem mainly, the development of resistance to insecticides, pest resurgence, outbreak of secondary pests into primary nature, environmental contamination and residue hazards, destruction of natural enemies of insect pests etc. All these problems contributed to developing a new way of pest control, i.e. the integrated approach of pest control. Integrated Pest Management is "an ecological approach in which utilization of all available techniques of pest control to reduce and maintain the pest population at levels below economic injury level". Though Integrated Pest Management (the term IPM was introduced by R.F. Smith and R. van den Bosch in 1967) was adopted as a policy by various world governments during the 70's and 80's, including the USA in 1972, India declared IPM as official policy only in 1985.

The importance of pest control in crop husbandry was recognized in the early days itself and initial investigations were on developing chemical control regimens for major pests of coconut. Concurrently, investigations were intensified for exploring natural enemies and standardizing their mass production and release in the field. Biological control of the coconut caterpillar, *Opisina arenosella* Walker, with the indigenous larval/ pupal parasitoids like *Bracon bevicornis* and *Goniozus nephantidis* became a reality in the 1980s itself29. Though the infection of *O. rhinoceros* by virus (OrV) was first reported in Malaysia in 1966, a detailed work on it was done in India only in 198330. The population of *O. rhinoceros* and its damage on coconut palm was checked substantially when the OrV was released/re-released in Minicoy and Androth islands of Lakshadweep, Chittilappillly in Trichur, Kerala and in Sipighat of Andaman Islands. Thus, the success encountered by the use of this microbial pathogen has endorsed its claim as one of the landmark examples in the biological control of an insect pest. *Metarhizium anisopliae*, commonly termed as the 'green muscardine fungus' (GMF), is a well-known entomopathogen. The susceptibility of *O. rhinoceros* to it was first reported in Western Samoa in 1913 and in India in 1955. *M. anisopliae* var. major (spore size 10-14 µm) is a highly infective strain used widely for the control of this pest.

Over time, the classical biocontrol has evolved into IPM, incorporating elements of biocontrol, minimal and judicious use of pesticides and cultural practices. It is most gratifying that IPM packages have been developed for all major pests of coconut. The beauty of IPM is that it is not (and should never be) static and it should evolve with the changing pest dynamics, underpinning the need for continuous evaluation and refinement. Presently, efforts are on to develop greener safer molecules as alternatives to many of the chemicals widely used at present, biopesticides and bioagents, with minimum health risk for humans and other living organisms and ensuring a safe and clean environment at large.

High Density Multiple Species Cropping System: Many crops and one cropping system that fits all!

Coconut based HDMSCS, initially conceptualized and developed in the eighties and further refined in the succeeding years, is a highly versatile, sustainable, profitable system, optimizing the use of available resources. Different models tailor-made for various agro-ecological zones and suiting different requirements of households have also been evolved over the years. The beauty is that you can select the component crops based on the food preferences and nutritional requirements of the family and optimum income possibilities considering the prevailing market realities. By the latest projections, a coconut based cropping system using multi species cropping of coconut with pepper, banana, nutmeg, pineapple, ginger, turmeric and elephant foot yam generated a net income of ₹ 3.7 lakhs per ha, which is 150% higher than that of coconut monocrop (₹ 1.4 lakhs).

Mixed Farming System: the 'Jewel in the Crown'

Multi species cropping system has further evolved into mixed farming system by integrating livestock enterprises in to it. It is a classic case of the society demanding it and the research institution answering the distress call. Off late, the coconut growers are exposed to economic risks and uncertainties owing to the frequent price f1uctuations for the produce. In this context, it is needless to emphasize the importance of crop/ enterprise diversification in coconut gardens. The research at CPCRI clearly indicated the scope for integration of crops and animals in the coconut garden for enhancing income and providing employment throughout the year. The system, thus developed, is a closed one, requiring less off- farm inputs, and gives importance to recycling of produces/ wastes among the components in the system. It facilitates high input use efficiency and energy-efficient practices through proper linking/integration of different components and intelligent management of available resources. Besides enhancing coconut yield, there was substantial improvement in soil and plant health status, soil physical properties and soil biology, thereby making CBIFS more economically feasible and ecologically sustainable. Added attraction is that subsidiary income is also realized from all the component units. As per the recent investigations, a coconut based mixed farming system (CMFS) comprising coconut, pepper, banana, fodder grass, crossbred cows, poultry birds, goat, and pisciculture generated a net return of ₹ 5.5 lakhs, which is 288% higher than that of coconut monocrop.

CPCRI in the 1980s: The mother institution for many

The second half of the 1980s witnessed the siblings leaving the '*tharavaadu*' (the grand joint family), building their fortunes independently. Research on spices and cashew were delinked from CPCRI. The CPCRI Regional Station, Calicut (Kozhikode) along with CPCRI Research Centre, Appangala was upgraded into National Research Centre for Spices (present ICAR-IISR). Similarly, the Cashew Seed Farm at Shantigodu along with at substation Kemminje in Puttur were converted into National Research Centre for Cashew at Puttur (presently ICAR-DCR). Little later, oil palm was delinked from CPCRI and established as National Research Centre for Oil Palm at Pedavegi in Andhra Pradesh (presently ICAR-IIOPR) and consequently the erstwhile Research Centre at Palode (in Thiruvanathapuram district) under CPCRI was transferred to the oil palm institute. Similarly, ICAR Research Complex at Goa, under CPCRI, was upgraded into Central Coastal Agricultural Research Institute.

Of course, it is far more easier and efficient to administer a smaller kingdom than a vast empire, as historians would tell us with the fate of great Roman empire and the British colonial empire where "the sun never sets". Though "smaller" in stature, "greater" was the research achievements in the next three and a half decades, vindicated by the fact that not less than 20 coconut varieties and hybrids were released from the institute. The latest in the impressive line-up is the coconut variety, Kalpa Satabdi and several others are in various stages of testing line.

Times have changed; the research institution taking farmers and other stakeholders along

No longer operating in isolation, as was the case in the early days. Initial attempts were to demonstrate the importance of proper cultural, manurial, and disease and pest management in coconut. The demonstration plot (permanent manurial trial) with three blocks (one properly cultivated and manured, the second ploughed but not manured, and the third neither ploughed nor manured) are still maintained at the Institute as a living testimony to the efforts at convincing local farmers of the benefits of ploughing and proper manuring of coconut gardens. The impact was so remarkable that the ordinary farmers who paid no heed in the beginning were convinced, in the long run, of the necessity for proper care and management of coconut palms.

Times have changed and the farmers are no longer disinterested observers. Package of practices for crop management developed by the Institute are being adopted all over the country. Removal of senile and nonbearing trees, which was a taboo totally unacceptable in olden days, has gave way to systematic replanting with high yielding seedlings coupled with adoption of management practices. Now, requests come in thousands at the Institute for planting materials of high yielding varieties of coconut, a fraction of which could only be met.

Now, one step ahead, mass contact programmes (Farmers-Scientists Interface) are being organized all over the major coconut growing tracts to reach out to the farmers hitherto unreached, enlisting the support and participation of the peoples' representatives, officials of commodity boards and state agricultural/horticultural departments and farmers' groups. Professionals from the mass media (both print and visual) are being sensitized through periodic interaction on latest developments in the field as a most effective medium of reaching the grass roots level. Social media is also meaningfully engaged in this endeavour.

Krishi Vigyan Kendras at Kasaragod and Kayamkulam: the extension machinery takes 'wings'

Initiatives at reaching out to farmers got a fillip with the establishment of two Krishi Vigyan Kendras (KVKs) under the administrative control of the institute. The KVK at CPCRI, Kasaragod, established on 01 January 1993, is the frontal organization for promotion of agricultural technologies and allied enterprises among the people of Kasaragod district, with an operational area of 1, 96,133 ha spread over six blocks, 39 grama panchayats and 77 revenue villages.

Krishi Vigyan Kendra-Alappuzha, hosted by Central Plantation Crops Research Institute (Regional Station), Kayamkulam, has achieved the status of one of the leading frontline extension providers in the district during the last decade. Having started functioning from June 2000 under the National Agricultural Technology Project (NATP) of ICAR, it was later remandated as a regular KVK from April 2004. The two KVKs have been successfully conducting technology assessment, refinement and demonstration programmes in addition to trainings to farmers, farm women, rural youth, and extension officials. Besides, they act as a source of seeds, planting materials and inputs for agri- based activities, and technology support center including soil testing facilities to the farmers.

Fostering institutional linkages and research collaborations

Right from the beginning, there were conscious efforts at fostering linkages and enlisting partnerships in collaborative research programmes, both at national and international levels. At the national level, work on electron microscopy for the investigation on etiology and remote sensing technique using infra-red aerial photography for diagnosing root (wilt) disease in early stage were in progress in collaboration with IARI and ISRO. A project on agrostology and mixed farming was initiated in collaboration with the Indo-Swiss Project at Mattupatty and the Intensive Cattle Development Project, Kerala.

As early as 1970, international level investigations on the bud-rot of coconut was in progress with USAID under the PL-480 programme. Collaboration with the Commonwealth Institute of Biological Control (presently ICAR-NBAIIR),

Dr. M.K. Nair succeeds Dr. Bavappa

Dr. M. K. Nair as Director of CPCRI (1987-1997) ably steered the ship since its reorganization in 1986, leading to the de-linking of spices and cashew from the ambit of the institute and played a key role in establishing the new research institutions - NRC for Spices at Kozhikode, NRC for Cashew at Puttur and NRC for Oil Palm at Pedavegi. He has played an exemplary leadership role in augmenting the genetic resources, especially with exotic germplasm through international collection missions, and establishing the ICG-SA. He himself handled new hybrid trials involving D x T hybrids, which later lead to the release of several hybrids in subsequent years.

Bangalore was facilitated for work on biological control of mites. Another area in which the institute was making concerted efforts to obtain collaborative support for the ongoing research programmes was the root (wilt) disease. There were four consultancy visits from overseas, by Dr FO Holmes (Rockefeller Institute, New York) in1964, Dr B Weischer (University of Munster, West Germany) in 1966-1967, Dr JW Randles (University of Adelaide, South Australia) and Dr DJ Raski (University of California, Davis) in 1979 to study the problem. Under the World Bank funded 'Kerala Agricultural Development' Project, started in January 1978, ₹. 41.0 lakhs (out of the allocation of ₹ 64 lakhs for CPCRI) was earmarked for intensification of research on root (wilt) disease. Six new research projects with specific funding under this programme were initiated in addition to the 23 ongoing research projects with institutional funding.

As part of the Indo-UK protocol signed in 1977-78 under the Natural Resources Development Programme, the CPCRI was identified to partner with Rothamsted Experimental Station, the biggest and the most prestigious agricultural research station in UK, for taking up co-operative research programmes on root (wilt) disease of coconut and yellow leaf disease of arecanut. International collaborations with BIOVERSITY/ COGENT/APCC in coconut research and development was strengthened in the 1990's with several IFAD/DFID/COGENT funded projects taking off. A total of 20 projects were undertaken by the Central Plantation Crops Research Institute (CPCRI). Funding support for coconut PGR-related projects amounted to a total of US$ 392,600 out of which US$ 215,975 was provided by ADB, APCC, DFID and IFAD, while US$ 176,625 came from counterpart financing by ICAR. Under this initiative, several meetings/ conferences/ workshops were held in India from 1995 to 2005, with CPCRI hosting the 4th COGENT Steering Committee Meeting and CGRNAP Annual Review and Planning Meeting in 1995 at Kasaragod and the 14th COGENT Steering Committee Meeting in 2005 at Mangalore.

Seven coconut specialists visited India from 1995 to 1999 for identifying a suitable site for the International Coconut Genebank for South Asia (ICG-SA), to evaluate COGENT's collecting strategies and conduct a pest-risk assessment. Another important area was training and human resources development, under which several scientists from the institute were trained on various topics including coconut embryo culture to improve collecting and safe movement of germplasm, the use of the microsatellite kit and dedicated statistical software, production of coconut-based food products, socio-economics and participatory approaches to reduce poverty in coconut growing communities, markets and market development.

International Coconut Gene Bank for South Asia (ICG-SA): the Crowning Glory

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, was established under a tripartite agreement among ICAR-FAO-ITPGRFA. Planting of coconut accessions in the ICG-SA, located at CPCRI Research Centre, Kidu, Karnataka, was initiated in 1998. 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, representing 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. This genebank is the treasure house of genetic diversity to combat the immediate challenges of the present and the emerging exigencies of changing climate.

Dr. K. U. K. Nampoothiri was the Director during 1997 to 2000

In his early research career, planted the coconut hybrid evaluation trial in diallel mating design involving nine parental accessions, probably the first in the world, as early as 1972. Later, as the Director of the institute during 1997-2000, he has guided all-round development of the institute and further strengthened research in coconut, especially genetic resources management and utilization. Subsequently, played a pivotal role in finalizing and notifying the DUS guidelines for coconut, as chairman of the committee constituted by the PPV&FRA.

The twenty first century beckons!

Developing technologies: A paradigm shift is the need of the hour

How much an agricultural/crop research institution should focus on research in basic sciences and applied research? This paradox has been plaguing the policy makers and R&D mangers alike ever since the advent of public funded research organizations in India, as elsewhere in the world some time or other in history. Of course, both are complementary, as the superstructure of a magnificent mansion can only be built upon the strength of a strong foundation underneath. It can be safely presumed that once the foundations are sufficiently strong, it is time to go aggressively for building upon it. Interestingly, the legendary Professor JBS Haldane, while visiting the Coconut Research Institute of Sri Lanka in 1961, is said to have remarked that *"the research and research programmes of a crop research institute needed a proper balance between pure research*

'Sharing is caring': Exchanging PGR and expertise with other Asia-Pacific countries

True to the spirit of exchange (*'not only receiving'*), we have also shared our coconut germplasm resources with other coconut growing countries in the Asia-Pacific region. Precious coconut germplasm from India was shared with Brazil and Ivory Coast in the 1960s and subsequently to Sri Lanka during 2003-04. We have also been magnanimous in sharing the knowledge and expertise with the rest of the coconut fraternity. One of the earliest case was that of Dr. K. Satyabalan, the eminent coconut breeder, deputed to the Fiji islands during 1971-73. As Senior Research Officer (Coconuts) in Fiji Islands, he played a pivotal role in giving a definite shape to coconut research and mentoring the aspiring young researchers in the island.

Dr. Satyabalan proudly recollects his service in Fiji thus, *"I was in-charge of the Coconut Section in the Research Division of the Department of Agriculture and was responsible for the research work on coconut. I was also Administrator of the Wainigata Research Station, Savu in Vanu Levu, one of the two developed large islands in Fiji. I guided technical officers and field staff in their research projects. My work also included taking classes on the scientific methods of coconut cultivation for the students of Fiji College of Agriculture in Suva"*.

Dr. R.D. Iyer, the Head of the Division of Genetics, was deputed to Mauritius during 1987 to 1989 as Adviser in Plant Tissue Culture, Ministry of Agriculture & Natural Resources of Mauritius, under the Commonwealth Fund for Technical Co-operation among Developing Countries (CFTC). In recent years, Dr. R. Manimekalai and Dr. P.M. Jacob from this institute were deputed to Sri Lanka under TCP/IP programme of FAO for devising a breeding programme for the Weligama wilt disease of coconut. Currently, Dr. B.A. Jerarad is in Fiji, deputed by the Govt. of India, for guiding the coconut programmes in that country.

which is fundamental and applied research which produced practical results. It is the duty of the Director to hold the balance and unless practical results are produced in reasonable time, the research workers may get into trouble". And, finally that hour of reckoning has arrived for the institute and it has responded to it splendidly.

"Survival of the fittest" holds good not only in evolutionary biology, but in modern competitive global commodity markets also!

The cardinal doctrine of Darwin's theory of evolution is 'the survival of the fittest'. The 'fittest' that is most likely to 'survive' in the evolutionary process is those species (even individuals also) endowed with desirable traits (possibly due to mutations) ensuring better chances of survival. By the same analogy, in the present day global commodity markets, the winner is always the country/organization/any other entity in possession of better technologies (imparting a competitive edge), that can produce/supply better products at lower prices. Needless to say, there has to be a continuum of innovation, as technologies also get less efficient over time and eventually become obsolete.

Atithi Devo Bhava

All through history, we have played perfect host *(Atithi Devo Bhava, 'guest is god' is historically enshrined in our national ethos)* to several visiting researchers both from the developing countries and the more scientifically advanced West, mutually benefitting from the interactions of scientific professionals. Dr. Francis O. Holmes, a noted virologist of the Rockefeller Institute, New York, undertook studies on the. root (wilt) disease at the Central Coconut Research Station, Kayangulam for about six weeks in October-November, 1964, under an assignment of the Food & Agricultural Organization of the United Nations.

On completion of his assignment, a memorable farewell was given to Dr. Holmes on the 27th November 1964 at the Central Coconut Research Station, Kayangulam with Shri K. P. Madhavan Nair, Vice-President of the Indian Central Coconut Committee presiding over the function. While addressing the gathering of research workers and progressive cultivators, he expressed the hope that the root (wilt) disease of coconut' in South Kerala was probably caused by a virus or virus-like pathogen but that the disease could be controlled as its spread to new areas was extremely slow, giving enough time to check it.

Mrs. Reeth D. Holmes who had accompanied her husband was full of praise for the natural beauties of Kerala and the hospitality shown them at the Central Coconut Research Station, Kayangulam. *"Our stay in India is an experience we shall always remember,"* she said and added *"The comfortable guest house of the Central Coconut Research Station surrounded by bright flowers and tall waving palms has been a pleasant home for us during our weeks in Kerala. Dr. and Mrs. Lal have played a triple role-as perfect host and hostess, as considerate, helpful neighbours and as good friends, and each role has been equally successful and greatly appreciated"*[37].

With the opening up of Indian economy by the end of the last century and liberalization of trade regimes in the first decade of the present century with the GATT and free trade agreements in place, the plantation crops sector in India has been increasingly exposed to competition. Naturally, from the beginning of the 21st century, the emphasis is on developing technologies for empowering the farming community in such an increasingly competitive global scenario.

Dr. V. Rajagopal takes over as Director on the first day of the 21st century

A Plant Physiologist by profession, Dr. Velammor Rajagopal was instrumental in unravelling the physiological basis of moisture deficit stress in coconut and developing sound mitigation strategies. Later as its Director (during 1-1-2001 to 31-3-2006), gave a fresh impetus to fostering international collaboration in PGR management with APCC/COGENT.

Value addition is key to survival

Traditionally, the share of value added products from coconut (apart from coir and coir based products) in the Indian export basket is very negligible. The silver lining is that the situation has started changing over the last few years. It is really heartening that the export of coconut products (except coir and coir products) during 2014-2015 rose by 13.5 per cent to ₹ 1,312.38 crore, against ₹ 1,156.12 crore during 2013-2014. The most notable thing is that the export earnings from coconut shell-activated carbon alone was ₹ 588 crore and virgin coconut oil recorded a significant increase (in both quantity and value) to reach ₹ 24.72 crore, up from ₹ 4.81 crore during 2013-14. This encouraging trend continued in 2015-16 also, fetching a record ₹ 1,450 crore, an increase of 10.50 per cent over the previous financial year. This achievement is all the more creditable in the backdrop of the overall picture of merchandise export from India showing a negative growth. However, a disturbing reading amidst this happy tidings is the reports that "in spite of the high demand for organic virgin coconut oil, the order for exports could not be met due to limited production of certified organic virgin coconut oil", a food for thought for all the concerned.

Evidently, there is no room for complacency, as there are plenty of opportunities still to be exploited. An exemplary case is that of Sri Lanka, which is a major exporter of value added products, though not a major producer of coconut. It may seem unbelievable that coir pith (a refuse from coconut fibre industry) from Sri Lanka is in great demand in USA, Europe and Australia, as an important ingredient of soilless potting media. Juxtaposed with this is the all too familiar sight in the west coast of India, especially in the coastal Kerala, where one can see heaps of coir pith, often rising to the heights of small hillocks, dumped in the premises of fibre extracting units.

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.

Kalparasa: the lifeline of coconut industry

Kalparasa, the nutritious health drink from coconut inflorescence, is actually the phloem sap rich in sugars, protein, minerals, anti-oxidants and vitamins and is literally the 'health and wellness capsule' in every drop. Moreover, the glycemic index (rate at which sugar is absorbed in blood) is found to be low in Kalparasa. The fresh sap has a very good colour like honey and it is sweet and delicious.Kalparasa is virtually the game changer for the coconut farmers faced with low profitability, consequent on high cost of cultivation and lower prices for the traditional products (copra/oil) coupled with the market uncertainties. Even by conservative estimates, it has been demonstrated that a farmer tapping 15 coconut palms for Kalparasa could earn on an average net profit of ₹ 45,000 a month, while a tapper can earn about ₹ 20,000 per month.

Realizing its huge potential, the Institute has developed a simple ice box technology (Cocosap chiller) to collect farm-fresh, hygienic, unfermented sap from coconut palm, totally free from contamination with insect, ants, pollen and dust particles. The sap, thus, collected under cold condition remains fresh and unfermented, and 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, for which technologies are also developed. Besides, a bottling technology has been developed for Kalparasa to extend its shelf-life up to 45 days under refrigerated condition without adding any preservatives and additives.

'Dwarf is handsome': Shifting focus in coconut breeding

Early attempts were at developing tall varieties and T x D hybrids considering their higher yield potential and oil percentage, hardiness and adaptability to varied climatic and edaphic conditions. Of the nineteen coconut varieties and hybrids developed by CPCRI so far, nine of them are either tall or T x D hybrids. Now, in the present scenario of acute shortage of palm climbers and the increasing demand for tender nuts and also kalparasa tapping, there is a rethinking in the breeding strategies, with the emphasis now placed on developing dwarf varieties and D x T hybrids suitable for tender nut and also dual purpose (conventional copra/oil and tender nut purpose). Apart from the Chowghat Orange Dwarf released in 1991, the recently developed varieties like Kalpa Surya and Kalpa Jyothi (as exclusive tender nut varieties), are a welcome step in this direction. Incidentally, the ICAR-CIARI, Port Blair has recently released four dwarf selections (Annaporna for copra purpose, Chandan, Surya and Omkar for ornamental and tender nut purposes) from the exotic germplasm of Pacific region conserved by CPCRI at the erstwhile WCGC, Port Blair (now under ICAR-CIARI).

Another facet of the present breeding strategy is to look for other desirable traits like suitability for value addition and/or biotic and abiotic stress tolerance, apart from the traditional emphasis on yield potential. Kalpa Pratibha, Kerachandra and Kalpa Haritha are recommended as dual purpose varieties suited for both copra and tender nut purpose. Kalpatharu is recommended as a ball copra variety, owing to minimal spoilage and higher recovery percentage of ball copra. The varieties, Chandra Kalpa, Kalpa Mitra, Kalpa Dhenu, Kera Keralam and Kalpatharu are also relatively tolerant to moisture stress. Kalparaksha and Kalpasree are recommended for root (wilt) affected tracts as disease tolerant varieties.

Semiochemicals in coconut IPM: Keeping with the changing times

Deciphering the 'chemical code' of insect communication has revolutionized the science of pest management. Semiochemicals, the signalling molecules used in insect-insect or plant-insect interaction, are now increasingly considered within IPM strategies as an alternative or complementary approach to insecticide treatments. Semiochemicals can be either allelochemicals or pheromones, depending on whether the interactions are interspecific or intraspecific. Pheromones are perhaps the most widely exploited semiochemicals at present, but recent efforts are also directed at identification and use of compounds involved in interspecific interaction as well, especially other behavior-modifying semiochemicals like host plant volatiles (which work either as attractants or repellants). Enormous work is involved in developing an efficient system, which involves identifying and optimizing pheromone blends, best dispenser dosages and fine-tuning trap designs to ensure that they are highly species-specific and optimally attractive to the target species.

The pheromones have been widely used for monitoring adult populations of endemic pest species, detection and survey programs for invasive species, mating disruption, and mass trapping of target species. The technique of mass trapping using pheromones has become a highly effective, environment-friendly and relatively inexpensive means of suppressing populations of those pest species whose pheromone communication systems and bionomical characteristics make them susceptible to this approach. In this technique, traps are deployed at optimum densities that have proven to attract and capture sufficiently large numbers of insects ensuring direct reduction in damage to the crop. In coconut IPM, the basic strategy employed is mass trapping of adult insects using pheromones. There are several reports of highly successful and effective commercial mass-trapping programmes being executed against weevil pests of coconut and other palm species like oil palm.

The institute has recently successfully characterized the kairomones (allelochemicals emitted from the host attracting the insects towards it) from host volatiles, which can act as pheromone synergists in red palm weevil management. Placing of food baits (fermenting banana, pineapple and neera) with the commercially available pheromone lure in the conventional bucket trap was found to have synergistic effect in attracting the red palm weevils. It was then reasoned that, if the volatiles released from these food baits are identified, it can facilitate development of efficient kairomones that could be used in tandem with pheromone, rather than the fresh food baits. Through concerted efforts over a considerable period of time, the physiologically relevant volatiles from the food baits were identified by combing with chemical and biological detectors, followed by wind tunnel behavioural assay. Thus, a 'kairomone blend' (having major and minor components) along with the pheromone (4 methyl 5 nonanol + 4 methyl 5 nonanone 9:1) was found to induce maximum activation. The next step was stringent evaluation of its field efficacy. Field evaluation at several locations across the major coconut tracts in India showed excellent results, with the pheromone loaded in nanomatrix combined with a kairomone blend' trapping higher number of weevils than the reference commercial lure (alone), thus ensuring better efficiency and better cost-effectiveness *(remember all commercial pheromone formulations are really expensive!)*, besides making it very user-friendly in the field.

Nanotechnology and IPM

Because of the complex biological activity of semiochemicals, their dispersion in the ecosystem need to be regulated carefully, which warrants development of slow-release devices ensuring a controlled release of these biologically active volatile compounds, from both biological and economic considerations. In India, aggregation pheromone (4 methyl 5 nonanol +4 methyl 5 nonanone 9:1) is used in tandem with food baits to attract the red palm weevils. Though effective, these lures need to be replaced once in 3-4 months. Nanoporous materials are a novel carrier/ dispenser for the volatile signaling molecules with controlled spatiotemporal release rates. A nano-dispenser, with ordered pore channels, has been developed for loading the pheromone and kairomone blends of red palm weevil, ensuring a delayed dissipation (as confirmed by Field Scanning Electron Microscopy (FESEM), X-ray Diffraction (XRD) and Thermal Gravity Analysis) and consequently longer life in the field.

PGPRs in coconut: Harnessing the 'mighty microbes'

Plant growth promoting rhizobacteria (PGPRs) are now being considered as new microbial resources for developing bioinoculants. They are known to possess multiple plant growth promotion properties. *Bacillus megaterium* isolated from coconut rhizosphere has been released under the brand name 'Kera Probio' for production of healthy and vigorous seedlings of coconut. Its inoculation has shown to give 30-38 % increase in total dry matter of coconut seedlings.

'Come, let's learn together': Participatory and co-learning approaches in extension

With the passage of time, the dreary 'preaching, teaching and monologues' have given way to more meaningful 'dialogue and engagement' with the stakeholders. This shift from the conventional 'transfer of technology' model to participatory co-learning and decision-making support could improve the extension service delivery and serve as an important strategy for the extension machinery to engage a broader client constituency. Two landmark advances in this approach were the evolving of a technology delivery mechanism for area wide community adoption of technologies (like IPM of rhinoceros beetle and red palm weevil in coconut) and developing methodologies for assessing and enhancing group performance and group capacity of community based organizations in coconut sector. Assessment and refinement of technologies are done with the active participation of farmers, by organizing various programmes with the cooperation of developmental departments/ commodity boards. Thus, research and extension activities have been fine tuned considering the demand of the stakeholders.

Dr. George V. Thomas was the Director during 2006 to 2014

Since joining the institute as an ARS Scientist in 1978, he walked up the ladder to become its Director in April 2006 and continued in that position till 2014. A microbiologist by profession, his contributions in bioresource management in production system of plantation crops, organic farming, recycling of crop residues, microbial activity and functions in cropping systems and biofertilizers were outstanding.

Dr. P. Chowdappa is the present Director

A distinguished Plant Pathologist, Dr. P. Chowdappa, steered the national programme on *Alternaria, Colletotrichum* and *Cercospora* diseases of field and horticultural crops at ICAR-IIHR, Bengaluru during 2009-14 and his work on *Phytophthora* diseases of horticultural crops is globally recognized. Since taking over as Director on 6-9-2014, his emphasis has been on result-oriented research, especially developing value-added products and technologies for the sustainability of the plantation crops sector and high quality publications. A new research initiative is the whole genome sequencing of coconut. Since then, he has embarked on a mission enhancing the visibility of the institute and reaching out to the farmers, its primary clientele, through a series of farmer outreach programmes (Kisan Melas) across India and meaningfully engaging the print and electronic media in this endeavour. He is also instrumental in building new infrastructural facilities like the Centenary Block and giving a new look to the existing structures in the institute by undertaking a massive renovation and refurbishing exercise.

Success is not an accident, and excellence is not a coincidence either

"Excellence is not by accident. It is a process, where an individual, organization or nation continuously strives to better oneself", said the former President (and the great missile scientist) of India, late Dr. A.P.J. Abdul Kalam. The ancient wisdom has enshrined that excellence is truly the result of high intention, sincere effort, intelligent direction, skillful execution and the vision to see obstacles as opportunities.

One Hundred Years may seem a fairly large period for an institution, but may not be so, if one considers that the economic life of a coconut palm exceeds 60 years, more or less on par with the intellectually most active and work-productive lifespan of a man. Nevertheless, for an organization at its 100-year milestone, with 100 years of experience and excellence behind it, it takes tremendous engagement and commitment for positively impacting the lives of the coconut farmers, one of the most fragile and vulnerable section of the present day Indian agriculture.

Important milestones in coconut research

1916 Initiation of coconut research in the country

1924 Introduction of exotic germplasm from Asian and Pacific ocean countries viz., Philippines, Malaysia, Fiji, Indonesia, Sri Lanka and Vietnam

1934 Planting of first coconut hybrid (West Coast Tall x Chowghat Green Dwarf)

1947 Intensification of coconut research under four disciplines viz., Agronomy, Botany Cytogenetics and Analytical Chemistry at CCRS, Kasaragod

1948 Intensification of research on pests and diseases with special emphasis on root (wilt) disease under CCRS, Kayamkulam

1955 Further introduction of exotic germplasm from different countries

1966 Systematic germplasm and hybrid evaluation trials initiated

1969 Development of Integrated farming system model in coconut with dairy

1972 World's first coconut hybrid evaluation trial in diallel mating design involving nine parental accessions

1978 Development of multi-storeyed cropping system model with coconut-black pepper-cocoa-pineapple

1981 Introduction of exotic germplasm from Pacific Ocean islands

1983 Phytoplasmal etiology of root (wilt) disease reported based on electron microscopy

1983 Establishment of high density multi-species cropping system with 17 crop species

1985 Release of coconut hybrds, Kera Sankara (WCT x COD) and Chandra Sankara (COD x WCT)) and high yielding variety Chandra Kalpa

1993 Release of Chowghat Orange Dwarf as the tender nut variety, a high yielding hybrid Chandra Laksha (LCT x COD) and a variety Kera Chandra

1995 Lignin rich crop residue recycling by coconut leaf vermicomposting with the earthworm, Eudrilus eugeniae local strain

1996 Standardised the protocol for embryo culture in coconut

1999 Planting in ICG-SA commenced

2000 Established Sub-Distributed Information Centre of Department of Biotechnology

2007 ELISA for detection of root (wilt) disease was refined to a simple and rapid test

2007 Four varieties viz., Kalpa Dhenu, Kalpa Mitra, Kalpa Pratibha and Kalparaksha released for commercial cultivation

2008 Association of phytoplasma with root (wilt) disease established through PCR amplification of DNA from tissues of root (wilt) diseased coconut palms

2009 Establishment of Agri-Bioinformatics Promotion Centre under Department of Information Technology

2009 Two hybrids viz., Kalpa Samrudhi and Kalpa Sankara and two selections viz., Kalpasree and Kalpatharu released for commercial cultivation

2010 PGPR formulations for coconut developed

2010 Genome sequence of PGPRs released

2011 Developed IDM strategies for bud rot of disease of coconut

2011 Technology for the coir pith cake formulation of Trichoderma (slow release) patented

2011 A novel nanomatrix dispenser with ordered pore channels for loading pheromones and kairomone blends for red palm weevil and pheromone for rhinoceros beetle developed

2012 Two dwarf varieties (Kalpa Jyothi and Kalpa Surya) suitable for tender nut purpose and a tall dual purpose variety (Kalpa Haritha) released

2012 Safety device developed for the popular coconut climbing device

2012 Value added products from kalparasa - coconut sugar and coconut jaggery and machineries (coconut milk extractor and coconut flaking machine) developed

2012 SCAR markers developed for confirming hybridity and dwarf/ tall cultivars

2013 IPM for coconut rhinoceros beetle developed

2013 DUS centre for coconut established and DUS guidelines for coconut developed

2014 A high yielding D x T hybrid, Kalpa Sreshta (MYD x TPT) released

2016 Kalpa Shatabdi (selection from San Ramon Tall) released

2016 Two bioresources, Kalpa organic Gold (coconut leaf vermicompost produced with CPCRI technology) and Kalpa Soil Care (composted coir pith with CPCRII technology) launched

2016 Agri-business incubation centre started

2016 Three value added products - Kalpa coconut sugar (ICAR-CPCRI product) and Kalpa bar dark chocolate and Kalpa drinking chocolate (jointly developed with CAMPCO) officially launched

VISTAS IN COCONUT RESEARCH

Coconut, legendarily known as *"Kalpavriksha"* or *"Tree of life"*, is a source of healthy food, drink, oil, the best natural fibre and many other products. Coconut, being an epitome of versatility, is unique among the horticultural crops in India and assumes considerable significance in the national economy in view of its role in rural employment and income generation. Coconut industry provides livelihood to about twelve million people in India. In the emerging climate change scenario, coconut is considered to benefit and provide invaluable environmental services, thus, assuming more significance than ever before. Since times immemorial, coconut has been interwoven in to the socio-economic, religious and cultural fabric of a large part of India.

Globally, coconut is currently produced in 93 countries occupying 12 million hectares, of which 75 percent area and production is from three countries, Philippines, Indonesia and India. India has produced 20,345 million nuts in 2015 from an area of 1.97 million ha, with a productivity of 10345 nuts per hectare. In India, most of the cultivated area under coconut palm (90 %) lies in the southern states (Kerala, Tamil Nadu, Karnataka, Telengana and Andhra Pradesh). The palm is amenable to both plantation and homestead management and it can be either a major crop or one in a homestead garden of mixed crops. It can adapt to the divergent farming situations and management practices that are prevalent in the different agro-climatic regions. More than 90 % of the five million coconut holdings in the country are less than one ha in size. Indian coconuts are largely used for domestic proposes, while in Philippines and Indonesia, coconut is largely exported.

Traditionally, the Indian 'coconut export basket' is predominantly of coir and coir based products. The export of coconut (value-added) products (except coir and coir products) during 2014-2015 was ₹ 1,312.38 crore, recording a substantial growth over the previous years, and heralding a perceptible new direction. In the present agricultural scenario, the crop is facing a number of challenges due to the fluctuating farm-gate prices on account of various macro and micro level factors, biotic and abiotic stresses impacting production and productivity. With a focus on improving productivity and overall profitability of coconut farming, research efforts have been focussed on development of high yielding varieties, enhancing further the efficiency of coconut-based farming and cropping systems, refining and encouraging better adoption of integrated disease and pest management practices, and enhancing the present level of value-addition and product diversification.

Genetic resource management and breeding

Research on coconut improvement has received considerable attention, from as early as 1916, with the establishment of the erstwhile Coconut Research Stations at Kasaragod and Nileshwar in India. The major objectives of breeding in coconut are improving the yield by improving the size of nut and per palm yield, improving copra and oil content of nuts, production of short-statured varieties and resistance to biotic and abiotic stresses. However, the genetic improvement of coconut is a very difficult and time-consuming proposition because of its long pre-bearing age, perennial habit, heterozygous nature, time lag involved in the study of progenies, low multiplication rate, lack of clonal propagation and requirement of a large area for field experimentation.

Genetic enhancement in coconut

Genetic resources are the basic building-blocks for undertaking any crop improvement programme. Variability within the gene pool is essential for selection and hybridization for bringing about improvement in the targeted traits. Coconut is considered to be an 'ancient' species with a long history of domestication and cultivation, resulting in the absence of wild forms and evolution of local populations having varying degrees of dependence on humans for its perpetuation. Locating, maintaining and using genetic diversity of coconut presents substantial challenges: the wide dispersal of the species, the limited knowledge of the history of that dispersion and of the current extent and distribution of diversity. The large, recalcitrant seeds also add to the complexity of managing coconut germplasm.

Coconut genetic diversity is desirable for long term crop improvement and reduction of vulnerability to various biotic/abiotic factors. Collection, conservation and cataloguing of coconut germplasm have been accorded the topmost priority in coconut research and the Central Plantation Crops Research Institute is actively involved in the collection and conservation of coconut biodiversity in the field gene bank for utilization in the coconut improvement programme.

Understanding the basics: Emphasis on morphology and floral biology

In the beginning, it was more or less a botanical study of the palm including the morphological characters and the inherent/environmental variations (the classical study of the crown and the bole) and elementary breeding work to select and distribute superior planting material, which would ensure higher yields. In the later years (in the 1920s and 30s), substantial fundamental studies were initiated, for the first time in the world, on the genetic aspects of coconut, led by JS Patel and CM John. Introduction and evaluation of the germplasm from within and outside India, exploitation of hybrid vigour in coconut, selection of mother palms, seed nuts and seedlings in the nurseries, and working out correlations between morphological characters and yield, were some of the important areas of work in the realm of Botany, then under the charge of a Botanist ably assisted by only one or two research assistants.

Coconut germplasm collection and conservation

Collecting of coconut germplasm in India began during 1923-24, wherein it was decided to try out coconut varieties from different parts of the world. Accordingly, diverse types from the coconut growing countries like Philippines, Malaysia, Fiji, Indonesia, Sri Lanka and Vietnam and also from Bengal, Laccadives and Andamans (under the colonial empire) were introduced and planted at the Coconut Research Station, Pilicode, for evaluation and selection. Progenies of these were later planted in 1940 at the Coconut Research Station, Kasaragod. In addition, 16 'Presidency varieties', representing coconut varieties of different regions in present day states of Tamil Nadu, Kerala, Andhra Pradesh, were obtained and planted at Pilicode No I station during June-July 1923. The germplasm collection was further intensified in 1952 and the first indigenous germplasm survey and collection was started in 1958.

Consequent to the establishment of the Central Plantation Crops Research Institute Kasaragod, the collection, conservation, characterization of coconut biodiversity in the field gene bank was streamlined for utilization in the coconut improvement programme. During 1972, a replicated germplasm evaluation trial with 16 accessions, including exotic and indigenous coconut germplasm (both tall and dwarf accessions) was laid at CPCRI Kasaragod.

Widening the genetic base with infusion of exotic germplasm

In 1981, the first coconut germplasm collection expedition funded by FAO/ IBPGR was undertaken to the Pacific Ocean Islands for enriching the Indian coconut germplasm base, with high yielding lines and sources of disease resistance, especially for root (wilt) disease. Exploration was undertaken in Solomon Islands, Fiji, American Samoa, Tonga, French Polynesia and Papua New Guinea and a total of 24 accessions, including four dwarf accessions, were collected.

Ten thousand seed coconuts of the Malayan Dwarf Yellow were introduced from Malaysia (JendarataEstate, United Plantations, Perak) under the World Bank aided Kerala Agricultural Development Project and raised in a post-entry quarantine nursery at the Seed Garden Complex, Munderi (Nilambur) in Malappuram district of Kerala. Dr. P.K. Koshy was deputed to Malaysia (during 7 May to 4 June 1984) to oversee the collection and shipment of the consignment, considering the risk of accidental introduction of exotic pests and diseases. It is the first time such a large number of parental stocks of coconut gerrnplasrn has been introduced for hybrid seed production.

Consequent to the decision of IPGRI-COGENT to establish the International Coconut Gene bank for South Asia in India, Asian Development Bank (ADB) funded explorations were undertaken in the Indian Ocean Islands and the member countries in South Asia during 1997-2001. A total of 42 accessions were collected from these IPGRI-COGENT-ADB funded expeditions: 15 from Indian Ocean Islands of Mauritius, Madagascar and Seychelles; eight from Maldives, eight from Comoros and Reunion; and 11 from Bangladesh. Subsequently, in 2000, the institute could collect four coconut germplasm from Sri Lanka (under the Indo-Sri Lanka bilateral agreement wherein Dr. V.A. Parthasarathy was deputed to Sri Lanka for joint exploration of coconut germplasm), eight accessions from Maldives and 11 accessions from Bangladesh (Dr. R.V. Nair and Dr. P. Rajan were deputed to Bangladesh during 21 November to 11 December 2001 for the purpose), which include diverse local tall and dwarf types of those countries.

'Looking inwards': Augmenting and prospecting the indigenous germplasm resources

As part of ADB Phase II project on strengthening the ICG-SA, 11 accessions from Lakshadweep Islands and 17 accessions from Andaman and Nicobar Islands were collected, which included sweet husked coconut, different types of Micro types, dwarfs, horned nuts, beaked nuts and thin husked coconut types. An extensive prospection and collection of indigenous coconut genetic resources from different coconut growing regions of the country was undertaken during 1999-2004 under the World Bank funded National Agricultural Technology Project on Sustainable Management of Plant Biodiversity (NATP-PB) and about 127 indigenous collections were made. Aggregation of germplasm, its characterization, evaluation and utilization gained momentum and the ICAR outstanding interdisciplinary team research in agriculture for the year 1999-2000 was conferred on the scientific team (V. Parthasarathy, P.M. Kumaran,

'The Second Coconut Expedition': This time to the Indian Ocean islands

Dr. P.K. Koshy, Head and Principal Scientist, CPCRI (RS) Kayamkulam and Dr. P.M. Kumaran, Principal Scientist, CPCRI, Kasaragod, Kerala were deputed in 1997 to the Pacific Ocean islands of Mauritius, Madagascar and the Republic of Seychelles, for survey and collection of coconut germplasm under the project "Strengthening of National Coconut Germplasm Collection". The mission was to enrich the International Coconut Gene Bank in India (established under CPCRI) with diverse collections, to serve the interests of the coconut growing countries in Asia and the South east Asia. Though, it was originally envisaged to visit different areas/islands in different countries for the collection of different types of coconut, survey and collection were confined to Mauritius, Madagascar and Seychelles, for shortage of funds. And, collection had to be limited to the main islands of Mauritius and Agelaga Islands, Sambava of Madagascar and Mahe of Seychelles. Exploration plan for Comoros, Re-union and the Republic of Maldives had to be altogether deferred for the same reason. Deviating from the original plan of 60 days, mission had to be cut short to 33 days from 20th April to 23rd May, 1997.

From Mauritius, 6 accessions (Pemba Orange Dwarf, Pemba Green Dwarf, Pemba Yellow Dwarf, Pemba Red Tall, Dupays Tall, Guelle Rose Tall) and from Madagascar, 4 collections (Sambava Tall, West African Tall, Sambava Green Tall, Comoros Tall) and from Seychelles, Coco Lerein Tall, Coco Le Haut Tall, Coco Bleu Tall, Coco Raisin Tall and Coco Gra Tall, were collected. The morphological details besides, fruit and nut characters of all these accession were also recorded. A most pertinent general observation was that coconut is neglected as a backyard crop (limited to 1-3 palms per household) in Mauritius except in the island of Agalega, confined to the coastal areas (without any management practices, whatsoever) in Madagascar, whereas in total shatters in Seychelles, where the coconut industry has lost all the importance it had in the past.

A novelty of this exploration was that the collection was carried out in the field as coconut embryos and not as seed nuts (as was the usual practice till then). A total of 1342 embryos of 15 accessions were brought back for further culturing in the tissue culture laboratory. The embryos were collected in sterile water/charcoal water/nutrient media contained in glass vials under sterile conditions. Of the 15 accessions, tender nuts of Guelle Rose Tall has a very attractive pink coloured mesocarp and the seedlings on germination also showed the bright pink colour at the collar region and at the root tips. The pink colour is exhibited even by the germinating embryos on nutrient media, a potential genetical marker in breeding programmes. The Coco Gra Tall of Seychelles is equivalent to the 'Makapuno' of Philippines, which could be exploited commercially. Most importantly, the methodology developed at CPCRI, Kasaragod, Kerala, India for the collection of coconut embryo was successfully field-tested, and in all probability, this must be the first ever successful coconut germplasm collection as embryos. The spoilage due to contamination/injured embry¬os was only 3.5%, a creditable achievement in a field exploration in far-off shores.

The Third Coconut Expedition: To Comoros and Reunion Islands

Dr. P.M. Jacob and Dr. A.S.Sukumaran started from where Dr. P.K.Koshy and Dr. P.M.Kumaran left in 1997, to cover the remaining island nations in the Indian Ocean. Dr. P.M. Jacob, the Acting Head stationed at CPCRI Regional Station, Minicoy, Lakshadweep and Dr. A.S. Sukumaran, Senior Scientist from CPCRI, Kasaragod were deputed to the Federal Islamic Republic of Comoros and Reunion of Indian Ocean Islands for a period of 33 days (13 July - 16 August 2000) from the total grant of ₹ 6.4 lakhs from ADB for the project "Strengthening of National Coconut Germplasm". Due to shortage of funds and the restrictions on visiting the island of Anjouan and Mayotee, the survey and collection was limited to the main island of Grande Comore and Moheli in Comoros, and two main areas of Reunion (St. Paul and St. Benoit).

From Comoros, five accessions (Comoros Yellow Dwarf, Comoros Tall (Moheli), Comoros Green Tall, Comoros Red Tall and Comoros Brown Tall) and from Reunion, De La Reunion Tall, Coco Bleu and Coco Fesse, were collected. The embryos were collected in sterile water in polythene vials under sterile conditions, as in the previous expedition. A total of 746 embryos of 8 accessions were brought back to the institute for further culturing. Besides, the morphological details (10 palms each) of all the accessions were recorded (except in Coco Fesse and Coco Bleu for want of sufficient number of palms) and fruit/nut characters (10 nuts each) of the accessions were also recorded.

Of the eight accessions, the tender nut water and the meat of Comoros Yellow Dwarf was found to be very sweet, and popularly used for tender nut purposes there (though coconut is not consumed extensively by the people of Comoros, probably because of their present 'Western' food habit), and has a great potential to be developed as an ideal variety for tender nut purposes in India. They have observed that one or two palms of this cultivar are found growing in front of most of the houses in Comoros. Another curious observation was that in Comoros, almost all the palms were affected by eriophyid mite infestation (90-95%) and on enquiries, it was found that the mite attack was first noticed in the island, roughly during the same period as it appeared in Kerala, India.

M.J. Ratnambal, Anitha Karun, V. Niral, V. Arunachalam and Anuradha Upadhyaya) in recognition of their outstanding work. 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. Further, with funding from the Indian Council of Agricultural Research, the accessions are conserved in the National Active Germplasm Site (NAGS) at the institute.

In the past one decade, about 123 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. 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. Moisture 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 Rich Repository of 'Tree of Life': Coconut Field Genebanks

Biodiversity or the 'gene-basket' is the golden key to the 'bread-basket' for food and nutrition security, besides meeting the future challenges being thrown up by the depleting natural resources and decreasing land fertility with consequential impact on crop productivity, pest and disease problems and climate change effects. Presently, ICAR-CPCRI has the world's largest collection of coconut germplasm with 455 accessions from 28 countries, representing coconut germplasm of South and South East Asia, Caribbean islands, Indian Ocean islands, Pacific Ocean islands and African countries, and India. The indigenous coconut germplasm comprises collections from Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Goa, Gujarat, Orissa, West Bengal, Assam, Meghalaya, Bihar, Andaman and Nicobar Islands and Lakshadweep Islands.

ICAR-CPCRI also hosts the International Coconut Genebank - South Asia (ICG-SA), at the CPCRI Research Centre at Kidu, Karnataka, which was established following Execution of a tripartite agreement between FAO-IPCRI-GOI ON 31st October 1998. Presently 91 accessions, representing indigenous coconut germplasm as well as accessions representing coconut ecotypes of Philippines, Malaysia, Pacific Ocean islands, Africa and the Caribbean region and germplasm collected under ADB funding from Sri Lanka, Bangladesh, Indian Ocean islands of Mauritius, Madagascar Seychelles, Comoros and Reunion and Maldives - are planted in the ICG-SA.

Such a large field genebank (including the national and international genebanks) for a perennial tree crop like coconut palm entails huge investments on land, water and other natural resources, manpower, infrastructure and financial commitments on its maintenance. Nevertheless, considering the strategic importance, it continues to be a priority area for the institute in terms of scientific attention and financial allocation.

The rare soft endosperm coconut accessions (ThairuThengai), similar to Makapuno of Philippines were collected from the Andaman and Nicobar Islands as well as Kerala. A sweet husked type (Kaithathali) was collected from Kalpeni Island of Lakshadweep and also similar types were identified in Nicobar Islands. A unique but popular coconut ecotype MohachoNarel, with less fibre and more sweetness in endosperm has been collected from Maharashtra. A rare 'aromatic' dwarf coconut has been collected from Andhra Pradesh and conserved.

More than 25 dwarf accessions have been collected from the states of Kerala, Karnataka, Assam, Andhra Pradesh as well as the union territories of Andaman and 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 and Nicobar islands, and Andhra Pradesh while fruits with large size and higher copra content have been collected from Maharashtra, Andaman and Nicobar islands and Lakshadweep group of Islands.

ICAR-CPCRI holds the largest assemblage of coconut germplasm in the world, with 455 accessions at present in the field genebank, morphologically, genetically and geographically most diverse. High yielding selections from conserved germplasm at the institute is provided to the centres under the All India Coordinated Research Project on Palms (AICRP on Palms) for evaluation and testing their regional adaptability.

Characterization and evaluation of coconut germplasm

The collected germplasm is conserved in the national gene bank hosted at the institute and characterized using the IBPGR descriptor. Coconut descriptors for 74 conserved coconut germplasm were published during 1995-2000. The institute has also contributed to the development of the World Catalogue of Conserved Coconut Germplasm, brought out by COGENT/Bioversity International during 2010. Characterization of coconut genetic resources has resulted in the identification of trait-specific variability with reference to morphological traits, floral traits and pollen recovery, fruit component traits and tender nut water quality. Evaluation for yield has always been an important component of the coconut improvement programme.

Fruit component analysis in the Indian germplasm collection indicated wide variability for most of the traits studied. The copra content ranged from 340 g in San Ramon Tall (SNRT) to 70.4 g in Surinam Brown Dwarf (SUBD). High copra content of >300g was also recorded in the accessions, Malayan Tall (MLT) and Markham Valley Tall (MVT), while low copra content >100g was also recorded in Pattukottai Green Dwarf (CGD 01), Chowghat Green Dwarf (CGD) and the tall accessions, Laccadive Micro Tall (LMT) and Nu Fella Tall (NUFT).

Copra is the major product of coconut in India, which is used for extraction of oil and edible purposes. Best quality edible copra is in the form of ball copra and about 45,000 t of ball copra is produced annually in the country. Traditionally, production of ball copra is limited to certain coconut tracts and all coconut varieties are not utilized for ball copra production. Since ball copra fetches a premium price in trade, a preliminary study was undertaken to assess the suitability of 17 coconut accessions for ball copra production. Recovery of ball copra was highest in Laccadive Micro Tall (LMT) followed by Tiptur Tall (TPT) West Coast Tall (WCT) and Java Tall (JVT), indicating the superiority of these indigenous tall accessions for ball copra production.

In addition, selected coconut germplasm at the institute was studied for their fatty acid composition and variability for fatty acid composition of coconut oil was observed among accessions. The concentrations of saturated fatty acids were maximum in ADOT, LCT and SSGT, whereas, the unsaturated fatty acid concentration was maximum in LCT × GBGD. The ratio of saturated to unsaturated fatty acid concentration was lowest in LCT × GBGD and highest in ADOT. The hybrids, in general, had lower concentrations of saturated fatty acids and correspondingly low ratios of saturated to unsaturated fatty acid concentrations. The talls had higher values for these parameters, except for WCT. Based on the characteristics of coconut oil, accessions suitable for various industrial applications were identified.

Further, in light of the importance of coconut husk fibre in the coconut coir industry, a pilot study on the physio-chemical and structural characteristics of coconut fibres of nine accessions was undertaken in collaboration with CIRCOT, Mumbai. The study identified varieties suitable for manufacture of stronger yarns (Gangabondam Green Dwarf), dyeing (Tiptur Tall, East Coast Tall, Benaulim Tall) and production of α-cellulose (East Coast Tall, Benaulim Tall, Lakshadweep Ordinary Tall, Lakshadweep Micro Tall, Tiptur Tall). Studies at the institute during 1990s revealed the possibility of identifying moisture stress tolerant cultivars on the basis of morphological/anatomical and biochemical parameters. A few accessions (West Coast Tall, Federated Malay States Tall, Java Tall and Andaman Giant Tall) have been identified as moisture stress tolerant and are being utilized in the moisture tolerance breeding programme.

Screening for disease resistance at the institute has primarily focussed on root (wilt) disease of coconut and has resulted in identification of Chowghat Green Dwarf and Malayan Green Dwarf as resistant varieties. Among the talls, Andaman Ordinary Tall exhibited lesser incidence of root (wilt) disease and shown resistance against nematodes. Screening of 26 selected coconut germplasm against the stem bleeding pathogen, *Thielaviopsis paradoxa* (de Seynes) Hohnel, using petiole inoculation technique, indicated differential levels of susceptibility, with higher lesion size in Malayan Green Dwarf and lesser lesion size in Benaulim Tall. Comparative evaluation of eriophyid mite damage in different accessions indicated lesser incidence of mite damage in Kulashekaram Green population (Kalpa Haritha) and Chowghat Orange Dwarf, while highest incidence of mite damage was recorded in Laccadive Ordinary Tall and Straits Settlement Apricot Tall (SSAT). Variations in susceptibility against leaf eating caterpillar (*Opisina arenosella* Walker), red palm weevil (*Rhyncophorus ferrugineus*) and rhinoceros beetle (*Oryctes rhinoceros* Linn), has also been observed among accessions, though no resistant accessions have so far been identified.

Descriptors in coconut: A monumental work

Characterization of plant genetic resources (facilitating a select set of accessions from a large collection, likely to be of utmost interest to specific end-users), is a pre-requisite for its successful utilization. Coconut Descriptors-I (in the conventional paper/print format), brought out in 1995, described 48 accessions (including 29 exotic and 12 indigenous cultivars) based on 13 vegetative, 21 reproductive and 20 nut and two biochemical characteristics. Colour photographs of full crown with inflorescence, mature nuts and cross section of the nut are given for each accession for easy identification.

As a sequel to the part I, the part II in a CD-ROM format (better meeting the requirements of the 'digital age') brought out in 2000, describes 20 exotic and 6 indigenous cultivars. Here, some more vegetative, reproductive and fruit characters have been added; besides, the standard deviation (SD) of individual characters have been mentioned in the appropriate place. Characters useful for classification and identification are highlighted, which will be highly useful for the coconut researchers in identification of different cultivars and in the exchange of specific genetic material of interest among the coconut growing countries.

Opposite: International Coconut Gene Bank for South Asia

Registering unique genetic stocks

For ensuring protection and equitable utilization of valuable germplasm resources under the institutional framework in the present-day IPR regime, seven coconut lines among the conserved and evaluated coconut germplasm were registered with NBPGR (the designated agency in India) for their unique traits having scientific/academic/commercial values.

- INGR13059 - KPDT (IND001): An indigenous tall selection from IC430667 with higher copra and low husk content
- INGR13060 - LMT (IND030): An indigenous tall selection from IC430669 with heavy bunches of micro nuts, high copra oil content
- INGR13061 - CRD (IND092): A dwarf selection from EC121436 with orange nuts, higher copra content among dwarf accessions
- INGR13062 - CYD (IND414): An indigenous dwarf selection from IC430664 with yellow fruits and erect frond tip
- INGR13063 - ADHT (IND221): An indigenous tall selection producing fruits with multiple horn like structures
- INGR13064 - LMMT (IND331): An indigenous tall selection from IC425040 with very small fruits with very low copra content
- INGR13065 - NLAD (IND099): A dwarf selection from EC415218 with breeding behaviour similar to talls and higher copra content, close leaf scars over the trunk, irregular trunk surface

In situ on farm conservation of coconut genetic resources

Modern conservation biology espouses the virtue of *in situ* conservation as having the distinct advantage of conserving naturally adapted germplasm and (along with *ex situ* conservation) it can contribute to conservation of a much larger genetic diversity and better utilization through farmer participatory improvement progarmme, CPCRI has undertaken studies on on-farm diversity in coconut through various farmer- participatory approaches and characterization of this diversity with modern molecular tools. *In situ* characterization of four local coconut ecotypes - Kuttiadi, Bedakam, Annur and Komadan - in Kasaragod/Kannur districts of Kerala (initiated during 2008) is in progress for promoting *in situ* conservation of genetic resources in farmers' fields.

DUS guidelines developed for coconut

Intellectual Property Rights in the domain of plant varieties was addressed in India with the enactment of the Protection of Plant Varieties and Farmers' Rights Act (PPVFRA), 2001. This legislation was introduced, recognizing the need for establishing 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 first 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. CPCRI has taken the lead in facilitating registration of coconut varieties through development of coconut DUS test guidelines, a daunting task since coconut does not figure in the UPOV list. 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, 2010. The coconut DUS guidelines finalized by the Task Force was approved and subsequently, on the 18th August 2011, the Ministry of Agriculture 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. 1913(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, authorized to undertake DUS testing of new coconut varieties and conducting need-based training/awareness programmes on the provisions and potential benefits under this landmark act.

'They Sow, We Harvest': Utilization of coconut genetic resources

Though the introduction and evaluation of germplasm was initiated way back in the 1920s, the first improved coconut variety (Chandrakalpa) was released only in 1985, an ample testimony to the 'inherent difficulties' in the breeding of a perennial palm like coconut and a tribute to the wisdom and foresight of the pioneering researchers then. With that, floodgates were thown open with a flurry of varieties developed since then. Concerted research efforts at ICAR-CPCRI, has so far resulted in the development of 20 improved varieties (including six hybrid varieties), for specific uses and for cultivation in different agro-ecological zones of the country. Apart from this, the germplasm provided from CPCRI has helped SAUs and other ICAR Institutes to develop and release nine improved varieties suitable for different states.

Chowghat Orange Dwarf: A dwarf variety recommended for cultivation as a tender nut variety. It is early flowering, (takes about 3 years for initial flowering) and gives an average yield of 112 - 192 nuts/palm/year, under irrigation and good management. Fruits are orange (red-yellow), medium-size and round

Chowghat Orange Dwarf

with very sweet tender nut water. This variety also serves as parental palm for production of Kera Sankara (WCT x COD) and Chandra Sankara (COD x WCT) hybrids. This variety also has potential in landscaping as an ornamental palm.

Kalpa Jyothi: A dwarf variety with compact spherical canopy and drooping frond tip, recommended for cultivation as a tender nut variety. Fruits are yellow, medium-size and oval in shape. It is early flowering, commences flowering 3-4 years after planting and gives average yield of 114 - 169 mature nuts/palm/year under good management. This variety also serves as parental palm for production of Kalpa Samrudhi (MYD x WCT) and Kalpa Srestha (MYD x TPT) hybrids. Further, this has potential in landscaping as an ornamental palm.

Kalpa Surya: A dwarf variety, with compact spherical canopy and drooping frond tip, it is recommended for tender nut production. Fruits are orange (red-yellow), medium-size and oval in shape. It is early flowering, (initiation of flowering within 3 years of planting) under irrigated condition. The average yield is 123 – 182 mature nuts/palm/year under good management conditions. Further, this has potential in landscaping as an ornamental palm.

Kalpa Surya

Kalpasree: A dwarf variety recommended for cultivation in root (wilt) disease prevalent areas. This is the earliest flowering variety, takes about 2.5 to 3 years for initiation of flowering. Fruits are dark green, oblong with a characteristic "beak" in mature fruit. It has superior quality of coconut oil, sweet tender nut water and meat and is tolerant to root (wilt) disease. The mean annual yield is 90 -107 nuts/palm with a copra content of 96 g. Caution is advised to adopt plant protection measures against major pests particularly red palm weevil, when large scale commercial plantings are adopted. This variety also serves as parental palm for production of Kalpa Sankara (CGD x WCT) hybrid.

Kalpasree

Kalparaksha: A semi tall, root (wilt) disease tolerant variety, recommended as a dual purpose variety for copra and tender nuts. Fruits are green, medium-size and round in shape. It comes to flowering 4-5 years from planting. In root (wilt) disease affected tracts, it gives an annual yield 65 - 77 nuts/palm with a copra content of 185 g. Under disease-free and rainfed condition, it gives an average annual yield of 87 – 101 nuts/palm.

Kalparaksha

Chandra Kalpa: A high yielding moisture stress tolerant variety recommended for copra and oil production. Fruits are greenish yellow to yellow-green, medium-size and oblong, with sweet tender nut water, copra content of 176 g/nut and oil content of 72%. The variety gives an average yield of 100 - 136 nuts/palm/year, under good management. It is good for tapping 'neera' (inflorescence sap), which can be consumed as such or converted to palm sugar/jaggery. This variety also serves as parental palm for production of Chandra Laksha (LCT x COD) hybrid.

Chandrakalpa

Kera Chandra: A high yielding dual purpose variety, it is suitable for copra and tender nut production. Fruits are green, large and round with very sweet tender nut water (440 ml), copra content of 189 g/nut. The harvested nuts are early germinating, which makes them unsuitable for ball copra production. The variety gives an average yield of 110 - 140 nuts/palm/year, under good management conditions.

Kera Chandra

Kalpa Pratibha: A high yielding dual purpose variety, it is suitable for copra and tender nut purpose. Fruits are predominantly green, large and round in shape with very sweet tender nut water (448 ml), copra content of 256 g/nut. The harvested nuts are early germinating, which makes them unsuitable for ball copra production. The variety gives an average yield of 98 - 131 nuts/palm/year, under good management conditions.

Kalpa Pratibha

Kalpa Dhenu: A high yielding variety, it is suitable for copra and oil production. Fruits are predominantly green, large and oval with copra content of up to 244 g/nut. The variety is relatively tolerant to moisture stress and gives an average yield of 86 - 128 nuts/palm/year, under good management conditions.

Kalpa Dhenu

Kalpa Mitra: A high yielding variety, it is suitable for copra and oil production. It is also suitable for production of ball copra, a premium product. Fruits are large and oval with copra content of 241 g/nut. The variety is relatively tolerant to moisture stress and gives an average yield of 80 - 126 nuts/palm/year, under good management conditions.

Kalpa Mitra

Kalpatharu: A high yielding variety, it is suitable for production of premium quality ball copra. Fruits are brown/brownish green, medium-size, oval with copra content of 175 g/nut. The variety produces 117 - 149 nuts/palm/year, under good management. The variety is relatively tolerant to drought and suitable for cultivation under rainfed and irrigated conditions. This variety serves as parental palm for production of Kalpa Srestha (MYD x TPT) hybrid.

Kalpatharu

Kera Keralam: This high yielding, moisture stress tolerant variety, it is suitable for production of copra and oil. It is also suitable for ball copra production and for tapping 'neera' (inflorescence sap). Fruits are green yellow, medium-size and oval with copra content of 176 g/nut. The variety, under rainfed conditions of Kerala, gives a mean yield of 109 nuts/palm/year. It gives higher yield of 152 - 213 nuts/palm/year, under irrigation and good management. The husk is of good quality and extensively used for making coir and coir products. This variety serves as parental palm for production of hybrids, namely Chandra Sankara (COD x WCT), Kera Sankara (WCT x COD), Kalpa Sankara (CGD x WCT) and Kalpa Samrudhi (MYD x WCT).

Kera Keralam

Kalpa Haritha: A high yielding, dual purpose tall variety, with lesser eriophyid mite infestation, it is suitable for copra and tender nut production. It bears green, medium-size fruits with copra content of 216 g. The variety comes to flowering within 4 years after planting. It produces an average yield of 118 – 205 nuts/palm/year, under rainfed conditions of Kerala and Karnataka.

Kalpa Haritha

Kalpa Shatabdi: A high yielding, dual purpose tall variety, with high copra out turn of 28.65 kg/palm/year or 5.01 t copra/ha. It is characterized by large fruits with average copra content of 272.9 g and higher volume (612 ml/ tender nut) of good quality tender nut water. The variety comes to flowering within six years after planting. The variety produces average yield of 71 – 105 nuts/palm/ year, in Kerala and Tamil Nadu.

Heterosis breeding in coconut

In India, heterosis breeding has been employed for development of hybrid coconut varieties by crossing indigenous and exotic selections of Talls and Dwarfs. The first coconut hybrid in the country was produced at the erstwhile Central Coconut Research Station, Pilicode in 1934 by Dr. J.S. Patel using West Coast Tall as female parent and Chowghat Green Dwarf as male parent. The resultant hybrid progeny exhibited seedling vigour in the nursery, resulting in the first documented report in the world of hybrid vigour/heterosis in coconut. Subsequently, these hybrids manifested earliness in flowering, increased nut yield, higher copra yield with better quality of copra and oil compared to the parents. This important finding paved the way for the successful breeding programmes in coconut not only in India but in other countries like the Philippines, Indonesia, Sri Lanka, Ivory Coast and Jamaica.

In the immediate years after the discovery of hybrid vigour in WCT x CGD hybrids, the emphasis was on development and evaluation of Tall x Dwarf (T x D) hybrids. Subsequently, Dwarf x Tall (D x T) hybrids were also produced and evaluated, considering the occurrence of 'naturally crossed dwarfs' (NCD) in open pollinated progenies of dwarf palms. Much later, Tall x Tall (T x T) and Dwarf x Dwarf (D x D) inter-varietal hybrids were also produced at the institute for evaluation of the hybrid progenies for yield and other desirable traits. Till date, more than 100 cross combinations have been developed for evaluation of yield potential at CPCRI, SAUs, and the centres under the AICRP on Palms. So far, 20 hybrids, including eight superior Dwarf x Tall hybrid varieties and 10 Tall x Dwarf and two Tall x Tall hybrid varieties have been developed in India for commercial cultivation in different regions across the country. These hybrids are capable of producing 2.79 to 6.28 tons of copra/ha/ year. The material exchanged by CPCRI has helped SAUs in development and release of 12 different hybrids suitable for different parts of the country.

'Fruits of crossing': Eleven coconut hybrids

The Institute has so far released six hybrid (two D x T and four D x T) varieties for commercial cultivation, based on the superior performance in the experimental trials at CPCRI and multi-location trials at Centres of AICRP. Besides, two more 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 new 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 have been identified as superior and released at Institute level by the Institute Research Committee, as a first step towards formal varietal release and registration.

Coconut hybrids released from CPCRI

Chandra Sankara (COD x WCT): A high yielding dual purpose D x T hybrid, it is suitable for copra/oil and tender nut production. This hybrid was produced by crossing Chowghat Orange Dwarf palms (female parent) with pollen from elite West Coast Tall palms (male parent). The variety is semi tall in habit, and bears brown, medium-size fruits, with copra content of 208-225 g. The variety comes to flowering within 3-4 years, much earlier than the WCT parent. It produces an average of 110-210 nuts/palm/year, under good management. It is comparatively susceptible to drought and performs better only under good management conditions.

Chandra Sankara

Chandra Laksha (LCT x COD): A high yielding dual purpose T x D hybrid, it is suitable for copra/oil and tender nut production. This hybrid was produced by crossing elite Lakshadweep Ordinary Tall palms (female parent) with pollen from Chowghat Orange Dwarf palms (male parent). The variety bears brown, oblong fruits, with copra content of 195 g. The variety comes to flowering within 4 years after planting, much earlier than the LCT parent. It produces an average yield of 109 – 175 nuts/palm/year, under good management. This hybrid is tolerant to drought stress and gives reasonably good yield under moisture stress situation.

Chandra Laksha

Opposite: Kalpa Jyothi

Kera Sankara (WCT x COD): A high yielding dual purpose T x D hybrid, it is recommended for copra and oil production. This hybrid was produced by crossing elite West Coast Tall palms (female parent) with pollen from Chowghat Orange Dwarf palms (male parent). The hybrid palms are precocious and exhibit higher productivity than the parents. The variety bears brown, medium-sized, oblong fruits, with copra content of 187 g. The variety comes to flowering within 4 years after planting, much earlier than the tall WCT parent. It produces an average yield of 108-213 nuts/palm/year, under good management. This hybrid is relatively tolerant to moisture stress and gives reasonably good yield under water limited condition.

Kera Sankara

Kalpa Samrudhi (MYD x WCT): A high yielding, semi tall, dual purpose D x T hybrid, it is recommended for copra and tender nut production. This hybrid was produced by crossing Malayan Yellow Dwarf palms (female parent) with pollen from elite West Coast Tall palms (male parent). The variety bears green, medium size fruits, with copra content of 220 g. The variety comes to flowering within 3-4 years after planting. It produces an average yield of 117–141 nuts/palm/year, under good management. It is relatively tolerant to moisture stress and has higher nitrogen use efficiency.

Kalpa Samrudhi

Opposite: Kalpasree

Kalpa Sankara (CGD x WCT): This is a semi-tall, root (wilt) disease tolerant, dual purpose D x T hybrid recommended for cultivation in the root (wilt) affected tracts and suitable for copra and tender nut production. This hybrid was produced by crossing Chowghat Green Dwarf palms (female parent) with pollen from elite West Coast Tall palms (male parent). The variety comes to flowering within 3-4 years after planting, bears green, medium size fruits, with copra content of 170 g. It produces 84 – 112 nuts/palm/year, in the root (wilt) affected tracts. The hybrid is relatively tolerant to water stress and gives good yield under rainfed conditions in farmer's plots in the root (wilt) disease prevalent tract.

Kalpa Sankara

Kalpa Sreshta (MYD x TPT): A high yielding dual purpose D x T hybrid, it is suitable for copra and tender nut production. This hybrid was produced by crossing Malayan Yellow Dwarf palms (female parent) with pollen from elite Tiptur Tall palms (male parent). The variety bears green, medium size, oval fruits, with copra content of 216 g. The variety comes to flowering within 4 years after planting, under irrigated conditions. It produces an average yield of 167 – 186 nuts/palm/year, under good management.

Kalpa Sreshtha

Breeding for root (wilt) disease

The root (wilt) disease is one of the major production constraints in India (especially in the traditional tracts of southern and central Kerala), considering the massive crop loss inflicted by this disease. In view of its phytoplasmal etiology, a three-pronged strategy for managing the disease with (a) uprooting the diseased palms and replanting, (b) breeding for disease resistance and (c) integrated management of disease-affected gardens (especially in disease early and middle stages) is being adopted. Conventional control/curative measures are not feasible for this disease and hence, the development of resistant/tolerant varieties is considered to the only lasting solution for root (wilt) disease. Since coconut belongs to the monotypic genus, the possibility of tapping the gene pools from related species is rather limited. Screening of the available coconut germplasm starting from 1972 onwards also failed to identify any disease tolerant accession. However, in areas where the disease was endemic ('disease hot-spots'), high yielding disease-free WCT and CGD palms were found and these palms were subjected to stringent physiological and serological screening, followed by electron microscopy, to ensure that they are free from the phytoplasma. These disease-free palms were then utilized for producing WCT × CGD and CGD × WCT hybrids and WCT inter se and self-pollinated material.

Based on the screening of these progenies in progress from 1989 onwards, CPCRI has released two resistant varieties Kalpasree (a selection from CGD) and Kalparaksha (an MGD selection) and a tolerant hybrid *viz*., Kalpasankara (CGD x WCT). All these three varieties are high yielding and have been released for cultivation in root wilt prevalent areas *(for more information on these varieties, please see the section on new varieties and hybrids)*.

Breeding for moisture stress tolerance

Breeding for moisture stress tolerance was initiated in the latter half of the 1980s. Well-distributed rainfall or adequate irrigation ensures high productivity in coconut. However, in the northern part of Kerala, the maidan part of Karnataka and almost all coconut-growing areas in Tamil Nadu, the crop is grown under rainfed conditions with about 5-7 months of prolonged dry spell. The palms are periodically exposed to low rainfall or delayed onset of monsoon or both, resulting in poor yield. The adverse effects of drought on coconut persist even for the subsequent 3-4 years. Under these circumstances, evolving a moisture stress tolerant variety was of paramount importance.

V. Rajagopal and his group standardized the techniques of screening coconut varieties for moisture stress tolerance using a set of morphological (anatomical), physiological and biochemical parameters like epicuticular wax, stomatal frequency and leaf water potential. They identified WCT, Federated Malay States (FMS), Java Giant, Fiji, Andaman Giant and LO × COD as relatively moisture stress tolerant. Recently, some more tolerant varieties have been identified and they are all currently being utilized in breeding programmes to identify high yielding hybrids with moisture stress toleranance. Currently, some of these promising types identified at CPCRI are under rigorous field evaluation in a farmer's garden in Sivaganga in Tamil Nadu, one of the most drought-prone areas in south India.

CPCRI shows the way: Registration of eleven extant coconut varieties on the anvil

The institute is in the process of registering all 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 (Kalpa Haritha, Kalpa Jyothi, Kalpa Samrudhi, Kalpa Surya and Kera Chandra) under the VCK (Varieties under Common Knowledge) category and six varieties (Kalpa Sankara, Kalparaksha, Kalpasree, Kalpa Pratibha, Kalpa Mitra and Kalpa Dhenu) under the extant notified varieties category, of which the six notified varieties got registered and the remaining are under the process of DUS testing/ registration after notification process. The registration under PPVFRA will give plant variety protection for 18 years, facilitating further commercialization of these varieties.

Quality planting material production in coconut

In full justice to its mandate, the Institute has been producing quality planting materials in coconut 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 established in the institute as well as in farmers' 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.

Planting material production in coconut (since 1922)

With the revolving fund schemes for augmenting planting material production in place, the ICAR-CPCRI Research centre, Kidu in the Dakshin Kannada district of Karnataka was strengthened to take up the role of a national seed garden for coconut to supply parental material and breeder's stock for the development of seed gardens all over the country. A massive community level root (wilt) disease-free material production programme has been undertaken by CPCRI Regional Station, 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. CPCRI Regional Station, Kayamkulam has also been accredited by the National Horticultural Board as a star rated nursery to meet the planting material needs of root (wilt) diseased tract.

Considering the availability of mother gardens, maintenance of strict quality standards and the existing resources/ expertise, CPCRI nurseries at Kasaragod and Kidu were graded with 'four stars' (in the five-star scale) from 2008 onwards by the National Horticultural Board (under the Ministry of Agriculture and Farmers' Welfare, Government of India), the designated authority for accreditation of horticultural nurseries in the country.

Exciting possibilities ahead

Coconut, once mostly considered as an oil purpose crop, is now widely used for oil, food, beverage, shelter and as an 'health-enhancing' crop. At ICAR-CPCRI, efforts are on to enrich the coconut gene pool with targeted trait-specific germplasm for product diversification and resistance/tolerance to biotic and abiotic stress tolerance. Also, development of superior trait-specific genetic stocks having greater homogeneity and better adaptability from the conserved germplasm is a pre-requisite for development of varieties suitable for different end uses and specific industrial uses. Considering the perennial nature and cross pollination behaviour of the crop, farmer participatory on-farm conservation and breeding is also being considered as an alternative strategy to hasten the crop improvement process in coconut. Focused characterization of germplasm for identification of more trait-specific accessions is in progress and is being strengthened through molecular/genomic approaches to enable identification of genes/alleles for desirable traits and development of donor lines for effective utilization of the available diversity.

Genetic studies to understand the combining ability, gene action and heterosis for yield and other economic traits is in progress for better utilization of identified genotypes. Similarly, to promote value addition and for enhancing income generation of coconut farmers, accessions with quality fibres for the coir industry and specific genotypes suitable for production of coconut chips, higher recovery of inflorescence sap, and preparation of shell products need to be identified for utilization in the breeding programme. Dual purpose varieties ('the all-rounders') for tender nut and copra production are going to be valuable in future. The breeding objectives also focused on exploiting novel traits such as sweet endosperm, soft endosperm, sweet husk and aroma of tender nuts which will help not only product diversification at farmers' level but also find new industrial uses for coconut products.

Breeding plans should not only reflect realities of the present, but they should visualize the possibilities of the future as well. Apart from the traditional emphasis on nut yield and copra/oil content, quality attributes like fatty acid profile and lauric acid in the coconut oil, various nutritional and nutraceutical constituents in the tender nut water and meat/virgin coconut oil should invariably form the signposts of future breeding efforts, as 'tailor-made varieties' for specific and combinations of different end-uses can play a pivotal role in promoting coconut as a health-wellness-food crop. Resistance breeding is at present confined to root (wilt) disease and drought tolerance, to a small extent. Germplasm evaluations have shown considerable leads as to the sources of resistance/tolerance for the major diseases like stem bleeding disease and pests like red palm weevil, rhinoceros beetle and eriophyid mites. Breeding for inculcating resistance/ tolerance to the major and minor pests *('minor' pests of today can turn 'major' tomorrow as in the case of the coconut eriophyid mite)* in the popular varieties/new tolerant varieties should receive due attention.

Women climbers for coconut pollination: A 'silent revolution' in the making

Transcending gender barriers, trained women now serve as 'skilled coconut pollinators' for coconut hybrid production at the Institute. 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. Traditionally, coconut climbing and pollination are men's territory, since the practice involves considerable drudgery and the inherent risk of accidental fall. Owing to a variety of socio-economic reasons, the number of palm climbers has been on the decline and coconut communities were experiencing severe shortage of skilled climbers-cum-pollinators. As the old adage goes 'necessity is the mother of invention', the drudgery in climbing was largely reduced with the introduction of climbing machines and safety consciousness was addressed by the addition of a safety device to the climbing machine. Still, the central problem persisted; where is the men for this skilled work, which is made much easier now?

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, the situation has improved to a large extent. Women have now learnt the nuances of coconut pollination with ease and carrying out the work with confidence and panache. 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, hopefully, encourage more women to take up this profession, as it is much remunerative and will certainly improve their social and economic status. This venture is a trend setter for augmenting hybrid seed production, overcoming the acute shortage of skilled labour, while at the same time ensuring women empowerment, gender equality, agricultural and rural development in the coconut communities.

The advent of biotechnology research: aspirations and achievements

Igniting imagination: The genesis of Biotechnology research at ICAR-CPCRI was in 1976 at the first International Symposium on Coconut Research and Development (ISOCRAD-I), which coincided with the Diamond Jubilee (1916-1976) celebrations of CPCRI. The then Director General of ICAR, Dr. M.S. Swaminathan, in his keynote address on 'Coconut Research-The Next Phase', called for initiation of biotechnology research at CPCRI, as a 'generation next' approach for breaking the inherent barriers for unleashing the full potential, which the conventional approaches failed to achieve. Prof. W.W. Schwabe of Wye College, Kent, U.K. in his talk on 'Attempts at Vegetative Propagation of Coconut Palm', reported for the first time the induction of shoot-like structures from floral primordia cultured on Eeuwens' Y3 Medium. And, Prof. H.Y. Mohan Ram from University of Delhi presented an overview of this newly emerging science in India, literally the 'new baby of biology' then, in his plenary lecture on 'Plant Tissue Culture: Challenges and Opportunities'. Understandably, one of the important decisions in the concluding Plenary Session (chaired by Dr. M.S. Swaminathan) was to standardize a tissue and organ culture protocol for clonal propagation of elite coconut genotypes.

The initial steps and first funding

In mid-January 1977, ICAR sanctioned an Ad-hoc Cess-Fund Scheme on 'Coconut Tissue Culture' and work was initiated on coconut tender leaf, embryo and endosperm tissue cultures, and coconut tender rachilla segment cultures, looking to transform the floral primordia into vegetative 'bulbil' shoots. Concurrently, a tissue culture laboratory was also set up at CPCRI Research Centre at Appangala in Coorg, Karnataka (now under ICAR-IISR) for cloning Katte virus resistant cardamom selections. Tissue culture research received a big boost when the Department of Biotechnology (DBT) sanctioned ₹ 26.5 lakhs for the project on 'Palm Tissue Culture'. With the ample funds received from DBT, the Tissue Culture Unit was equipped with a 11 KVA Diesel Power Generator for providing uninterrupted power supply, a large water-purifier system with a capacity of 10 litres / hr, additional laminar air flow cabinets, BOD incubators, deep freezers, adequate chemicals, glassware, culture storage racks and trolleys fitted with timers for regulating lights and post-culture hardening facility.

Success stories in coconut biotechnology

Coconut embryo culture protocol for the international exchange of germplasm

The natural distribution and transcontinental dispersal across land and sea routes since times immemorial, and scientific collection and exchange of PGR in coconut in recent times have solely been through seednuts, since other vegetative means are not available in this crop. However, bulkiness of the seed, short dormancy period, presence of nut water, stringent phytosanitary requirements and high cost for transportation are the major difficulties encountered during germplasm collection and storage. The success of *in vitro* germination of coconut zygotic embryos in recent times has provided an alternative way of transportation of coconut germplasm in the form of embryo cultures. A protocol for culturing coconut zygotic embryos from 8-11 months old nuts was developed at CPCRI and successfully utilized in all the germplasm expeditions undertaken by the institute since then. This technique makes effective use of artificial media with available macro and micronutrients and microclimatic conditions, which support the embryo to grow and to form entire plantlets. The field collection technique involves inoculating the sterilized zygotic embryos excised from the nuts on to the nutrient medium *in vitro*. When storage of zygotic embryos is necessary, as when the collection sites are far off or under overseas collection missions, sterile water could be used as medium for storing zygotic embryos for two months.

The embryo culture protocol developed by ICAR-CPCRI was first utilized during 1994 for transferring six Pacific Ocean accessions (maintained at the World Coconut Germplasm Center, Andaman Islands) to the main land. From the 87 embryos brought, 83 plantlets were retrieved and from this lot, 25 plantlets were field planted at the International Coconut Gene Bank for South Asia (ICG-SA) Kidu, Karnataka during 1996. Since then, five international expeditions were conducted by ICAR-CPCRI during 1997-2001 for the collection of coconut genetic diversity, wherein 45 accessions (a total of 4182 embryos) were collected from eight countries, *viz.*, Mauritius, Madagascar, Seychelles, Maldives, Comoros, Reunion, Sri Lanka and Bangladesh. The per cent retrieval of embryos varied among the locations and among accessions. The germination percentage varied between 54 % (Sri Lanka) to 82.2 % (Bangladesh). All these exotic accessions collected through embryo culture protocol have been planted in International Coconut Gene Bank (ICG-SA) and have started flowering since 2004. From our experience, it is suggested that about 300 to 400 embryos are needed to be collected for field establishment of 100 palms in a gene bank (*i.e.*, about 3-4 times the actual requirement). The collection and transportation of coconut for the safe movement of coconut germplasm through embryo cultures (instead of seed nuts), has now been recommended as per the Technical Guidelines of FAO/IPGRI (currently Bioversity International) based on this pioneering work at CPCRI.

Embryo-rescue of rare types: the 'Caesarean section' in the world of plants

Embryo culture technique can effectively be used for obtaining plantlets from embryos resulting from incompatible crosses which fail to germinate naturally. Embryos from sweet-kernelled nuts collected from Konkan region of Maharashtra were excised out and plantlets were regenerated successfully through embryo culture protocol. Similarly, from the 'Horned Cocos' accessions collected from the Andaman Islands in 1999, embryos were cultured *in vitro* using embryo culture technique. The 'horned' coconut (considered to be a mutant) is reported to produce multiple ovaries resulting in formation of horn-

like structures over the mature fruits. Moreover, the embryo cultured plantlets in the National Coconut Gene Bank at ICAR-CPCRI palms have commenced flowering in about six to eight years and it is observed that the trait is inherited to the next generation.

Cryopreservation for long-term conservation of valuable germplasm: Complementing the field genebanks

Palm genetic resources are traditionally conserved *ex situ* as whole plants in field genebanks which require large area, besides huge investments in terms of financial, infrastructural and manpower resources. Cryopreservation of embryos and pollen is an excellent option for long-term conservation of genetic resources, which can provide a viable backup to field gene banks. However, in the case of embryos, pre treatment is very much essential before conserving in liquid nitrogen at –196 ºC. The pre treatments include simple desiccation (using laminar air current and use of silica gel), the use of high concentration of sucrose, various cryoprotectants in various combinations (glycerol, propylene glycol, DMSO, sorbitol, formamide) and encapsulation with sodium alginate and dehydration techniques.

Cryopreservation of mature embryos of West Coast Tall variety of coconut was first developed at the Institute by desiccation pretreatments. Maximum retrieval of healthy plantlets was obtained from the embryos subjected to 18 hours silica gel or 24 hours laminar air flow desiccation treatment. Irreversible damage of shoot meristem was observed when the moisture content of the embryo was reduced below 20%, which should invariably be avoided. Later, cryopreservation of mature coconut embryos through vitrification was also developed and successfully validated. The PVS 3 solution, which consists of equal proportion of glycerol and sucrose, was found to be most effective for regeneration of cryopreserved embryos among the seven plant vitrification solutions tested. Most effective protocol involved preculture of embryos for three days on medium with 0.6 M sucrose, followed with PVS3 treatment for 16 h, thereafter cooling rapidly in liquid nitrogen and rewarming and unloading in 1.2 M sucrose liquid medium for 1.5 h. The survival rates of 70-80% (corresponding to size enlargement and weight gain) was achieved with this protocol and 20-25% of the plants regenerated (showing normal shoot and root growth) from cryopreserved embryos could be established in pots.

Coconut pollen is another excellent source of diverse alleles within a gene pool. Viability of coconut pollen under ambient conditions lasts for only a few days. But, ultra low temperature storage retards most of the molecular reactions in the cells and effectively extends the viability to hundreds of years. Both *in vitro* and *in vivo* studies showed that pollen of both West Coast Tall and Chowghat Orange Dwarf cultivars retained their viability and fertility even after storing in liquid nitrogen for four years. Seed set after hand pollination using cryopreserved pollen (for a period of four years) was found to be normal. Besides, one hundred percent germination was observed in embryos extracted from hybrid nuts produced with cryostored pollen and plantlet development was normal, confirming the feasibility of setting pollen cryobank in coconut. Even though field gene bank is the preferred mode of conservation in coconut, embryo and pollen cryopreservation should be taken up as a complementary conservation strategy, and in the most unfortunate eventuality where precious materials conserved in the field genebanks are irrevocably lost, there is always a chance for its retrieval from cryopreserved germplasm.

Molecular biology laboratory: The nascent years

Coconut has certain inherent disadvantages at breeding - a long juvenile period, large crop size, inherent heterozygosity, out-breeding nature and poor vegetative propagation ability. Since improvement through conventional breeding is rather slow, besides being time and resource-demanding, modern molecular technologies are thought to have a great potential in accelerating these breeding programmes. From this perspective, setting up of a molecular biology laboratory for strengthening biotechnological research was mooted. Procuring minimal equipments for conducting molecular biology experiment was the foremost requirement, which was met from funds available under a NATP project and work on isozyme analysis and DNA extraction was initiated in 1995. Molecular biology research received a major fillip, when DBT sanctioned a project on 'RFLP analysis of coconut germplasm'. Several sophisticated instruments were procured under this project. Work on genomic library preparation for developing probes for RFLP and RAPD analysis for DNA fingerprinting of coconut accessions was started under this project. Several research papers have been published in reputed international journals with high impact factor, based on the results from these experiments. What started out as a small molecular biology facility, has now grown to a separate section, (presently housed in a new building), where some pioneering research work on coconut is being done at present.

Molecular markers, a modern tool for assessment of hybrid purity in coconut

It is a creditable achievement that 15 different hybrid combinations have been released for commercial cultivation, with various tall and dwarf cultivars as parents. However, one of the major challenges in planting material production of these released hybrids is the inherent hetrozygosity in almost all tall cultivars and some of the dwarf cultivars to a lesser extent, as it results in segregation among F1 progenies. Presently, breeders select hybrid seedlings in coconut nurseries relying solely on morphological markers like days taken for germination, vigour of seedlings (in terms of leaf production, higher collar girth over a specific duration) and petiole colour. Though widely adopted and practiced, purity assessments based on morphology are often affected by environment and hence not totally reliable, besides being time and resources-intensive. Selection of hybrids by petiole colour has limitations, as it is reliable only if the parents homozygous for yellow, red or green petiole are used. Therefore, identification of reliable molecular markers for distinguishing plant-type trait is highly imperative for isolating true-to-type high-yielding hybrid lines in the early stage of coconut breeding programmes, which would be helpful in commercial hybrid seedling production in coconut.

Molecular markers are known to be reliable for hybridity testing of several economically important crops. Thus, efforts were made to develop a set of molecular markers which could be universally used for differentiation of tall and dwarf coconut cultivars and utilize the selected markers in hybrid seedling purity assessments. Simple sequence repeats (SSRs) based markers (also known as microsatellites), which could detect polymorphism among the parental lines, were utilized to screen four parents (GBGD, FJT, MYD and TPT) and their hybrid progenies (GBGD x FJT and MYD x TPT). The true hybrids possessed the banding pattern of both the parents, while the selfed progenies possessed the banding pattern of only the female parental line. This technique would allow accurate and rapid identification of true hybrids in the nursery stage itself.

Finger printing coconut genetic resources with the unique, indelible molecular tags

The sagacious prospection of our precious germplasm resources, its characterization and documentation of potential benefits and uses, and establishing their unique biological/genetic identity have become a priority area, considering the increasing claims to our native genetic resources and the need to protect them in the present era. On the other hand, the other new development is the need to register new varieties developed in the institutional framework for patents and IPR protection, with the institutionalization of PPV&FR Authority in India.

Morphological and physiological markers are frequently used to determine distinctness, uniformity and stability (DUS) for registration of new varieties. A mandatory requirement is that new varieties have to be distinct from all existing varieties by at least one character. Besides, they have to meet established standards with respect to uniformity and stability of the characteristics used to demonstrate distinctness. DNA based markers have many advantages for plant variety identification over the more conventionally used morphological characters. Of various approaches to DNA profiling, microsatellites have proved to be the most efficient tool for characterizing coconut cultivars. So far, DNA finger printing using microsatellite markers has been carried out in 160 conserved coconut accessions, representing all the coconut growing areas around the world, to document the genetic integrity and diversity. A database of DNA fingerprints in coconut for warehousing and easy retrieval of the DNA profiles has also been institutionalized.

Bioinformatics Centre: Heralding the Genomics Era

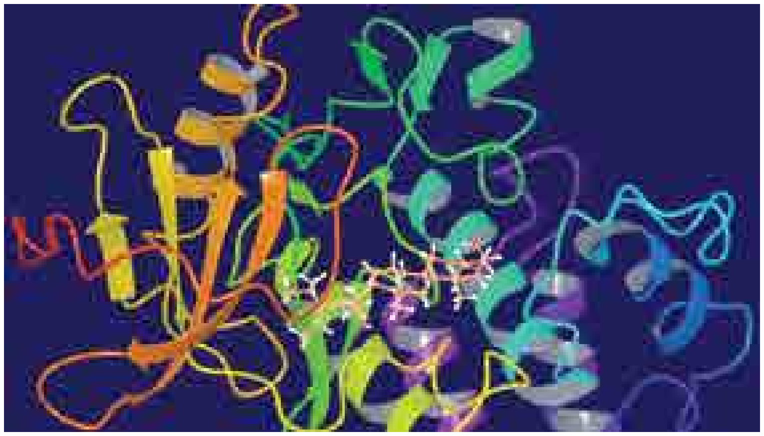
Recognizing the importance of information technology for pursuing advanced research to keep pace with the rapid progress in modern biology and biotechnology, DBT-funded ‘Distributed Information Sub-Centre’ (DISC) at CPCRI was launched in December 2000, one of the three such centres in ICAR. The bioinformatics programme was envisaged as a distributed database and network organization, to provide an environment for collaborative

interdisciplinary research in Bioinformatics. The main aim of the Centre is to bridge the gap between the wet lab and *in silico* analysis by actively promoting collaborative projects between agricultural scientists and Bioinformaticians. Since its inception, the Centre has been actively engaged in research activities, bioinformatics and has provided computational support to the various research projects of the Institute and also has been instrumental in imparting the Bioinformatics knowledge and training to students and scientists. In 2009, with funding from Department of Information Technology, the bioinformatics programme at CPCRI was further strengthened with the establishment of the Agri-Bioinformatics Promotion Centre (ABPC) with four components: genomics of phytoplasma, palms, cocoa and PGPRs.

Bioinformatics and Agri-Bioinformatics Promotion Centres: Driving Discoveries

Database development, human resource development and a variety of other services in support of R&D programmes in biotechnology and bioinformatics have made the Bioinformatics Centre very popular and useful to the scientific community. Under the Bioinformatics initiative at CPCRI, over 25 comprehensive databases and software tools for the mandate crops have been developed, which include ‘MAPS’ (Microsatellite Analysis and Prediction Software), computational method based on support vector machines for prediction of gibberellic acid biosynthetic enzymes in palms, tool for prediction of the resistance gene analogues (RGAs) motifs developed using Support vector machines (SVM), standalone BLAST and Hidden Markov Models (HMM), stand alone EST-SSR analysis pipeline (‘SEMAT’), prediction of miRNAs in date palm, coconut and *Phytophthora* spp., transcriptome based reconstruction of carotenoid biosynthetic pathway in cocoa and gibberellic acid biosynthetic pathway in coconut. ‘PHYTODB’, a comprehensive and user-friendly web server and a knowledgebase devoted to phytoplasma, has been made available in the public domain. Various algorithms have also been developed for prediction of genes/promoters in plant growth promoting bacteria (PGPR) *viz*., ‘PROMIT’, ‘LTTRPred’, ‘NRPS Pred’, ‘BACPred’.

Besides, substantial emphasis has also been placed on developing skilled human resource at various levels. During the last 16 years, the Centre has conducted more than 15 training programmes in which more than 300 researchers were trained in frontline areas of Bioinformatics. Besides, the Centre has trained 25



Bioinformatics post graduates under the 'traineeship' programme and supported 30 M. Sc. students to do their bioinformatics project under the 'studentship' programme.

Coconut biotechnology: where reality failed to match expectations

Tissue culture in coconut remains an enigma

In vitro mass multiplication of elite coconut palms endowed with high yield, resistance to biotic and abiotic stresses, is of huge significance in coconut farming. Unfortunately, coconut continues to be a highly recalcitrant species with respect to tissue culture. Over the past few decades, in spite of concerted efforts towards developing a method for clonal propagation of coconut, success in this area has been rather very limited and only a few clonal plants have ever been established in the field. Various problems encountered during *in vitro* propagation of coconut are intensive tissue browning (due to oxidation of polyphenols), slow *in vitro* response, low rate of somatic embryogenesis and variation in tissue response due to heterogeneity of explants taken from different individuals. Standardization of a viable protocol for clonal propagation would open up tremendous possibilities of meeting the requirement for quality, uniform, disease resistant/tolerant planting material and of breaking down productivity barriers.

Mixed fortunes so far

Many tissues such as leaves, inflorescence, ovary, anthers and zygotic embryos have been utilized for coconut tissue culture. Prolonged incubation of immature inflorescence in auxin-cytokinin combination media resulted in conversion of floral primordia to vegetative primordia, but at a very low frequency. The major bottleneck here is the development of abnormal tissues and lack of friable callus. Coconut leaf explants from juvenile palms were used with successful induction of callus. However, the embryogenic capacity of leaf explants lasted only for a short duration, which limits its use as explant in clonal propagation studies. Direct development of coconut shoots were also reported from the rachilla explants of immature inflorescence.

Most of the recent studies on clonal propagation of coconut at CPCRI have utilized plumular tissues as explants. Callus was induced from plumular tissues in Y3 media supplemented with either 2, 4-D alone or in combination with cytokinin (TDZ). The frequency of callus induction increased and the browning of explants was reduced when a TDZ was added along with the auxin (2,4-D) in the callus induction medium. The calli developed were subcultured at monthly intervals to media containing lower levels of 2,4-D and a constant level of either cytokinins (BA and TDZ) or polyamines (spermine and putrescine). Higher percentages of embryogenic calli, somatic embryoids and meristemoids were obtained in Y3 media supplemented with either spermine or BA. Plantlets with balanced shoot and roots were transferred to pots and established in the greenhouse. Histological studies of the differentiated tissues confirmed the development of shoot buds (organogenesis) and typical bipolar embryoids (somatic embryogenesis).

Even though plantlets have been regenerated and successfully established in the field, a commercial-scale protocol has not been developed and conversion of somatic embryos into plantlets remains one of the major bottlenecks. Efforts are being made to refine the coconut tissue culture protocol such as use of polyamines and media combinations. For overcoming these bottlenecks, it is imperative to understand the molecular events underlying *in vitro* recalcitrance in coconut, which remain largely unknown, to identify possible factors which could contribute substantially to rational improvement of existing protocols and also, to the establishment of new protocols with novel plant growth regulators. From this perspective, transcriptome and proteomics studies have been initiated to decipher the molecular basis of somatic embryogenesis in coconut.

New initiatives, new hope

Though, development of improved high yielding varieties with tolerance/resistance to biotic/abiotic stresses is acclaimed as the most economical and practical solution for successful crop production in the long run, there are several inherent impediments to adoption of conventional breeding techniques in coconut. Non-availability of markers associated with important agronomic traits is a major constraint in plant breeding, limiting utilization of modern techniques of marker-assisted selection for facilitating screening in juvenile stages for higher yield and predicting disease pre-disposition.

There is an urgent need for genomic approaches to gain insight into genes governing important traits in coconut. Availability of genome sequence information in coconut (through whole genome sequencing) will provide the basic data for enhancing utilization of available genetic resources in breeding programmes. Development of molecular markers associated with quantitative traits will facilitate marker-assisted molecular breeding to enable trait-based breeding and faster development of varieties for specific requirements. CPCRI has initiated whole genome project of coconut during 2016.

Deciphering genome sequences of *Phytophthora* and *Ganoderma* causing diseases in coconut will help in understanding the host-pathogen relations at the molecular level, identifying the markers for resistance and diagnosis, genes coding for the effectors and novel ways for development of effective control measures. Development of molecular diagnostic kits will also be easier once the whole genome sequence of these pathogens and the molecular events during the pathogenesis is available. RNA interference (RNAi), induced in insects after ingestion of plant-expressed hairpin RNA, offers promise for managing devastating crop pests. RNAi approach could be employed to control red palm weevil in coconut by silencing some of the vital genes of the insect that play an important role in insect-plant interaction, growth and development, reproduction etc. by delivering cognate double stranded RNA (dsRNA).

Optimization of inputs for enhancing productivity

The ultimate goal of any crop research is *(and should always be)* increasing production and productivity, and invariably all initiatives/programmes should contribute to that goal, directly or indirectly.

The research work on coconut was started way back in 1917, with the planting of coconut seedlings in the three new stations near the village of Nileshwar, with the three representative soil types (laterite, red sandy loam and coarse sandy soil). Stemming from the realization that research, in a perennial tree-crop like coconut from the seedling stage onwards, takes many years to get results, an existing garden in the village of Kudlu in Kasaragod (where the present CPCRI is located) was also acquired and initial experiments were started there.

Initial days

Realizing the importance of good seedlings in establishing better gardens, nursery studies were initiated at Nileshwar. At the same time, to understand the growth habit of coconut, root studies were initiated at Kudlu which will help in proper placement of nutrients and water for better use efficiency and inclusion of inter crops in coconut gardens. The number of roots given off from the whole tree was enumerated as 1728 living and 1804 dead roots. Bulk of the roots (70%) was seen at approximately 20 inches from the bole, between 2.5 to 4.5 ft from the surface/ ground level. This classical study of the bole formed the basis of all subsequent investigations, leading to the development of spacing/ fertilizer/irrigation schedules in coconut.

Nursery studies

Seed nuts collected during April-July germinated in less than 125 days after sowing, whereas those collected during September-January took 160-180 days for germination. The seed nuts collected during April-August produced seedlings with significantly more leaves, leaf area and girth at collar and height, indicating that they were more vigorous in growth. Considering all the growth characters, May and June were identified as the ideal time for sowing the seed nuts. Application of FYM (25 t/ha) + N and K (80 kg each /ha) as soil application in 3 splits was found to be better for production of vigorous seedlings in the nursery.

Importance of cultivation realized early!

Soil aeration and moisture conservation play a major role in growth and yield of coconut in the long run. The efforts to demonstrate the importance of ploughing the garden was started early in 1919. The observation plots were set up in 1919 to study the long-term effect of 'neglect' on growth and yield of palms as compared to regular intercultivation alone, and manuring plus intercultivation. The intercultivation consisted of two harrowings in September and October. Manuring consisted of 1 kg urea, 1 kg ultraphos, 2 kg muriate of potash, and 50 kg green leaf per tree annually. This study, running over many years, showed the palms in the cultivated plots as having better tolerance to drought situations than the palms in the uncultivated plot. It also indicated that cultivation of the garden resulted in higher yield than the plot not cultivated and manured. The treatments were later modified in 1972, by including chemical weed control, fertilizer application and forking and cultivation plus inorganic fertilizers under the ambit of the studies. The study indicated the superiority of 'cultivation plus inorganic fertilizers plus green leaf application', over 'no cultivation' and 'no manuring' and other cultivation practices.

Soil amelioration can work wonders

'Unsatisfactory performance' (low yield) in the littoral sandy soil under the Coconut Station-III of Nileshwar was reported as a problem right from the beginning. Burying dry coconut husks (at 1000 husks per tree) in trenches 6' wide and 15" deep between rows of trees was found to be a useful way of improving coconut gardens under dry system of cultivation. The beneficial effects of one operation will last for about six years. This technology has been utilized for growing different intercrops like grass, vegetables, flower crops and pineapple in coconut garden in littoral sandy soil. The average coconut yield in littoral sandy soil was only 40 nuts/palm/year. The same was increased up to 150 nuts/palm/year by adopting the technology of husk burial and cropping system. The husk burial improved the moisture holding capacity of soil and released nutrients slowly upon its decomposition.

Evolution of the nutrient management practices in coconut

The systematic study on nutrient requirement of coconut was started in early 1920s. One tell-tale statement in the Annual Report of the Coconut Stations for 1921-22 tells the whole story on the impact of proper manuring on the growth and production in coconut. *"The coconut trees in all the blocks (in Station IV at Kudlu) made excellent growth during the year. Contraction of their stems on account of 'starvation diet' before acquisition of the farm and their expansion above this portion under subsequent favourable conditions form a lasting and unmistakable register"*. The increase in yield was so striking (30,341 nuts from all the ten blocks put together in 1918-19 has nearly doubled to 54,463 in 1921-22) not to miss attention.

The initial studies indicated that three to four pounds of ammonium sulphate, 2 to 3 lb. of super phosphate and 2 to 3 lb. of muriate of potash along with 50 to 100 lb. of green leaves per year per tree was normally sufficient for the majority of coconut areas. Application of these manures broadcast in the field was better than applying them in circular trenches of 1 foot deep and dug 6 feet from the base of the tree. Chilean nitrate appeared to be better than ammonium sulphate.

Further studies to refine the nutrient management including the time of applications and method of application were taken up in the 1950s. A balanced N P K fertilizer mixture was found necessary to ensure satisfactory growth of palms during the pre-bearing stage and an adult palm dosage of 0.75 kg N +0.40 kg P and 1.20 kg K_2O (to be applied at an increasing rate with age) is about the optimum for the Tall variety. The high yielders like NCD, T x D and pre-potent Tall require a higher dosage proportionate to the adult palm dosage consisting of 1.0 kg N, 0.5 kg P_2O_5, + 1.5 kg K_2O. Annual application of fertilizers in 2 splits was found to result in the highest yield, followed by annual application in one dose. Summer irrigation increased the response of palms to fertilizer application. Foliar application of fertilizers was not effective as that of soil application. In the 1960s, one more nutrient trial with different levels of N, P and K was initiated. To revive the palms growing under neglect and to improve their productivity, application of annual doses of 500 g N, 320g P_2O_5 and 1200g K_2O/palm in two splits was found desirable.

Based on long-term observations, it was concluded that 70 to 80 ppm of mineralizable nitrogen in soil and 10 to 12 ppm Bray extractable 'P' can sustain sufficient levels in coconut. Work at CPCRI revealed that if soil available P is less than 10 ppm, full recommended dose of 320g P_2O_5/palm/year may be applied and for a soil test value of 10 to 20 ppm, 50 per cent of the same may be applied. For soil test values of more than 20 ppm, P application can be skipped. The quantity of K fertilizer required to optimize the soil solution K concentration in red sandy loam soil is 1150g K_2O palm^{-1}year^{-1}, which very well matches with the general K recommendation (1200g K_2O palm^{-1}year^{-1}) for the crop in India.

Multiple regression analysis of soil available nutrient and the coconut nut yield in the red sandy loam soil at CPCRI Kasaragod was carried out, which revealed that there is a linear increase in the nut yield with the increasing level of available K when the total N level is high, suggesting the N and K have co-limiting role in the coconut productivity. Soil application of Borax @ 50 g/tree twice at monthly intervals after appearance of the first symptom corrects the B deficiency. The critical limit for hot water soluble boron was 0.1 ppm. In the coconut growing tracts, the hot water soluble B ranged from traces to 12 ppm. In Kerala, 12% of coconut soils are reported to be deficient in boron. Application of 500 g MgO/palm/year as Epsom salt ($MgSO_4.7H_2O$) can correct Mg-deficiency in the coastal sandy soils of the Onattukara series of Kerala.

Leaf calcium content of 0.3 per cent in 14th frond may regulate the Ca requirement of the palm under West Coast conditions of India. A critical level of 0.2 per cent Mg (frond 14) may be adopted as a diagnostic aid for regulating Mg nutrition of the palm under West Coast condition of India until specific critical levels for each variety/type are established. An integrated nutrient management technology has been developed for palm based cropping systems comprising coconut as main crop intercropped with banana, clove, pineapple and black pepper trailed on coconut for sustained productivity under coastal ecosystem. Integrated nutrient management by using 2/3 recommended fertiliser dose along with recycling of biomass by vermicomposting gives the best economic benefit in a sustainable manner. The total cost involved in maintaining the system under various fertilizer doses ranged from ₹ 48,983 (No fertilizer dose) to 56,973 (Full dose). The highest net returns (₹ 63,579/-) were in the treatment - two third of the recommended fertilizer dose - with a cost benefit ratio of 1: 2.18.

Importance of water management

The importance of water management was understood early and the research on water management was initiated in the late 1920s. Application of water was in terms of number of pots per palm then. Later, the method of watering was modified to keeping mud pots in the basin of seedlings and filling the pots once in 4 days. Then, the research started with different quantity of water being applied to palms at different intervals. Irrigation with 45 liters of water once in 4 days with red earth application was found to be better. Since a major share of the coconut cultivation is in coastal belt, attempts were made to utilize sea water for irrigation. The results indicated that irrigation with sea water did not leave any residual harmful effect. During the dry months from December to May, irrigations of 60 mm depth given at IW/CPE ratio 0.15 (average interval of 17 days) were found to be better than those of 40 mm and 20 mm depth given at the ratios 1.0, 0.75 or 0.5.

With the increasing scarcity of water and advancements in technology, drip irrigation was invented as most efficient irrigation method. Attempts were started to adopt drip irrigation in coconut on different soils. To standardize the quantity of water the irrigation schedule was decided based on the evaporation data. WCT palms irrigated with 20 mm water/irrigation at IW/CPE ratio of 1.0 gave highest mean yield. For humid tropics, there is need for irrigation to coconut palms and it is sufficient if we irrigate at the rate of 66% of the open pan evaporation through drip in the basin area (1.8m radius) of the palm based on the monthly mean evaporation, irrespective of the varieties, talls or hybrids. From the above study, it was concluded that, for Northern Kerala (India) condition, under littoral sandy soil application of water through drip at the rate of 66% of Eo coupled with coconut leaf mulch is beneficial for nut and copra production. Irrigation once in four days with 45 l water to young palms planted in laterite soil resulted in better growth and vigour than other treatments. The performance of young palms around which dry coconut husks were buried during the first three years along with subsurface irrigation once in a month with 45 l water using bamboo pipes was the next best. Under Kasaragod condition in sandy loam soil the coconut need 20mm irrigation water at IW/CPE ratio of 1.00 and a fertilizer dose of 1000g N + 1000g P_20_5 + 2250g K_20 + 170g MgO for optimum yield.

'Fertigation', the name tells it all!

The fact that efficient use of water and nutrients makes agriculture more profitable is now well established. Then, what if these two are given together as 'one wholesome meal'? Thus, studies were conducted to evaluate the feasibility of supplying nutrients through water for ensuring better use efficiency of both water and nutrients, while increasing the crop productivity also. The easily available source of nutrients like urea, phosphoric acid/DAP and muriate of potash were used as nutrient sources. The triple benefits of adopting this technology of fertigation are that 50% of the chemical fertilizer could be saved, and the cost on labour can also be brought down by about 50%, apart from increasing the yield by 20%. This is a classic case to prove that the development and adoption of appropriate technologies can make coconut farming more efficient and sustainable.

Organic farming: theory and practice

The importance of enriching the soil with organic matter was realized long back and efforts were made in this direction. The first attempt to increase the organic matter content in soil was made in the early part of the 1920s. Cow dung was used as organic manure in the beginning. Later, green manuring was started with inclusion of crops like cow gram, glyricidia, *Calopogonium muconoides, Crotolaria striata, Crotolaria refusa, Tephrosia purpurea, T. candida* and *Indigofera parviflora*. *Calopogonium muconoides* was found to be the best green manure crop, which can be grown in coconut garden and used as in situ green manure crop. Cow pea can be grown as cover crop to check soil erosion and improve the organic matter content of the soil. Glyricidia can be grown as a boundary crop and the prunings of the plants once in three months can be applied to coconut as green manure. Further studies indicated that sowing of cow pea before monsoon is beneficial compared to sowing during monsoon, as the germination was affected when the crop is sown during July-August. Coconut husk burial was also used as a technology to enrich the soil with organic matter.

The supplementation of organic sources with inorganic fertilizers (blending) is beneficial to coconut during the early establishment period than at later stages in the coastal sandy soils. It is possible that the enhanced buffering capacity of the littoral sands through the influence of organics in the slow and steady supply of nutrients and moisture, and indirect effects of organic matter might have contributed to the enhanced vegetative and reproductive characters observed. Of the organic sources compared, forest leaves and cattle manure appeared better, though coir dust and coconut shredding could also be profitably utilised for successful establishment and better performance of coconuts in coastal sandy soils. Technologies like recycling of available biomass from the garden, green manuring, cover cropping in basin and incorporation, use of biofetilizers, husk burial in the interspaces, application of vermiwash and vermicompost, and FYM application constitute the components of organic farming, improving the sustainability of coconut farming.

Cropping systems are highly rewarding!

A cropping/farming system aims at crop diversification and intensive cropping in the inter space available in coconut to increase the per palm productivity as well as productivity of unit holding in a system approach, wherein the available natural resources like soil, water/rainfall and sunshine, farm labour and agricultural inputs (seeds, fertilizers, agro-chemicals) are utilized to produce both food and non-food agricultural products from the farm, in a business or profitable way. Under such a cropping/farming system, all the management practices and component production systems should be able to maintain high productivity, profitability and sustainability of the existing coconut palms to maximize economic yield of the farm. Sustainability is the main objective of farming system, where production process is optimized through efficient utilization of the inputs in safeguarding the environment.

The importance of increasing productivity from unit area and efficient utilization of resources was felt long back and screening for different crops which can be grown as intercrop in coconut was initiated in the early 1920s. Different tuber crops and annuals like ragi, paddy, potato, pineapple, groundnut, hill cotton, horsegram, cow gram, gingelly, fodder sorghum, fodder maize were grown in the interspaces of coconut garden.

Later in the 1970s, the work was given more importance and systematic research was initiated to grow different vegetables, flowers, medicinal plants and perennial crops as intercrops in coconut garden. Vegetable crops like brinjal, chilli, tomato etc. were grown successfully in coconut gardens. Similarly, medicinal crops like kacholam gave additional income, apart from improving the yield of coconut. Crops like cocoa, banana, pepper were also grown in coconut garden and it was reported that these crops are suitable to be grown as mixed crop in coconut garden. They gave additional income to farmers. There was improvement in yield of main crop also, making the system more sustainable. The results indicated that the income from coconut garden can be doubled by adopting a cropping system approach.

It was felt that the resources are not being utilized efficiently even when one crop is grown as intercrop in coconut garden and still there is scope for increasing the number of crops. It was estimated that young bearing palms (spacing 7.5 m^2) and adult palms permit less than 20% incident radiation to reach the ground, while the middle aged palms allowed about 30% light and pre-bearing and old palms permit up to 80% light. Hence, an observation trial of multi-storey cropping was established during 1970 with crops like cocoa, pineapple and pepper in coconut garden. After confirming that the crops did not adversely affect the coconut yield, a systematic study on multi-storey cropping was initiated in 1972 with five crop combinations involving coconut, cinnamon/cocoa, pepper and pineapple with 4 replications. The yield of coconut increased by 117–171% over the years, apart from the additional income from the other crops, making the system more efficient and sustainable.

By seeing the success of multistory cropping in coconut, a coconut based high density multispecies cropping system was established which aims at developing a coconut based cropping system which is self sustaining and produces maximum biomass and returns with least inputs. It was initiated during 1983 in a 1.2 ha area with 18 years-old coconut plantation and 17 different annual, biennial and perennial crops. The research over years has resulted in identifying crops which can be grown as inter/mixed crops in coconut gardens.

- Tuber/root crops and rhizomatous spices: cassava, elephant foot yam, sweet potato, greater yam, lesser yam, chinese potato, colocasia, ginger, turmeric, potato
- Cereals and millets: rice, pearlmillet, fingermillet
- Pulses and oilseeds: cowpea, green gram, black gram, redgram, Bengal gram
- Vegetable crops: chillies, French bean, snake gourd, amaranthus, brinjal, bottle gourd, ridge gourd, coccinia, dolichos bean, tomato
- Fruit crops: banana, pineapple, papaya, guava, lemon, lime
- Fodder crops: Pusa Giant, Hybrid napier-NB-21 and BH18, Guinea grass, Stylosanthes, Fodder cowpea, Mochi (*Lablab purpureum*), Hybrid Napier PBN-16, Hybrid napier DHN 3 + Centrosema, Hybrid bajra napier (CO-3), Hybrid napier+ Stylosanthes gracilis
- Medicinal and aromatic crops: chittadalodakam (*Adhatoda beddomei*), karimkurinji (*Nilgirianthus ciliatus*), nagadanthi (*Baliospermum montanum*), vetiver (*Vetiveria zizanioides*), Indian long pepper (*Piper longum*)
- Flowering crops: Heliconia, Anthurium, *Jasminum* sp.
- Tree crops: Acacia mangium, *Acacia auriculoformis, Casuarina equisetifolia, Ailanthus* sp., *Tectona grandis, Tamarindus indica, Erythrina indica*
- Spices/tree spices: black pepper, vanilla, nutmeg, cinnamon, clove,

Coconut based integrated farming systems

The concept of mixed farming system in coconut is in line with the tradition of Indian farmers to include animal husbandry as an integral part of agriculture. Coconut based integrated farming system research was started in 1972 at Kasaragod and Kayamkulam during 1970. At Kasaragod, experiments were initially conducted by intercropping fodder grass in a 60 year old coconut plot with integration of a dairy unit. The experiment continued for a period of 16 years (1972-1988). During 1988-1999, the experiment was conducted with the integration of coconut and components like coconut + fodder grass, dairy unit (five to six Jersey and Holstein Friesian cross breed cows), poultry unit (100

Opposite: Coconut Based Multi Species Cropping System

layers and 100 broiler in each batch and 100 number quail layer birds), biogas unit, aquaculture and sericulture (which was integrated with the system during 1999). Thereafter this experiment with the same components except sericulture was maintained under NATP from 2000 to 2003. From 2004 onwards, the experiment was continued with the fodder grass variety NB 21 replaced with Hybrid Bajra Napier Co3 and introduction of azolla cultivation unit. The goat unit was later added to the system during 2012.

The overall benefits from the system has been significant in terms of both quantifiable (monetary) and non-quantifiable (ecological) terms. The system has been self-sustainable, as the system components are inter-related and support one another. The outside application of inputs in the system is reduced to a large extent. The net returns from the system was ₹ 7.5 lakhs, whereas the net returns from the coconut monocrop was only ₹ 1.5 lakhs during 2014-15. The cultural acceptance/economic viability of animal husbandry as a livelihood option in the traditional/rural life ensures a fairly higher levels of adoption of this technology. However, factors like high cost of labour, non-availability of family labour and lack of irrigation facilities for growing fodder crops are perceived as constraints in adoption of this system among different coconut growing communities.

Remote Sensing, GIS and IT Applications in Coconut R&D

Remote sensing and GIS application for the identification of root (wilt) disease affected coconut

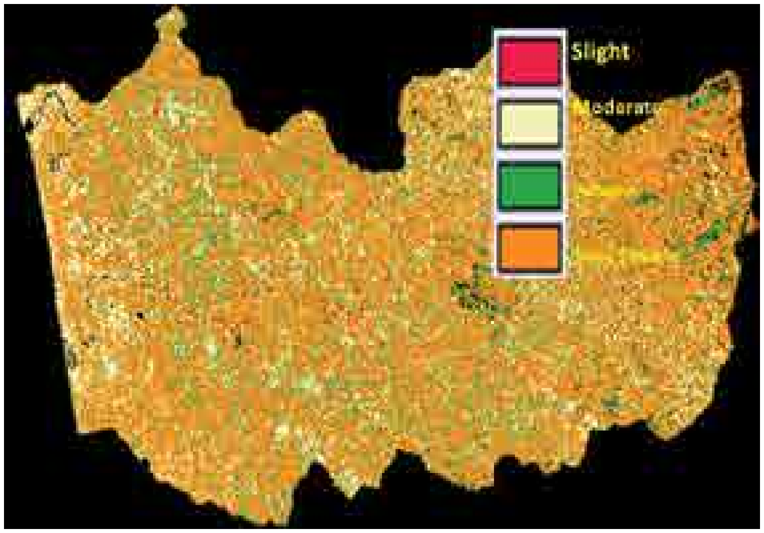
A linear spectral model for identification of root (wilt) affected palms has been developed to study the coconut root (wilt) disease spread. Since the GA based spectral unmixing techniques needs enormous computing time, the recently developed Nonnegative Constrained Least Square (NCLS) technique algorithm was tested in the simulated data. In the simulated data, sub pixel classification accuracy was 98.7 and 98.2 % in GA technique and NCLS respectively. CPU time taken for NCLS technique is one hundredth of the GA based algorithm in the 3.00 GHz Pentium-4 server machine. Hence the NCLS algorithm was implemented in IRS P-6 satellite digital data in the sub pixel classification of the coconut root (wilt) affected palms mapping.

Remote sensing and GIS application for the coconut land cover area estimation using spectral mixture analysis of remote sensing data

Coconut land cover mapping with satellite data using spectral mixture analysis technique was developed. Using this technique, coconut land cover maps were developed for Alappuzha, Thrissur, Ernakulam, Idukki, Pathanamthitta, Kollam, Kottayam, Thiruvananthapuram, Palakkad, Malappuram, Kozhikode, Wayanad, Kannur and Kasaragod districts of Kerala state and Madurai, Salem, Namakkal and Coimbatore districts of Tamil Nadu in India.

Use of RS and GIS for soil and water conservation

Soil erosion map and land cover maps were developed using remote sensing and GIS techniques for Kadalundi and Tirur river basins in order to develop the spatial information system on soil erosion and run-off. These river basins were found to have soil erosion potential ranging from moderate to very severe and most of the areas were coming under very severe soil erosion-prone category. This information enables us to formulate appropriate site-specific management techniques for soil conservation measures in the slope lands.



A Management Information System (MIS) for Precision farming

A Management Information System (MIS) for precision farming in coconut has been developed. This MIS has seven modules for the storing and retrieval of information with built-in databases on coconut planting, monthly weather data, harvest, cultural operations, pest and disease incidence and treatment of pests. Detailed soil sampling was done by the integration of GPS and GIS for individual tree. Individual coconut palm yield variation within farm fields mapped with spatio-temporal database. The yield variability was analyzed using GIS. Soil fertility surfaces (maps) were created with geostatistical software. The soil fertility map(s) was combined with yield variation maps in GIS to determine the relationships between fertility variables (total Nitrogen, Bray –P, neutral normal Ammonium acetate extractable K , Ca, Mg and DTPA extractable Fe, Zn, Cu and Mn). From the analysis, it was observed that application of variable Nitrogen and Phosphorous fertilizer will increase the farm profit by 23%. This Management Information System opens up opportunities for improvement in the environmental and economic efficiency of our farm management practices.

On a pilot-scale, precision farming strategies for Madikai grama panchayath in the Kasaragod district of Kerala was developed. The soil available potassium is the major deficient element found under coconut based cropping system. The nutrient deficiency maps showing the spatial information of area under different nutrient deficiency have been created for the coconut and arecanut based land use pattern in Madikai panchayath. Soil nutrient deficiency maps were also been created for the land use patterns based on cashew, rubber, banana and paddy cultivation.

Harnessing the Mighty Microorganisms

Microbiology is relatively a new entrant in the saga of coconut research. Research in the field of Microbiology began during 1977 at the ICAR-Central Plantation Crops Research Institute, about six decades after the establishment of this Institute in 1916. The early investigations were focused on studying the microbial activities in root region of coconut palms (particularly with reference to root (wilt) disease), the role of bacteria in yellow leaf disease and the effect of cultivation of intercrops in coconut, if any, on the plant-beneficial microorganisms. During 1985, microbial ecological studies in coconut based

Opposite: Mixed Farming Unit

high density multiple species cropping system were initiated at Kasaragod. In the same year, research on microbial control of an important coconut insect pest, the rhinoceros beetle, using baculovirus was initiated at Kayamkulam. In the year 1986, studies on vesicular arbuscular mycorrhizae in coconut and symbiotic bacteria involved in green manure crops commenced. Microbial studies in retting of coir pith also formed an important area of microbiological research at CPCRI during the latter part of the 1980s.

During 1990s, recycling of coconut biomass residues through vermicomposting and composting was initiated and a method to produce coconut leaf vermicompost using a local isolate of earthworm was standardized by 1998. Much of the microbiological studies, from 1977 to 2000, were of ecological nature that brought out useful information on the presence and diversity of plant-beneficial microorganisms such as free-living and associative diazotrophs, phosphate solubilizing bacteria and fungi and arbuscular mycorrhizae in the rhizosphere of coconut and arecanut and their cropping systems. Basic studies about the beneficial characters too were carried out and their efficacy was assessed in a few field- level experiments.

A product/technology development oriented research in microbiology began from 2006 with the commencement of network project on 'Application of Microorganisms in Agriculture and Allied Sectors' (AMAAS). The research carried out under this project yielded PGPR based bioinoculant products by 2014. In tandem with the coconut leaf vermicomposting and coir-pith composting technologies, the bioinoculant technologies have given a new impetus to the organic cultivation in coconut. These products were backed up with cutting-edge basic research since 2009, that included whole genome sequencing of PGPRs from coconut, arecanut and cocoa, transcriptomic analysis of acid tolerant *Bacillus* spp. and metagenomic analysis of microbial diversity in coconut leaf vermicomposting technology using next-generation pyrosequencing platform.

Microbial control of insect pests

By the early 1990s, noteworthy achievements were made in the area of coconut rhinoceros beetle management using Baculovirus (later to be termed Oryctes virus, followed by Oryctes nudivirus) and the entomopathogenic fungi, Metarrhizium anisopliae. A method to maintain the viral pathogen in healthy rhinoceros beetle grubs and their field application by the release of virus-inoculated beetles were standardized. Mass-multiplication of *M. anisopliae* in locally available and cheap solid media (cassava chips) and liquid medium (coconut water) were developed. Methods of and doses of application of *M. anisopliae* in the form of spores in breeding sites were standardized. Using Baculovirus application, a significant control of the rhinoceros beetle was achieved in the mainland and in Andaman and Nicobar/ Lakshadweep Islands during the late 1980s and early 1990s. Presently, the microbial approach is an important component of the integrated management strategy being popularized through several ToT-oriented projects/ programmes.

Biomass recycling technologies

Coconut palm wastes, being highly ligno-cellulosic, is very hard and they are decomposed in nature rather very slowly. Such an 'intransigent' waste from the plantation was successfully converted to a brown, non-odorous, granular vermicastings using earthworms, an creditable achievement itself. In recognition of the significant contributions made in improving the soil health and fertility, and the economic status of coconut farmers, through the organic recycling technologies, the ICAR Outstanding Team Award for the biennium 2005-06 was bestowed on this inter-disciplinary scientific team (George V. Thomas, Murali Gopal, C. Palaniswami, P. Subramanian, V. Krishnakumar, Alka Gupta and B.T. Rayudu) that made it possible.

Vermicomposting technology

The most arduous task of recycling of large-scale biomass residues generated in arecanut and cocoa gardens was initiated in 1997 at CPCRI Regional Station, Vittal and published this work in the 1999 voulme of Indian Journal of Agricultural Sciences by Dr.P.Chowdappa and his group. Later, Dr. S.R. Prabhu standardized technology for vermicomposting of coconut leaves using a local earthworm isolate, *Eudrilus eugeniae*. Composting can be done in cement tanks/ tubs or trenches/ pits of convenient size in the field itself, where heaped leaves along with the cow dung (10% by weight) added, are subjected to preliminary weathering for 1-2 months (organic wastes already weathered in rains for 3-4 months can be directly used), and then the earthworms in sufficient number is introduced. They are so efficient in their work that 70% of the biomass can be recovered as vermicompost in about 70 days.

Popularization of this technology by giving training to end-users and supply of nucleus earthworm material for initiating it became the main stay of organic farming since then. Supply of more than 25 lakh nucleus earthworm cultures all over the coconut growing areas in India and tonnes of coconut leaf vermicompost to stakeholders since 2002 bears a strong testimony to the success of this grass-root level technology. Along with these outreach programmes, basic information about the optimum weather factors for efficient vermicompost production and the impact of application of coconut leaf vermicompost on soil health, fertility and crop yields were also assessed.

Impact of coconut leaf vermicompost technology

With this 'low-cost', but 'high-return' technology, about 4 to 4.5 tonnes of fresh vermicompost can be produced from 6 to 8 tonnes of residues produced annually from one ha coconut garden. This vermicompost can meet 50% of the nitrogen requirement of coconut palms of 1 ha area, thereby reducing the expenditure on chemical fertilizers substantially. Alternatively, sale of the vermicompost and earthworms can potentially generate an income of ₹ 50,000-60,000 a year. This technology provides a steady income to the farmers, besides enhancing the soil

health and fertility as well as ecosystem services of coconut based cropping system. Now, the packaged coconut leaf vermicompost under the trade name, 'Kalpa Organic Gold', was released during launching of centenary celebrations on 12, March 2016.

Coir-pith composting technology using poultry manure

Another useful technology for the farmers to recycle coir-pith, a by-product generated from coir industries, was developed and standardized during 2004-2012. This technology involves co-composting coir pith with poultry manure along with lime and rock phosphate for about 45-60 days. The advantage of this technology is that it can be easily carried out with locally available materials and it does not involve the use of urea, therefore making the product entirely of organic nature. The packaged coir-pith compost produced by this technology has been launched under the trade name 'Kalpa Soil Care' during 2016.

Three PGPR/AM-based bioinoculant products

During the period 1980-2000, several basic studies clearly indicated the presence of nitrogen-fixing bacteria such as *Beijerinckia*, *Azospirillum brasilense* and *Azotobacter* spp., and mineral pohosphate solubilizing fungi (*Aspergillus* sp. and *Penicillium* sp.) with P-solubilizing capacities ranging from 26-74%, and bacteria (*Pseudomonas* sp., *Micrococus* sp and *Bacillus* sp.) with P-solubilizing range of 19.5 to 54.0%. Studies to bring out the diversity of arbuscular mycorrhizae present in coconut rhizosphere had indicated the presence of *Glomus* and *Gigaspora* as predominant species. Their ability to help coconut seedlings in overcoming moisture deficit stress was also reported. Benefits of inoculation of *Azospirillum brasilense* to coconut seedlings grown in polybags indicated profuse growth of root biomass suggesting that it is a viable option to take advantage of the microorganisms in producing healthy coconut seedlings.

Under the network project on Application of Microorganisms in Agriculture and Allied Sectors (AMAAS) (from 2006 to 2014), hundreds of soil and root samples were collected from coconut and cocoa rhizospheres cultivated in different agro-ecological zones of India, which yielded eight native effective PGPRs for raising healthy and robust coconut and cocoa seedlings. These isolates possessed multiple plant growth promoting properties including mineral phosphate solubilization, indole acetic acid, siderophore and antibiotic production, ACC deaminase and antifungal activities. The effective bacterium from each crop was selected and developed into talc-based bioformulation. *Bacillus megaterium* isolated from coconut rhizosphere, which could increase total dry matter weight of coconut seedlings significantly, was released under the trade name 'Kera Probio'. *Pseudomonas putida*, that could increase the total dry matter weight of cocoa seedlings, was launched under the brand 'Cocoa Probio'. Similarly, based on five years of study under this project, a soil based arbuscular mycorrhizal bioinoculant, 'KerAM', was released during 2014. This bioinoculant contained *Claroideoglomus etunicatum*, one of the dominant AM species isolated from coconut agro-ecosystem, with a high potential to increase the plant growth parameters of coconut seedlings.

Genomic initiatives in exploring the 'microbial world'

The plant beneficial microbial profile of the coconut leaf vermicompost was unraveled using conventional and cutting edge next generation sequencing

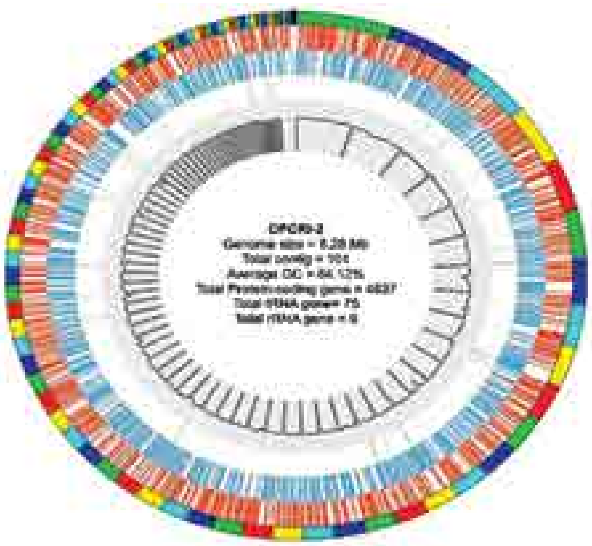
tools, as efficiency of vermicomposting depends greatly on the microorganisms present in the substrates, earthworm gut and composting environment. The microbial community dynamics during the different vermicomposting stages employing pyrosequencing was carried out using NGS based pyrosequencing technology. The results indicated that the diversity of the bacteria increases as the substrates were converted to vermicompost by the earthworms and then decreases in the finished product to stabilize on par with the initial stage.

DNA bar coding of *Eudrilus* sp.

Bar-coding is a concept that uses identifying organisms using short gene sequence, which is standard portion of the organism's genome. The coconut leaf vermicomposting local strain of earthworm, *Eudrilus eugeniae* was 'bar-coded' 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, and the gene sequence was deposited in the 'Barcode of Life Data systems' (BOLD).

Whole genome sequencing of PGPR

An in-depth knowledge on the whole genome sequence of plant-beneficial bacteria and its functions helps in developing a better bioinoculant technology. Whole genome sequencing of three PGPRs was carried out during 2009 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.



PCircos plot representing the Pseudomonas putida genome*

The innermost circle represents the GC content, the second circle from the innermost circle represent non-coding genes, the third circle from inside represents coding genes on negative strand, the fourth circle represents coding genes on positive strand, and the outermost circle represent contigs

*Source: Alka Gupta et al. (2014) Whole genome sequencing and analysis of plant growth promoting bacteria isolated from the rhizosphere of plantation crops - Coconut, Cocoa and Arecanut. PLOS ONE. 9 (8): e104259. doi:10.1371/journal.pone.0104259. This work was carried out under a public-private partnership between CPCRI and SciGenom Lab Pvt. Ltd. Kochi.

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 analyze the molecular mechanisms employed by *Bacillus* to mitigate acid stress, transcriptome level studies were initiated with next-generation sequencing (NGS) for mapping and quantifying transcriptomes. The transcriptome profile of an acid tolerant *Bacillus* has delineated a total of 182 transcripts as differentially regulated (83 up- and 99 down-regulated) under acid stress, with 152 transcripts exclusively acid induced.

Reducing Crop Losses Through Disease Management

It is known that human concerns about the protection of plants started from the beginning of agriculture itself, ever since 5000 BCE. Coconut, popularly known as "Kalpavriksha" in India, is also known to be affected by many pests and diseases. Though there are no record of occurrence of coconut diseases in ancient times, it can be reasonably assumed that diseases and causal agents of the plant diseases were present even before humans started cultivation of plants. Like any other plant, coconut is also affected by number of diseases and pests, some of which are fatal while others reduce its vigour resulting in economic loss. More than 830 insects and mites, 173 fungi, 78 species of nematodes, few species of bacteria, viruses, viroids and phytoplasmas have been found to be associated with coconut, though only few of them cause serious damage and economic loss to farmers.

Bud rot and fruit rot, basal stem rot, root (wilt), stem bleeding and leaf blight are the important diseases of coconut in India. Bud rot is a fatal disease prevalent in most of the coconut growing areas. Though incidence is sporadic, occasional severe outbreak of the disease has killed hundreds of coconut palms in major coconut growing areas. Root (wilt) disease coupled with leaf rot is a debilitating disease and attributed to be a major cause of low productivity of coconut in Kerala. The spread of the root (wilt) disease to neighbouring state of Tamil Nadu is also a major concern. Basal stem rot or Thanjavur wilt is another severe fatal disease prevalent in most of the coconut growing areas. Most of these diseases have been recorded about 75 to 100 years back and later on systematic efforts have been made to identify the causal organism, understand the epidemiology of the disease and to develop effective management strategies for these important diseases.

Disease scenario before 1970

Occurrence of major diseases of coconut in India, especially the bud rot, root (wilt) were recorded more than 100 years. The occurrence of root (wilt) disease of coconut was first noticed in 1882 in Erattupetta area of Meenachil Taluk in Kottayam district. Sir Edwin J. Butler, the Imperial Mycologist, was the first one to make an attempt to understand the etiology of many of the diseases including root (wilt) and bud rot disease of coconut. Later, research on root (wilt) disease (RWD) was initiated in a modest scale in 1937 by the Plant Pathologist, Mr. M.K. Varghese, under the ICAR funded scheme for the 'Investigation of root and leaf diseases of coconuts' in the erstwhile Agricultural Research Laboratory with its headquarters at Kollam and a field station at Kayamkulam. As per the recommendations of the Plant Pathological Committee of ICAR in 1945, Professor J.F. Dastur, the Imperial Mycologist and Mr. K.M. Thomas, the Madras Government Mycologist visited the infected areas and experimental stations and recommended a multi-disciplinary approach to tackle the problem. In January 1947, this scheme was transferred to the Indian Central Coconut

Committee and from April 1949 onwards the scheme was absorbed in the Central Coconut Research Station (CCRS), Kayamkulam. Research on coconut diseases continued since then under the scheme of Indian Central Coconut Committee.

Bud rot disease was described by Butler in 1906 and he isolated the fungus and reproduced the disease by inoculation. Later, based on several inoculations, association of *Phytophthora palmivora* was confirmed. M.K. Varghese in his "Diseases of the Coconut Palm" (1934) writes thus, *"During his visit to Travancore, Dr. Butler observed cases of this disease at Changanacherry and elsewhere. He examined specimens from the diseased palms, and isolated the same fungus, which he had got from the Godavary disease, so that no doubt is left as to the identity of the disease or its causation in Travancore"*.

Similarly, *Ganoderma lucidum* causing basal stem rot disease of coconut in Karnataka was described by Butler in 1913. Later occurrence of this disease in Thanjuvur district of Tamil Nadu was described in 1952 and the disease was recognized as Thanjavur wilt. Occurrence of stem bleeding disease on coconut was reported in 1922.

Scenario since 1970

Research was strengthened and streamlined after the establishment of Central Plantation Crops Research Institute at Kasaragod in 1970. Since then, work on symptomatlogy, pathogen identification, epidemiology and management of root (wilt) disease, bud rot disease, stem bleeding and basal stem rot disease of coconut has been continued under several schemes. This has resulted in development of methodologies for detection and identification of causal agents of the diseases, understanding the epidemiology of the diseases to a certain extent and development of integrated management strategies for all the major diseases of coconut. Important milestones are systematic recording of symptoms and indexing of root (wilt), bud rot, stem bleeding and basal stem rot, identification of the pathogens associated with all the major diseases, identification of effective biocontrol agents against *Phytophthora*, *Ganoderma* and *Thelaviopsis* and development of integrated management strategies for all the major diseases of coconut.

Bud rot disease

Phytophthora species is identified as the pathogen

Diagnosis of a disease and correct identification of the pathogen is the first step in management of any plant disease. The pathogen causing bud rot and fruit rot of coconut was identified as *Phytophthora palmivora* way back in 1906 and belong to the A2 mating type. Later, detailed population analysis of Phytophthora isolates associated with bud rot and fruit rot diseases of coconut collected from major cococnut growing areas of India indicated that *P. palmivora* is the dominant pathogen, although stray incidences of *P. nicotianae* and *P. capsci* occurred.

Understanding the climatic factors favouring disease development

The bud rot is generally noticed during wet weather and younger palms (>20 years of age) are more vulnerable to the disease. Palms with damage by rhinoceros beetle, or injury to spear leaf or spindle during wet weather are likely to develop bud rot. Detailed epidemiological investigation has showed that a climatic envelope with temperature of 21-24 °C and relative humidity of 98-100 % are highly congenial for disease development, and such favourable days determine the disease incidence. Rainfall is a critical factor which

determines the disease development and heavy rainfall years have invariably showed higher bud rot incidence. The severe outbreak of bud rot in 1992, when more than 5000 palms were affected in Kuttiyadi area of Calicut district of Kerala was attributed to high rainfall. The fungus was reported to survive at the base of the fronds during dry months and the surviving fungus (up to five months) in the crown acts as a source inoculum in the subsequent monsoon season.

Managing the disease

Crown cleaning, field sanitation (removal and burning of dead and rotting palms) and prophylactic spray with Bordeaux mixture (1%) just before the onset of monsoon and one more spray after 40 days was found to be effective in management of the disease. As a curative treatment, application of Bordeaux paste (10%) was recommended. In the early stage of symptom development (yellowing and withering of spindle/spear leaf), just pull the spindle and cut the rotten portion of the bud with a sharp knife, immediately apply Bordeaux paste on the wound and cover with polythene bag (to avoid washing of the paste by rain). In the subsequent years, efforts were made to develop an alternative to Bordeaux mixture, because of the difficulties in spraying of Bordeaux mixture to the crown and base of the spindle, especially in the peak monsoon season.

An integrated management schedule has been now developed for management of the bud rot disease. Field trials conducted in the bud rot endemic areas has shown that pouring of mancozeb solution to the base of the spindle + placing of two perforated sachets containing mancozeb per palm or placing pesticide slow release cake (PSRC) pieces in the innermost leaf axils is effective in management of bud rot. Pouring of potassium phosphonate in leaf axil pit around the spindle was also found to be equally effective in managing bud rot. Apart from these chemical and cultural practises, the biocontrol agent, *Trichoderma harzianum* (CPCRI isolate No.28) was also found useful in management of the disease. Keeping two pieces of Trichoderma enriched coir pith cake (TCPC) containing

T. harzianum in the innermost leaf axils of each palm at bimonthly intervals (starting from the last week of May) has also shown significant reduction in bud rot incidence in the endemic areas, an exciting new development in eco-friendly disease management.

Impact of IDM practices

Effective management of bud rot disease can be achieved only if the integrated plant protection measures are adopted at the right time. Since bud rot disease incidence is erratic in nature, it is better to adopt preventive measures well in advance. It is recommended to adopt preventive measures such as sanitation (cutting and burning of affected dead palms) and fungicide application to neighboring palms in infected areas to prevent further spread of the inoculum. Bordeaux mixture and Bordeaux paste were used widely by coconut farmers and has become very popular among households in plantation sector including coconut. These fungicides are still being used by farmers to protect coconut from bud rot disease. Integrated approach consisting of phytosanitation and prophylactic spraying of Bordeaux mixture and curative application of Bordeaux paste has saved thousands of coconut palms which would have been killed every year by bud rot. In recent years (after 2009), the IDM consisting of placing of mancozeb sachets in place of spraying of Bordeaux mixture has also become popular in management of coconut bud rot. The field trial laid out at Malom village of Balal Panchayath in Kasaragod district of Kerala in a 10 ha area comprising 1250 palms (30 farmers' gardens) has shown about 75 % reduction in bud rot incidence with the IDM comprising of mancozeb pouring and placement of sachets.

However, highly fluctuating and often less than remunerative coconut prises often discourage farmers from adoption of scientific cultivation practices. Hence non-adoption of prophylactic measure against bud rot, climatic changes especially erratic rainfall, improper and inadequate use of fungicides and lack of skilled climbers coupled with high wages have often been pointed out as the constraints in proper implementation of recommended IDM packages against bud rot disease. Mechanization for application of crop protection measures and low-cost, long-lasting management strategies are required for effective management of bud rot henceforth. Use of un-manned aerial vehicles (drones) with infra-red cameras to diagnose bud rot affected palms at an early stage of symptom development (and possibly targeted application/spraying of fungicides on the spindle/crown as curative treatment as well) to save the affected palms is the need of the hour. State-sponsored surveillance and community based approach for integrated pest and disease management is going to be critical in the coming years. Development of appropriate technologies tailor-made for the ever changing climatic, socio-economic conditions of the coconut sector is the major challenge before the scientific community.

Root (wilt) disease

Root (wilt), also known as Kerala wilt is a non-lethal, but a debilitating disease of coconut. Palms of all ages are susceptible to infection. The occurrence of root (wilt) disease of coconut was first noticed after the great floods in 1882 in Erattupetta area of Meenachil Taluk in Kottayam District of Kerala State. Around 1907, the disease was reported from Kaviyoor and Kalloopara areas of Tiruvalla Taluk and later from Kayangulam of Karthikappally Taluk. The disease, which appeared almost simultaneously in the above foci began to spread to adjoining areas.

In later years a number of attempts were made to determine the extent of spread and intensity of the disease. A comprehensive survey undertaken by CPCRI64 in the 1980s, in collaboration with Kerala State Agriculture Department and other agencies, indicated that disease has spread from its original foci and is prevalent in about 4, 10,000 ha in eight southern districts of Kerala from Thiruvananthapuram to Thrissur in Kerala. The root (wilt), coupled with leaf rot, is still a major disease prevalent in these districts. Later, occurrence of disease in isolated pockets in northern districts of Kerala and adjoining districts of Tamil Nadu has been observed.

The annual loss due to the disease was estimated to be about 968 million nuts and the monetary loss assessed in terms of loss in husk, copra yield and leaf on the basis of 1984 price index of coconut was of the order of about Rs. 3000 million. A decline in yield to the tune of 45% in West Coast Tall variety and 60% in D x T hybrids and delayed bearing of seedlings that took up the infection has also been reported. Though figures are not available for the loss in Tamil Nadu, the disease is very serious and causes considerable crop losses in Cumbam valley, Shenkottai, Kulasekharam and Pollachi areas.

Diagnostic symptoms

Butler in 1908 in his 'Report on the coconut palm disease of Travancore' has given a detailed description of the symptoms of the disease. Wilting and drooping of the leaves, flaccidity, paling, yellowing and necrosis of leaflets, chlorosis of leaves, shedding of immature nuts, reduction in size of crown, root rot, reduction in vitality of female flowers were reported to be associated with the disease. The symptoms of RWD of coconut were found to be complex and variable. Symptom expression also varied with the age of the palm, genotype of the host and environmental conditions. Moreover some of the disease symptoms were found to be produced in response to different biotic and abiotic factors. Clarification of the symptoms caused by the primary pathogen and secondary associated factors was therefore considered necessary for a better understanding of the nature of the disease as well as diagnosis. Hence a systematic study was taken up by the

institute during 1960s on quantitative evaluation of the foliar symptoms on over 7000 palms of varying age and growing under varying ecological conditions.

Based on the frequency of occurrence of symptoms and association with each other, flaccidity or ribbing of leaflets was found to be the common and consistent foliar symptom. In general, 67 to 97% of RWD affected palms showed flaccidity, 38 to 67% showed yellowing and 28 to 48% developed marginal necrosis. In a majority of the young palms at an early stage of the disease flaccidity appeared to be the only symptom. Foliar yellowing and marginal necrosis sets in with the advancement of age and disease. Studies undertaken on the sequence of development of symptoms from 1970-76 also revealed flaccidity as the earliest foliar symptom.

In order to assess the extent of root damage in RWD affected palms and their relation to foliar symptoms, detailed studies were undertaken from the 1950s. The percentage of root decay in RWD affected palms varied from 10.6 to 94.4 %. Rotting of roots has been considered as one of the major symptoms of the disease by the earlier workers. Significant difference in the extent and frequency of root decay could not be traced in RWD affected palms by many workers and hence it could not be considered as a characteristic symptom of the disease.

Measuring the disease

Disease assessment is the most important aspect in any crop management programme because it is the process that generates data to quantify disease progress. Based on the relative contribution of the flaccidity, yellowing and marginal necrosis, a scoring system for quantifying the disease intensity was developed in 1973. As per this method, the disease index is obtained by adding the weighted average grade points of the three characteristic foliar symptoms of the disease from all the leaves of a palm. Disease index $DI = \Sigma \frac{F+Y+N}{L} \times 10$, where F, Y, N are the grade points assigned to flaccidity, yellowing, necrosis and L is the total number of leaves in the palm. The grade points assigned to different symptoms vary from 0 to 5 for flaccidity, 0 to 3 for yellowing and 0 to 2 for marginal necrosis according to the intensity and number of leaflets showing the symptoms. When palms below the age of 10 years are affected, flaccidity was found to be the prominent symptom and hence more weightage was given to it for indexing. For young palms, observations have to be taken from all the leaves for calculating the disease index ($DI = \Sigma \frac{15F+5Y+5N}{L} \times 10$). Disease index can vary from 0 to 100 where 0 represents the total absence of all the symptoms, indicating that the palm is in perfect health (visually) and 100 means the presence of all the symptoms in the acute stage on all the leaves. Based on the disease index the palms can be categorised into disease early (DI<20), middle (DI 20-50) or advanced stage (DI >50). The indexing method developed is based on the visual symptoms on all the leaves (on an average 25-35 leaves) in the crown of the palm.

Though, it helps to critically evaluate the disease intensity, this method was time consuming and cumbersome. Hence, the indexing method was further simplified in 1985 and made easier by scoring the symptoms on the leaves present in any of the five spirals. Usually, only 4-5 leaves are present in a spiral and hence the number of observations per palm to be taken for calculation of diseases index is less. This indexing system helps in quantifying disease severity in a simple numerical expression that can be analyzed statistically.

'May be' or 'May not be': Etiology of the disease from fungus to phytoplasma

Fungi, the first 'suspect'

Though the disease has been reported to be present in southern parts of Kerala since 1882, the causal agent of RWD remained an enigma for over a century now. Bourdillon in 1906 first reported that the disease was 'fungoid' in nature. Root decay was observed to be a significant symptom associated with root (wilt) disease by Butler in 1908 and he isolated *Botryodiplodia theobromae* from infected roots. Preliminary investigations conducted during 1930s and 1940s on the etiology of the disease were primarily focused on fungal pathogens associated with the root rot of coconut. *B. theobromae, Rhizoctonia solani, R. bataticola, Cylindrocarpon effusum* and *Fusarium equiseti* showed constant association with infected roots. Though these pathogens induced localized rotting of roots in inoculation experiments, they failed to produce the characteristic foliar symptoms of RWD.

Then virus ruled out

The search for the causal agent gained new dimensions with the advancements in the field of Plant Pathology. Investigations initiated in 1952 indicated the possible association of a virus or virus like submicroscopic pathogen in the development of the disease. Suspecting the viral etiology, attempts were made to transmit the disease by mechanical inoculation of leaf extracts, pin prick inoculation, leaf insertion, root and petiole grafting, sap transfusion and by different species of vector. Preliminary results of sap inoculation and vector transmission experiments indicated the association of rod shaped tobacco mosaic virus (TMV) with the disease. Further detailed studies using EM, serological tests and infectivity trials conducted in collaboration with IARI during late 1970s proved that the TMV is not involved in the development of root (wilt) disease.

Not bacteria either!

The research on role of bacteria in RWD was initiated in 1970 based on the preliminary observation of characteristic vascular streaming movement of *Pseudomonas* sp. in roots of disease affected palms. Repeated isolations from diseased roots yielded *Enterobacter cloacae* that was conspicuously absent in roots collected from disease free areas. Large scale pathogenicity experiments were conducted and the bacterium failed to produce characteristic symptoms of the disease.

Nematodes are 'innocent'!

Suspecting viral etiology the role of nematodes in transmitting RWD was studied by Weischer in 1967 and concluded the presence of Longidorus in diseased areas and Xiphinema in both diseased and healthy areas. Organized research in plant nematology was initiated at CPCRI in 1972. However, the establishment of evidences against viral etiology of RWD by late 1970s diverted the research from its putative role as a vector to causal organism. However, the seedling inoculation experiments conducted could not establish the role of nematodes in the etiology of RWD.

Phytoplasma - clinching evidences

The research on root wilt disease was considerably strengthened from 1978 under the world bank funded Kerala Agricultural Development Project (KADP). Electron microscopic examinations of tissue samples from sieve tubes

of root, inflorescence axis and tender leaf from diseased palms showed vesicular pleomorphic structures. Prof. F. Nienhaus of Institute for Pflanzenkrankheitan, West Germany confirmed the presence of Mycoplasma like organisms or MLOs (now known as phytoplasma) in the fixed ultrathin sections of tissues from diseased palms sent from Kayamkulam during 1981-1982. Through EM, the RWD phytoplasma appeared as coccoid forms in the size range of 250-400nm. EM studies enabled the direct visualization of RWD phytoplasma and its uneven distribution in affected palms. Phytoplasmas have been found in large numbers in the sink region especially heart tissues, rachillae of developing inflorescence and root tissues. Significantly, none of the other biological agents reported earlier to be associated with the disease could be observed in the vascular tissues examined.

The discovery of phytoplasmal association with RWD led to the reorientation of research programmes in to establishing or substantiating the etiology with more scientific evidences, involvement of other biotic factors and management of the disease. Light microscopic studies with nucleic acid specific stains and fluorochromes lent support to the association of phytoplasma in the phloem tissues of root (wilt) affected palms. The results of the experiments on antibiotic therapy, dodder transmission and vector transmission provided conclusive evidences on the association of phytoplasma with RWD67.

Molecular characterization of RWD phytoplasma

Preliminary attempts made to detect the coconut RWD phytoplasma using 16S rDNA sequence based universal primers failed to give consistent results in direct and nested PCRs due to the low titre and erratic distribution of phytoplasma in the coconut palm, seasonal fluctuations, presence of phenolic compounds and PCR inhibitory substances in the DNA preparations and changes in the universal primer binding sites. Molecular detection of phytoplasma associated with RWD was achieved by modification of phytoplasma enrichment technique for DNA extraction by addition of 5% polyvinyl pyrrolidone, designing six highly sensitive primers and seminested PCR technique. The primers were designed from the sequences obtained from coconut root (wilt) disease phytoplasma as well as multiple sequence alignment of 16S rRNA sequences of different phytoplasmas. The phytoplasma causing RWD has now been characterized as ‘Candidatus Phytoplasma oryzae’ related strain belonging to 16SrXI-B sub group (rice yellow dwarf group).

Identification of insect vectors

Investigations on the vectoral role of lace bug *Stephanitis typica* Distant (Tingidae) initiated in 1950s and the positive results obtained in these

‘Through dodder to periwinkle’: Experimental cross-transmission of phytoplasma

Dr. Sasikala and her group in 1980s attempted experimental transmission of Phytoplasma employing common phanerogarnic parasites like the dodder species (*Cuscuta campestris, C. chinensis* and *C. subinclusa*), to periwinkle (*Catharanthus roseus*), a known mycoplasma indicator host. The dodder species, although established on coconut foliage, failed to put efficient haustorium to reach the vascular bundles (phloem being the abode of the phytoplasma or ‘MLO’ as it was called then) in the mid-rib of the coconut leaf. As luck would have it, the chance-discovery of dodder laurel (*Cassytha filiformis*) parasitizing coconut seedlings in the Minicoy Island (Lakshadweep) resurrected the experiment, nearly doomed to fail. Immediately, coconut seedlings parasitized by the dodder laurel were brought over to the Kayamkulam station and planted in steam-sterilized soil in RCC tubs. The dodder laurel, *Cassytha filiformis*, established well on coconut seedlings, putting forth haustorium to reach and form intimate contact with the vascular bundles. Periwinkle (grown in sterilized soil in mud pots and protected inside insect-proof muslin cloth cages), bridged through dodder laurel established on diseased coconut seedlings in the field, developed chlorotic spots in the interveinal areas at vein-endings of fully opened leaves, three to four weeks after the establishment of the haustorium. Passage of Phytoplasma, as confirmed by positive staining reactions and detection of the organisms through electron microscopy in the mid vein and petiolar tissues of the periwinkle, dodder strands and leaflets of diseased coconut seedlings, established the transmission of the disease from coconut to periwinkle. Most pertinently, Phytoplasma was not observed in dodder on disease free coconut and control periwinkle plants.

Although *C. filiformis* had been earlier employed to transmit citrus mosaic from sweet orange (*Citrus sinensis*) to acid lime (*C. aurantifolia*), this is the first instance of Phytoplasma being transmitted by an unconventional dodder species. The disease was earlier experimentally transmitted through the lace bug to healthy coconut palms. As all attempts at in vitro culturing Phytoplasma (considered to be one of the pre-requisites to prove the pathogenicity of the organism as per the Koch’s Postulates) has failed so far (as is the case with all other phytoplasma diseases), this has turned out to be a clinching evidence for establishing the phytoplasmal etiology.

transmission experiments indicated the involvement of a virus or virus like submicroscopic pathogen in the disease. With the discovery of phytoplasma as the causal agent, the ability of lace bugs to imbibe and transmit the phloem limited pathogen was reinvestigated. Transections of coconut pinnae with lace bugs fixed in feeding position by a cold immobilization technique revealed the termination of the stylet in phloem thereby confirming the ability of the insect to pick up the phloem limited pathogen.

Phytoplasmal diseases are known to be transmitted by leaf hoppers, plant hoppers (*Auchenorhynca*) and rarely by psyllids. Inventories of insect fauna on coconut available then (till 1979) did not include Auchenorhyncan insects from India. Hence, work on a systematic inventory of insects prevalent in RWD affected gardens was carried out for over two years. In this study, a leaf hopper (*Sophonia greeni* (Distant)) and a plant hopper (*Proutista moesta* Westwood) were recorded. The potential of *S. typica*, *P. moesta* and *S. greeni* to acquire the RWD pathogen was studied using electron microscope. Phytoplasmas were observed in the brain and salivary glands of lacebug given an acquisition plus incubation period ranging from 18 to 23 days and also in the salivary glands of plant hopper with acquisition plus incubation period of over 40 days. The vectoral role of these two insects were assessed through transmission experiments on coconut seedlings under insect proof conditions. Three out of the four seedlings inoculated with S. typica and five out of the eight P. moesta inoculated seedlings showed flaccidity, the characteristic symptom of RWD. Electron microscopic examination, serological tests and light microscopic

Insect - proof cages used in insect transmission studies

'A hopper and a bug': the two vectors of coconut phytoplasma

The plant hopper, *Proutista moesta* Westwood, breeds in decaying organic matter in the soil and only adult insects are seen feeding on the leaves of coconut palm. Egg to adult period of this insect is completed in 28-35 days with five instars, having an average incubation period of 7 days and a nymphal period of 25 days. Adult longevity ranged between 50- 60 days. Adult lays on an average of 45 eggs with sex ratio of 1:0.59. The population build-up of plant hopper was noticed with the onset of summer showers in late May-June and highest population was recorded during October-November. Alternate hosts of the insect include arecanut, oil palm and sugarcane. Plant hoppers are occasionally observed on banana, jowar, maize, rice and Napier grass. The feeding by *P. moesta* is confined to the leaflets of middle and outer whorls, in a non-destructive manner as they suck sap from the abaxial surface of leaflets and no feeding marks were observed in leaflets due to their feeding.

The lace bug, *Stephanitis typica* (Distant) (Tingidae), is polyphagous (originally recorded from banana), and both the adults and nymphs drain the contents of the mesophyll tissue on coconut foliage. It completes its life cycle in about 25 days with an average incubation period of 12 days and a total nymphal period of 13 days, covered under five instars. There are two peak periods of abundance in March- May and September-October. Fluctuations in populations are directly correlated to temperature and sunshine, inversely to relative humidity and rainfall. On individual palms, abundance increases from outer to the tender leaves and on each leaf, they occur in greater numbers in middle leaflets. Diseased palms harbour more insects than the healthy.

The lace bug feeds on coconut leaflet from its abaxial side. It inserts its stylet through stomata and sucks the contents of the coconut foliage. Besides this intracellular feeding, the stylet also ruptures the walls of the cells traversed in its course to reach the vascular bundles. The stylet tip in such cases terminates in phloem, thereby suggesting the ability of the bug to acquire the phloem-bound phytoplasma, associated with coconut root (wilt) disease in India.

Investigations on these putative vectors revealed the presence of phytoplasma in the salivary glands of *S. typica* and *P. moesta* which were given specific acquisition access and incubation periods. Electron microscopic studies revealed the presence of phytoplasma in salivary glands of lace bugs which were given acquisition access and incubation period ranging from 18-23 days and in plant hopper with AAP of 30 days and more. The vector role of these two insects was proved experimentally on coconut seedlings kept under insect proof conditions. The lace bug inoculated seedlings showed the presence of phytoplasma between 9 and 27 months after first inoculation and by 17th month after inoculation, 50% of the inoculated seedlings showed flaccidity, the diagonostic symptom of the disease. In the case of plant hopper, 6/8 inoculated seedlings showed the presence of phytoplasma in 5-24 months after first inoculation.

staining confirmed the presence of RWD phytoplasma in inoculated seedlings and these transmission experiments conclusively proved the vectoral role of S. typica and *P. moesta*.

Diagnostics for early detection

Development of robust diagnostic techniques for RWD has been the priority area of research of ICAR-CPCRI since 1950s. Development of visual symptoms of RWD is very slow and there is a time lag between infection and symptom expression. In case of latent infection, the palm may be harbouring the RWD phytoplasma without showing any external diagnostic symptoms at all. Moreover, similar symptoms can be produced in response to different biotic and abiotic factors. Hence, the use of symptoms alone is often an inadequate method for disease identification and may lead to an improper diagnosis. Considering the need for the early detection of RWD, attempts were made to develop RWD diagnostics based on biochemical tests, microscopy, physiological tests, serology and nucleic acid based techniques.

The search for a diagnostic technique initially was based on the altered host metabolisms detectable in the form of either accumulation or depletion of substances consequent to differential enzymatic activity in diseased palms. But, these changes can also be induced by other biotic and abiotic stresses. Colour tests developed during 1960s and 70s based on dehydrogenase activity, accumulation of free amino acids especially arginine and other ninhydrin positive free amino acids in the leaf tissues of RWD affected palms, low tannin content in diseased leaves and Ethylene diamine tetra acetic acid as an extractant of biologically active organic constituents/ pigments could not give consistent results under varying environmental conditions and hence could not be used as a reliable diagnostic technique.

The collaborative project with Indian Agricultural Research Institute, Indian Space Research Organization and NASA of USA was initiated on January 1970 for the early diagnosis of RWD by remote sensing using false infrared aerial photography. The findings by and large indicated that the crown of healthy palms appeared red and those of diseased palms showed paleness as a result of weaker infra-red reflectance on the film as measured by microphotometer. This variation in 'spectral signature' of healthy and diseased palms could not be used as a diagnostic tool for want of adequate data on ground level.

As early as in the1980s, transmission electron microscopy (TEM) was successfully employed by the institute to establish the association of phytoplasma with RWD affected palms and its localization in phloem elements. Though this technique remained as the most reliable method for visualization of RWD phytoplasma detection till late 1990s, the method was not suitable for screening large number of samples since the technique was time consuming, expensive and needs skilled personnel.

Light microscopy using Dienes staining and fluorescent dyes like 4,6-diamidino-2-phenyl indole (DAPI) and Hoechst 33258 were also used as preliminary methods to detect the presence of phytoplasma in RWD affected palms. These microscopic techniques were cheap, quick and simple but were not specific for RWD phytoplasma. Moreover, the low concentration and uneven distribution of phytoplasma in RWD affected palms also limited its application in RWD detection.

The research on sero-diagnostics gained momentum with the establishment of phytoplasmal etiology. During 1980s, the disease specific/ pathogenesis related antigen fractionated and purified from the spear leaves of RWD affected coconut palms was used in preparation of antiserum. The first sero-diagnostic test standardized by CPCRI for RWD was agar gel double diffusion test. The test was found to be in agreement with the visual identification of the diseased palms up to 95.3%. Though the double diffusion technique was found to be consistent, it was time consuming, allowed the screening of only limited number of samples and antiserum consumption was high.

By late 1990s, more thrust was given on the standardization of Enzyme linked immunosorbant assay (ELISA) as this technique will enable the screening of large number of samples. Direct antigen coated indirect ELISA (DAC-ELISA) using horse raddish peroxidase (HRP) conjugated secondary antibody showed better delineation between the healthy and diseased samples. Experiments were carried out by with the addition of different additives to the extraction buffers singly and in combinations to enhance the specificity of the test. Nonchlorophyllous spindle leaf was found to be the ideal test material for ELISA since they possess high titre value. By the year 2000, DAC-indirect ELISA for RWD detection has been developed and reported by Mrs. M. Sasikala and co-workers. This formed the first report on which ELISA has been successfully used for the detection of coconut RWD. Following this standardized method, the test for about 20 samples with three replicates could be completed within 44 h in one ELISA plate.

With the standardization of a protocol for the purification of phytoplasma in the highly pure form (free from host contaminants) and production of phytoplasma specific antiserum, modifications were made in 2005 on incubation period and extraction and coating buffers. By the refined method, the results could be obtained within 24h, with a very high sensitivity of 98.4% and specificity of 96.4%. The investigations on developing a more simple and rapid protocol was continued and DAC indirect ELISA, which requires only seven hours has been optimized in the year 2010 by using leaf bits (instead of leaf grindate), plain buffer (in place of buffer with additives) and reduction in incubation time. This modified method showed 98% sensitivity and about 1200 samples with 3 replications could be screened using 1 millilitre of the primary antibody.

The modified ELISA protocol is now being used for routine screening of coconut samples for selecting healthy mother palms for breeding purpose or seednut collection, confirming the presence of phytoplasma in new areas of disease incidence and screening the nursery seedlings. It can detect phytoplasma about 24 months before the appearance of visual symptoms. The institute also facilitates the state department of Agriculture in the selection of RWD mother palms suitable for seednut collection by the serological screening of the selected palms.

A physiological test was also developed based on the difference in the stomatal resistance and transpiration rate of the youngest fully opened leaf of healthy and diseased palm. The RWD affected palms show low stomatal resistance and high transpiration rate whereas healthy palms show high stomatal resistance with a correspondingly low transpiration rate. A comparative study between serological and physiological tests has clearly established that these could complement each other in disease detection.

With advancement in molecular biology, from the year 2000 onwards more emphasis has been given to the development of PCR/ nucleic acid based RWD detection technique. In order to overcome the inconsistency in detection and to enhance the specificity and sensitivity, sampling and DNA extraction techniques, primers and semi- nested PCR conditions were standardized. Immature spindle leaves and midribs have been found to be ideal for DNA extraction as they have high phytoplasmal titre and low amount of PCR inhibitors.

A SYBR Green-based real-time PCR assay using the specific primer pair designed from the 16S ribosomal DNA sequences of RWD phytoplasma has been developed by the institute for quick detection of phytoplasma in diseased coconut palms. The F1/R1 primer pair amplifies a 218bp sequence with a melting peak of 80.71°C The present efforts at ICAR-CPCRI to improve the RWD diagnostic procedure is aimed at devising a reliable, consistent, economic, user-friendly on-farm diagnostic kit, with which the farmer can ensure the health status of the mother palm or the planting material in his garden.

Impact of investigations

The establishment of phytoplasmal etiology and identification of vectors are the major breakthroughs in understanding RWD. These findings have resulted in partial purification of phytoplasma from RWD affected coconut and production of polyclonal antiserum and development of ELISA assay for detection of phytoplasma. This technique is being used for the last 10 years to identify the disease-free mother palms identified by breeders for development of disease resistant varieties. The technique has also helped the breeders in screening the breeding populations for freedom from phytoplasma, which has resulted in development of RWD resistant varieties like Kalpasree, Kalparaksha and the hybrid, Kalpa Sankara.

Controversy! Thy name is root (wilt) disease

Coconut, being the mainstay of the southern Indian states, especially Kerala (etymology of the name itself is 'the land of coconuts'), root (wilt) disease has always been (even now also) an 'emotional' or 'emotive' issue in socio-cultural, economic and political spheres of life. Questions were asked in Indian Parliament and representations from honourable members of Parliament and Ministers from the state petitioning the government of India for taking measures for intensifying research towards finding a lasting solution to this malady.

In fact, root (wilt) disease had always its share of controversies right from the beginning, be its terminology ('root disease', 'root rot', 'wilt disease', 'root (wilt)' or 'coconut decline'), etiology (as to whether 'disease' or a 'disorder' as a result of one or more abiotic factors like nutritional imbalance-micronutrient deficiency-heavy metal toxicity) and then the causative organism (fungi-bacteria-virus-nematode-phytoplasma).

And, scientific community could not keep itself aloof from it for long. Ripples in the scientific fraternity in CPCRI also was discernible the 1970s and 80s, with different schools of thought propounded by the erudite, scholarly and often mercurial personalities, passionate and animated arguments in the scientific fora advancing their arguments in favour of and against, especially in the discourse on 'pathological-disease vs. nutritional-physiological disorder'. Truly, a fertile ground for differing perceptions, with the scientific fraternity divided with those subscribing to the generally accepted (official) position and a few refusing to toe the official line. Worse still, it became truly an 'every man's science', as all sorts of preposterous/empirical assumptions and presumptions, often resulting from unscientific and unreasonable conclusions based on apparent, but unreasonable correlations derived from most disparate factors and observations ('false-positives' as modern biologists calls it) filled the air. An emotionally surcharged atmosphere found its echo in the mainstream media as well as local/vernacular press. Slowly, sanity prevailed in the 90s, as evidences for a phytoplasmal etiology became irrefutable and by the time, several stalwarts inevitably 'left the scene' or became 'silent'.

Leaf rot of coconut, 'the companion devil' to root (wilt) disease

Leaf rot disease of coconut presumably was in existence in the erstwhile states of Travancore and Cochin since 1880. Though Butler (1908) briefly described the symptoms on unopened spindle, he did not report any pathogen from the affected leaflets. Later systematic studies showed that leaf rot disease gets superimposed on 65% root (wilt) affected palms. Leaf rot appears in almost all root (wilt) affected palms and leaf rot minus root (wilt) is not a disease of economic importance. In some of the RWD affected palms, leaf rot may develop quickly but in certain palms it may take even 5 or 7 years depending upon the genetic makeup, age of the palm, nutritional status of soil, irrigation etc. The rotting of the spear leaf is always the first symptom to appear in seedlings. Flaccidity, yellowing and necrosis occurs later on these seedlings. Incidentally, most often the farmers identify a palm to be root (wilt) affected only when leaf rot sets in. Flaccidity and marginal necrosis of leaflets are not easily recognised by the farmers, especially in the early stages. The coconut palms weakened by RWD phytoplasma become susceptible to leaf rot disease. Hence the loss due to leaf rot caused by fungi seems to be more than the root (wilt) alone. The loss due to leaf rot was computed and estimated to be 461 million nuts annually.

Management of leaf rot disease

The leaf rot disease, caused by *Colletotrichum gleosporioides* and *Exserohilum rostratum*, is the most important factor in the management of root (wilt) disease, because it is leaf rot which is responsible for the reduction in photosynthetic area, disfiguration of the palm, and reduction in yield. Hence, controlling leaf rot with fungicide or bicontrol agets application will help in sustaining the yield levels of RWD affected coconut. Most of the new generation as well as old generation contact and systemic fungicides are effective against all these fungi reported in association with leaf rot. Though initial/earlier recommendation of sequential spraying of Bordeaux mixture, Dithane M-45 and Fytolan on leaf rot affected palms using rocker sprayer and separate application of BHC or Sevidol for the control of rhinoceros beetle three times a year is effective, farmers had not adopted because of the very high requirement of skilled labours and the cumbersome spraying involved.

Later management practices were refined after screening severl fungicides. It was observed that most of the fungi attack only the spear leaf, protection of this portion alone is enough. Hence, the latest recommendation of application

of hexaconazloe after removing the initial rotted portion of the spindle is increasingly being adopted by the farmers. This control measure along with other RWD management strategies helped to increase the coconut yield level in RWD affected tracts from 15-20 per palm to 45-50 nuts per palm.

Basal stem rot disease

Basal stem rot of coconut is known as Thanjavur (Tanjore) wilt in Tamil Nadu. It is also called as bole rot. In India the causal agent of basal stem rot of coconut, *Ganoderma lucidum* was first recorded in Karnataka State by Butler in 1913. This disease was noticed in Thanjavur district of Tamil Nadu after the cyclones of 1952 and hence the name Thanjavur wilt. It also occurs in parts of Andhra Pradesh, Gujarat, Karnataka. Kerala, Maharashtra and Orissa. While root (wilt) disease of coconut is a major constraint in the production of coconut in Kerala, basal stem rot of coconut is threatening the coconut industry not only in Tamil Nadu, Andhra Pradesh and Karnataka and Assam States.

Among the various fungal diseases affecting coconut palm, basal stem rot (BSR) or wilt or root rot caused by *Ganoderma* spp. *viz., G. lucidum, G. boninense, G. applanatum* etc., is the most destructive. *Ganoderma* spp. has a wide host range attacking a variety of palms and several forest, avenue and fruit trees. Hosts belonging to 19 families, 36 genera and 48 species have been reported to be affected by Ganoderma spp. Coconut palms in the age group of 10–30 years are easily attacked by the pathogen. The fungus first infects the root system and during the very early stage of infection, no external disease symptoms are clearly visible. Symptoms first appear as exudation of reddish brown viscous fluid from the basal portions of the stem in coconut palm. The bleeding patches begin from the base and extend upwards as the disease progresses and discoloration in the stem can be seen up to the height of bleeding . The most usual symptoms in the crown are leaflets of outermost whorls exhibit wilting symptoms, and yellowing, withering and drooping of the outer fronds, which remain hanging around the trunk for several months before shedding . The younger leaves remain green for sometime and later turn yellowish brown. The new fronds produced become successively smaller and yellowish in color, which do not unfold properly. As the disease progresses, normal development of flowers and bunches is arrested leading to button shedding and nuts become barren. The characteristic symptom of the disease is extensive discoloration and rotting of root systems, which leads to tissue disintegration and the stele turns brown. The roots become watery with a typical smell of alcohol. More often, the formation of new root produced is progressively reduced. In the advanced stages of infection, the fungus produces fruiting bodies (sporophores) which may or may not develop before foliar symptoms appear. Sporophores may develop at the trunk base and the appearance of sporophores is most diagnostic of the disease. The sporophores initially appear as small, white buttons of fungal tissues that develop rapidly into the familiar bracket-shaped mature sporophore. The young sporophore is white or yellow, whereas the mature sporophore upper surface can be light to dark brown, with a light margin and a shiny lacquered finish.

The disease is generally observed in sandy or sandy loam soils in coastal areas on the east coast where coconut is grown under rainfed conditions and also in neglected plantations. Soils with poor drainage and water stagnation during rainy seasons were found to favour the disease. The disease incidence was very high between March and August. It was directly related to mean soil temperature, rainfall and relative humidity. The presence of old infected stumps in the garden and non-adoption of recommended cultural practices will pave the way for disease spread. Basically, the Ganoderma is a soil-borne pathogen and it survives well in the soil for a long time. The formation of chlamydospores during adverse conditions helps survival of pathogen and chlamydospores become more resistant to environmental factors than basidiospores and could be responsible for dissemination of the disease. Irrigation water and rain water help in the spread of the fungus from one field to others.

Management

Integrated disease management package has been developed for basal stem rot disease of coconut and refined over the years. Isolation of the affected palm by digging a trench around the palm, application of neem cake enriched with *Trichoderma harzianum* and root feeding with hexaconazole has been recommended for management of the disease. Root feeding with fungicides also helps in recovery of palms.

Stem bleeding disease

It is a major disease of coconut occurring in almost all coconut growing countries. The disease was first reported from Sri Lanka and later from India and other countries. Present in all major coconut growing tracts of India. Usually non-lethal but in extreme cases, the palms become barren and die. The disease is caused by *Thielaviopsis paradoxa* (De Seyen.) Hohn. The characteristic

symptoms of the disease are exudation of reddish brown fluid from the cracks (mostly at the basal part of the trunk) and decay of tissues beneath the lesions. As the disease progresses, more area underneath the bark gets decayed, lesions spread and coalesce to form large patches, exudates dry up and turn a black crust, tapering of trunk towards the apex, reduction in vigour, crown size and nut yield of tree.

Management

Apply a paste of talc based formulation of *Trichoderma harzianum* (isolate CPCRI TR 28) on bleeding patches or remove completely the disease affected tissues using a chisel and smear the chiseled portion with hexaconazole (0.2%) and apply coal tar after 1-2 days on the treated portion. Destroy the chiseled diseased tissues by burning. Apply recommended dose of fertilizers (N (560g), P (320g) and K (1200g) in two equal splits during June-July and December – January) and provide irrigation (45 to 50 L per palm per day) during summer. Apply neem cake (5 kg/palm) enriched with *Trichoderma harzianum* (CPTD 28) during September-October.

What the future holds?

Disease management packages have been developed for all the major diseases of coconut and refined over the years. The effectiveness of the adoption of recommended packages in control of diseases has been demonstrated in the farmers field and training has been imparted to farmers during Krishi melas, farmers-scientists interactive meeting etc. Adoption of the IDM package has helped farmers to protect thousands of coconut trees from these diseases. However, the changing climatic conditions especially erratic rainfall and re-emerging of diseases, non adoption of scientific cultivation practices by the farmers due to fluctuating prices and shortage of skilled labours coupled with high wages has occasionally resulted in emergence of diseases like bud rot, basal stem rot and stem bleeding. Development of technologies for quick detection of many of these diseases and refining the management strategies for easy adoption by coconut farmers in the changing socio-economic environment is the big challenge before the scientific community.

Containing Insect Pests

Worldwide, coconut is widely depredated by at least 830 insect and mite species, 78 species of nematodes and eight species of rodents, drastically affecting the productivity. Crop loss, as high as 30%, has been reported in coconut, on account of incidence of diseases and damage by insect pests. The major insect pests infesting coconut are rhinoceros beetle (*Oryctes rhinoceros* Linn.), red palm weevil (*Rhynchophorus ferrugineus* Olivier), coconut eriophyid mite (*Aceria guerreronis* Keifer), leaf eating caterpillar (*Opsina arenosella* Walker) and the white grub (*Leucopholis coneophora* Burm.).

In the initial years, investigations on coconut pests and diseases were mainly done at the Central Coconut Research Station, Kayamkulam (under the Indian Central Coconut Committee) since its formation in 1945. Dr. K K Nirula, the head of the entomology section then, laid the foundations for a systematic investigation on the insect pests with his pioneering work elucidating the biology, bionomics and their control measures. Most importantly, the results of these investigations were promptly brought out as classical research papers. An illustrative case is the ‘trilogy of research papers’ on the rhinoceros beetle, published in the Indian Coconut Journal during 1950-52 and subsequently, the series of papers, summarizing the available information on all the major pests in coconut, under the title “Investigation on the pests of coconut palm” during 1955-56.

With the reorganization and unification of the two coconut research stations into a single national research institute in 1970, research programmes were totally revamped and various subject matter divisions were formed at the new headquarters for better co-ordination and giving better direction to the ongoing research. With better availability of scientific manpower and research infrastructure at Kasaragod and for catering to the R&D requirement of large tracts of coconut cultivation in northern Kerala, investigations on some aspects/ pests in coconut was started at Kasaragod also, complementing the work at the new Regional Station Kayamkulam, which continued to be the ‘hub of pests and diseases research’ in coconut.

Entomology, the art and science of managing insects/insect pests, has undergone several cycles of molting and metamorphosis to the present scenario, just like in the life of an insect. In the initial years, the emphasis was on chemical control, obviously the easier and faster option. But with the increasing concerns on the long-term environmental fallouts, the spotlight shifted to the biological control. Notwithstanding breakthrough success in some isolated cases, concerns were raised on sustaining the field efficacy over a period of time, with the frittering out of the populations of the biocontrol agents (predators/parasitoids/pathogens) necessitating periodical re-introductions and recurrence/ re-emergence of pests. Going one step ahead, understanding the intricacies of the host-parasite-parasitoid interactions led to ‘engineering’ the chemo-ecological behaviour of insects (parasite and/or the parasitoid) enhancing the field-efficiency of the parasitoids in their assigned job. The exciting development of sex pheromones and pheromone synergists along with efficient delivery systems for field application took the concept to newer heights of efficiency and ease of adoption. Over time, all these concepts and practices merged together to the practice of an integrated system, exploiting the synergy of all these components complementing one another.

A classical text book-case of the (augmentative) biocontrol is, perhaps, the story of the leaf eating caterpillar (*Nephantis serinopa*) in coconut. Success stories in the management of the other major pests like the red palm weevil, black headed caterpillar and the eriophyid mite extol the virtues of adopting an integrated management approach.

Management of the black headed caterpillar (*Opisina arenosella*) in India: A classical case of biological control

Coconut black headed caterpillar, *Opisina arenosella* Walker (Oecophoridae: Lepidoptera) (Syn. *Nephantis serinopa* Meyr.) is a serious pest of coconut palm in India, Sri Lanka and Burma. The larvae live in galleries made of silk and frass on the undersides of mature leaves and feed there on the chlorophyll-containing parenchymatous tissues. The oldest record of the pest was by E E Green in 1900 from Batticaloa of Ceylon (Sri Lanka)77. In India, the pest was first recorded in Coimbatore (Tamil Nadu) on Palmyra leaves during 190778 and the earliest record of its occurrence on coconut leaves was reported from Bapatla (Andhra Pradesh) in 1909. Subsequently, its outbreak was reported from Quilon (1919), Mangalore (1922), Cochin (1925), Konkan (1948), Orissa (1927), Bengal (1927) and Bihar (1948). During 1923, a serious outbreak of *O. arenosella* was reported in Mangalore, necessitating the enforcement of the “Pest Act” and the declaration of this insect species as a ‘notorious pest’.

Population dynamics

The pest is mostly observed in the proximity of water bodies especially in coastal and backwater tracts and occasionally in interior areas adjacent to river beds and paddy fields. On the West coast of India, *O. arenosella* is present throughout the year and reported as a serious pest during March, April and May. On East coast of India, the pest is least active during North-East monsoon and quite common during the dry months of April, May and June. The duration of life cycle from egg to adult was found to be 2 months on the West coast, with five-six larval instars. Studies conducted during 2002 to 2005 highlighted an yield loss of up to 45% from the infested palms in the succeeding year of severe pest infestation.

Pest management strategies

A variety of chemical, cultural and biological control measures have been employed against this pest. The use of chemical control methods were recommended in the 1960s. Mechanical control of the pest by removal and destruction of all infested leaves or parts of leaf which show any traces of larval galleries in stray incidences in isolated plantations was advocated as early as 1960 to avoid further pest spread.

Biological control

The field success on biological suppression of black headed caterpillar through release of stage-specific parasitoids was established as early as 1920. There are reports of mobile 'boat-laboratories' to breed and transport parasitoids, functioning in the Travancore and Cochin belt in the 1930s, with spectacular results. Under the second Five Year Plan, there was an exclusive scheme79 on "Parasite breeding stations for biological control of *Nephantis serinopa*". Under this scheme, two stations each in the States of Madras, Andhra Pradesh, and Bombay and one in Kerala were set up in 1958-59 by the erstwhile Indian Central Coconut Committee for breeding parasites of *Nephantis serinopa* on a mass-scale under laboratory conditions and liberating them in the pest-attacked gardens, better illustrating the wreaking devastation brought about by this insect and its economic impact in the last century.

Opisina arenosella has about 40 parasitoid and 20 predator species feeding on it. The initial investigations could identify several larval/pupal antagonists like *Apanteles taragamae*, (an early instar endoparasitoid) in 1956, and *Pyemotes ventricosus*, a gregarious ectoparasitic mite parasitizing the larval and pupal stages during 1968, besides fungal pathogens like *Bacillus thuringiensis* Berliner, *Serratia marcescens* Bizio, and *Aspergillus flavus* in 1961, with varying degree of efficiency.

The major breakthrough was during the 1980s when a few effective natural enemies like the larval parasitoids, *Goniozus nephantidis* and *Bracon brevicornis* and prepupal (*Elasmus nephantidis*) and pupal parasitoid, Brachymeria nosatoi were identified, mass multiplied and field released. While *Goniozus nephantidis* and *Bracon brevicornis* are commonly reared on the common laboratory host (*Corcyra cephalonica*), while *Elasmus nephantidis*, and *Brachymeria nosatoi*, are reared only on *O. arenosella* itself. *Bracon hebetor* Say / *Bracon brevicornis* Wesmeal, the Braconid parasitoids, were found to be very effective against O. arenosella and a mass multiplication on larvae of *O. arenosella* and *C. cephalonica* using glass chimney sandwich method was developed in 1986. The systematics, distribution and life history of *Goniozus nephantidis* (syn. *Parasierola nephantidis*), the larval parasitoid of *O. arenosella* was exhaustively studied as early as in 1961 itself. Biology of *G. nephantidis* was studied on three different host insects (*C. cephalonica*, *Galleria mellonella* and *O. arenosella*) during 2003 and highest survival was obtained on *C. cephalonica*, followed by *O. arenosella*. Field observations on the rate of larval parasitism showed that 8.5% larval parasitism of *O. arenosella* (out of a total of 12.6%) was due to *G. nephantidis* alone and that larval parasitism was directly proportional to host density. As a new initiative, studies on olfactory conditioning in *G. nephantidis* reported that the parasitoid could be conditioned to the odour of the natural host, *O. arenosella*, for better field efficiency.

During 1982, the mating behaviour and biology of *Elasmus nephantidis*, the pre-pupal stage of *O. arenosella* was elaborated. A technique for mass culturing was developed and the use of the pupae in cocoons inside galleries to develop a breeding technique for the pupal parasitoid, *Brachymeria nosatoi* was also proposed. Data on parasitoid emergence in the field collected pupae from Kerala showed *B. nosatoi* as the most common pupal parasitoid (up to 30% parasitism), followed by *B. nephantidis* (16%).

Area-wide field delivery, a great success

Being a classical pest that could be controlled by sole release of parasitoids, biological control in the country took shape with the management of this pest.

Studies conducted in an endemic area during 1990-1993 at Thodiyoor (Kollam District, Kerala) with the field release of the three stage-specific parasitoids - *G. nephantidis, E. nephantidis* and *B. nosatoi* - at fixed norms and intervals in *O. arenosella* infested coconut garden (2.8 ha) resulted in significant reduction in its *O. arenosella* population by 94%. During 1994-1998, following an epidemic outbreak of the pest, a bio-intensive IPM demonstration was taken up at Padukere in Coastal Karnataka effecting 96% reduction in pest density in a period of four years.

Release of stage-specific parasitoids induced 94.7 per cent reduction in pest population after two years of parasite release in a heavily infested tract at Neendakara, Kollam Dist., Kerala during 1999-2002. An area-wide field validation of the bio-suppression technology of coconut black headed caterpillar was taken up during 1999-2002 in different geographic locations in coastal Karnataka (Ullal and Jeppinamogru) and Coastal Kerala (Purakkad and Ayiramthengu) comprising a total of 1,400 ha and could achieve 93-100% reduction in *O. arenosella* population in a period of two years. During 2009, an outbreak of *O. arenosella* was noticed in Vechoor (Kottayam District) infesting about 5000 coconut palms and this area was selected for field demonstration of the biocontrol technology. The *O. arenosella* population could be brought down to negligible level in 12 months by six releases of parasitoids. By the second year (December 2010), there was complete recovery of the palms from *O. arenosella* attack in the parasitoid released areas.

Moderate level of *O. arenosella* infestation was observed in Valiyathura Sewage farm, Trivandrum district during 2011-12 in 62.5% of the palms with 61% leaf infestation. Monitoring and release of stage specific parasitoids *viz*., *G. nephantidis* and *B. brevicornis* could reduce leaf damage to the tune of 63% and population of *O. arenosella* by 91.3% in a period of eight months. Further monitoring and timely release of parasitoids could control the pest infestation completely during subsequent years. During 2012-13, a medium level of *O. arenosella* infestation was noticed in Puthiyavila (Trivandrum) with leaf infestation of 59.6% and population of 141/100 leaflet. Awareness campaign was conducted in the area with collaboration of the parasite Breeding station (PBS), Trivandrum/ Dept. of Agriculture, Kerala. Regular monitoring and release of parasitoids resulted in 55.7% reduction of leaf damage and 94% reduction in pest population over a period of 8 months.

An outbreak of *O. arenosella* was also noticed in Kallara (Kottayam) region during August 2012 with leaf infestation of 83.4% and pest population of 288/100 leaflets. Systematic monitoring and release of larval parasitoids *viz*., *G. nephantidis* and *B. brevicornis* could reduce leaf infestation (42%) and pest population (88%) in a period of 7 months. An IPM demonstration was undertaken in Arsikere region, Hassan District, Karnataka where an outbreak of *O. arenosella* was observed during October 2013. Pest infestation showed visible decline in a period of four months from an initial leaf damage of 76% during October 2013 to 43% during February 2014. Subsequently complete recovery of palms was achieved in a period of 15 months by January 2015.

Emergence of new flushes in the pest-inflicted garden after technology intervention is so convincing that most of the nearby farmers readily adopted the technology. Need-based irrigation and nutrition enhanced the faster revitalization of palms. This is one of the classical success stories in biological control and ICAR-CPCRI has been the pioneering Institute to refine, field-validate and execute area-wide demonstrations in large areas all over the country. In a period of two years, the entire pest-inflicted zone has recovered with no tinge of pest attack

Rhinoceros beetle (*Oryctes rhinoceros* Linn.), the ubiquitous pest in coconut

Rhinoceros beetle (*Oryctes rhinoceros* Linn.) (Scarabaeidae: Coleoptera) is a cosmopolitan pest and the adult beetles feed on spear leaves and damage inflorescences causing crop loss of about 6-8%. Of late, the beetles bore through the collar region of young seedlings and damage the spear leaf causing wilting, thereby resulting in improper establishment. As a native of Asia, rhinoceros beetles attacks a wide array of palm species as well as some ornamental palms. Ever since *O. rhinoceros* was reported as damaging coconut palms in 1889 by HN Ridley in Singapore, it continues to be a major pest of coconut palm in majority of the coconut growing tracts.

Bionomics

The adult is a stout black beetle with a characteristic ‘cephalic horn’, which is longer in males. The beetle breeds in the decaying organic matter like cattle dung, farm yard manure, compost heaps, coconut stumps, dead and decaying coconut logs, saw dust, coir pith, heaps of coconut fronds etc., where the adults lay eggs and complete the larval and pupal stages. The grubs are creamy white in colour with the body strongly arched dorsally (C-shaped). Grub period is about 130 days with three instars. The pupal period varies from 20-29 days and uniformly brown in colour. Pest occurs throughout the year, with peak adult emergence during June-September. Population of the beetle was observed to be high in young plantations with multiple breeding sites and high rainfall. The extended grub and adult life span make the pest so dynamic, at the same time vulnerable for effective execution of management technology.

Management strategies

Being an active flyer, integrated pest management (IPM) strategies adopted on a community basis are essential to bring about an effective control of *O. rhinoceros* population. Farm hygiene through disposal of active breeding sites (coconut logs, organic debris etc) in the immediate vicinity of coconut garden, correct depth of planting in well-drained soil, avoiding mulching of coconut leaves during early stage of seedling establishment and adoption of recommended spacing for judicious release of volatile cues are some of the essential cultural techniques to be strictly adhered to minimize the pest attack. Systematic examination of the palm crown and removing the adult beetle by means of a metal hook during peak periods of pest abundance (June- September) is the most successful technology that was in vogue. In addition, all breeding places should be rendered innocuous or the grubs collected from them regularly so as to reduce the population build-up. Absence of such a mechanical exclusion is one of the main reasons for the flare up of the pest in the recent past.

Application of powdered oil cakes of neem (*Azadirachta indica*), or marotti (*Hydnocarpus wightiana*) or pongamia cake (*Pongamia pinnata*) @ 250g mixed with equal volume of sand, into the top most three leaf axils around the spindle leaf thrice a year (during May, September and December) is recommended as a prophylactic measure against rhinoceros beetle and red palm weevil. Placement of two perforated sachets containing chlorantraniliprole (3 g) or fipronil (3 g) was found effective in monsoon phase for successful seedling establishment, warding off rhinoceros beetle attack. Placement of two botanical cakes (in tablet shape) on the top most leaf axils reduced 54% leaf damage and was found superior to chlorantraniliprole sachets (34%) in reducing rhinoceros beetle attack. Swiping a paste based on botanical extracts/oil over the spindle and adjoining petioles @ 10 g safeguards the juvenile palms for about three months from rhinoceros beetle attack.

Biological suppression options

Two potential microbial agents - Green muscardine fungus (*Metarhizium anisopliae*) and *Oryctes rhinoceros* nudivirus (OrNV) - cause disease to the immature and adult stages of the beetle. Use of these microbial control agents is advantageous because they are relatively host-specific, does not cause environmental pollution, safe to humans and are compatible with other control methods.

Green muscardine fungus

The susceptibility of *O. rhinoceros* to the fungus was first reported in Western Samoa in 1913 and in India in 1955-56. *Metarhizium anisopliae* var. major (spore size 10-14 mm) is a highly virulent variety widely used for the control of the pest. In vermicomposting sites, treatments with *M. anisopliae* spores killed all third-instar larvae, with the highest dose giving the fastest kill, taking 8 days with favourable high humidity. Currently, *M. anisopliae* is multiplied on semi-cooked rice-based media for field application in organic manure as well as vermicompost pits (100 g per cubic metre). This technology through farmer-participatory and women group approach has created a great impact on the long-term bio-suppression of the pest. An area-wide technology adoption approach (covering 1500 ha) in Alappuzha district of Kerala indicated 76 to 85% reduction in leaf damage by rhinoceros beetle.

***Oryctes rhinoceros* nudivirus**

OrNV was first reported from Malaysia by AM Huger in 1966, and he named it as rhabdion virus of *O. rhinoceros*. Occurrence of OrNV was first reported in India in 1981 and elaborate work was undertaken since then. Studies indicated that OrNV infected grubs become less active and stops active feeding. As a result of virus multiplication in the mid gut epithelium, fat body disintegrate and haemolymph content increases, causing translucency in the abdominal region, an important exopathological symptom of the OrNV infection. The infected beetles disseminate the virus through their faecal matter into the surrounding feeding and breeding sites after 3-9 days of inoculation (at the rate of 0.3 mg virus/adult/day).

The simplest and best practical method of dissemination of OrNV is by releasing the infected adult beetles in the field. Healthy adult beetles are allowed to crawl on the viral inoculums (1g mid gut/100 ml of buffer) for half an hour and then kept under starvation for 12-24 hours. The beetles are released (preferably at dusk) in the infested coconut gardens at the rate of 12-15 beetles/hectare. Horizontal spread of OrNV was reported as 1 km/month. Introduction of OrNV in Minicoy and Androth Islands of Lakshadweep, Chittilappilly in Thrissur, Kerala and Sipighat of Andaman Island successfully reduced the population of *O. rhinoceros* and its damage on coconut.

Attractants, a promising option

The potential of using Ethyl 4-methyl octanoate (E4MO), a male-produced aggregation pheromone to attract and control rhinoceros beetle was reported in 1995. Trapping of adult beetles in a PVC trap using the pheromone 'Oryctalure (E4MO)' is a recent innovative method in the IPM for rhinoceros beetle. Dispensing E4MO through a nanoporous matrix ensures sustained efficacy in trapping beetles for more than six months.

Integrated pest management

To combat incursion by rhinoceros beetle, an integrated biological suppression technique has been developed with leaf axil filling of botanical (neem, pongamia, marotti) cakes (250 g) and sand, incorporation of entomopathogenic fungus, *Metarhizium anisopliae* (CPCRI-MKY) (5 x 1011 spores/m3) and incorporation of *Clerodendron infortunatum* in the breeding sites, release of *Oryctes rhinoceros* nudivirus infected beetles (12 beetles/ha) and PVC pheromone trap embedded with ethyl 4-methyl octanoate (rhinolure) (1 trap/ha) for effective management of the pest.

Intercropping of palms with nutmeg, rambutan, curry leaf, banana along the interspaces disorients the pest away from the source due to crop-habitat diversification induced pest-repulsion cues. Crop heterogeneity is therefore preferred for continuous employment of farmers, income generation as well as pest regression. Installation of bird-perch and flowering plants like coral vines maintains pest defenders and executes ecosystem services. A greater environmental heterogeneity, high species diversity and less host density favour less rhinoceros beetle attack on palms.

Success stories in plenty

Area-wide (1575 ha) farmer-participatory trials undertaken at Kerala (Kandalloor, Krishnapuram, Edava), Tamil Nadu (Semanampathy), Andhra Pradesh (Voodimudi) and Karnataka (Doddenahally) in India significantly reduced the damage level (spear leaf & inflorescence) to about 42.6% from an initial damage level of 81.2%. Low-cost, farmer-friendly community level mass production strategy of *M. anisopliae* in the village itself is the hallmark of this initiative. Based on the overall impact, a 10-13% increase in nut yield per palm could be realized.

Red palm weevil (*Rhynchophorus ferrugineus*), the most destructive pest

Red palm weevil, *Rhynchophorus ferrugineus* Olivier (Curculionidae: Coleoptera), a concealed tissue borer, is a lethal pest of palms and is reported to attack 26 palm species worldwide. Though first reported from Mesopotamia during 1920, it was only in mid 1980s that RPW attained a major pest status on date palm in the Middle East. The agro-climatic conditions prevailing in South and Southeast Asia and other palm growing countries, along with unique morphology and perennial status of the crop coupled with intensive farming practices, have offered the pest an ideal ecological niche to establish and destabilize palms.

Bionomics

A damage level of even 1% can cause significant economic loss. Palm injuries, damage by rhinoceros beetle, lightning and disease incidences aggravate the vulnerability to the red palm weevil damage in endemic zones. Dwarf cultivars are relatively more susceptible to pest damage. Adult weevils are ferruginous brown colour with elongated snout. Snout of female is bare, relatively slender and little longer than the males. Eggs are laid in small holes scooped out on soft tissues of palm. A fully-grown grub is stout, fleshy and apodous (having no 'legs'). Fully grown grubs make out a fibrous cocoon and pupal period lasts for 12-20 days. The weevil completes from egg to adult stage in a period of 3-6 months.

Early detection is a 'matter of life and death'

Being a concealed tissue borer, early detection by farmers would be a key empowerment strategy in diagnosis and adoption of curative pest management strategies. No curative treatment can save palm at advanced stages (once the growing point is badly damaged and the crown toppled). Hence, right from the beginning, the emphasis was on developing an early detection method/device for this pest. An early attempt in this direction was the development of a prototype detector (based on an electronic amplifier), which, unfortunately, could not specifically pin point the presence of grubs due to extraneous noise factor. Recently, a prototype acoustic detection device in collaboration with the Centre for Advanced Computing (CDAC), Thiruvananthapuram, has been developed for early detection of the pest and its refinement/calibration is presently ongoing.

The knowledge on the possible methods of entry of red weevil into the palm and the important symptoms manifested in an infested palm and personal involvement of the farmer/periodical surveillance are the critical components of the management strategy. Needless to say, knowledge-empowerment and capacity building of farmers holds the key.

Sterile male release technique, an early attempt at eco-friendly management

Control of *R. ferrugineus* using radio-sterilized males (1.5 Krad for 1-2 days) was in 1973. A total of over 5000 radio-sterilized males were released in an 800 acre young coconut plantation near Kayamkulam in Kerala and the data on the fertility pattern of native females reported only a limited success, due to the fact that the floating female weevils were already mated inside the infested palm. Studies on biotypical variability among four populations of red palm weevil from different parts of India found the populations as genetically different and strainal variability existing among them. The weevil has a very high fitness due to high production potential and the absence of effective parasites, predators and pathogens. In addition, gamma radiation did not have significant effect on the F2 generation.

Attractants have great promise

Log-traps consisting of tender coconut stems (50cm long and spilt longitudinally) were treated with macerated fruits, molasses (jaggery from sugarcane), acetic acid, yeast and toddy, singly or in combination. Logs treated with coconut toddy + yeast + acetic acid attracted more weevils and this combination is being used in the management of red palm weevil. When traps were set up with pheromone and food-bait together, better results were in the field. A recent refinement is the use of the aggregation pheromone (4-methyl 5-nonanol plus 4-methyl 5-nonanone 9:1) in tandem with the pheromone synergists from food baits (kairomones). Though effective, these lures need to be replaced once in 3-4 months interval. Recently, the use of a nanoporous matrix as a novel carrier for loading the pheromone and kairomone of red palm weevil has resulted in trapping higher number of weevils than the commercial lure alone and also ensuring its sustained release for more than six months.

Biological suppression

The infectivity of red palm weevil grubs and adults to entomopathogenic nematodes (*Heterorhabditis indica, Steinernema glaseri* and a local isolate *Steinernema* sp.) was reported in 2003 and the higher virulence of the local strain of *Heterorhabditis indica* (LC 50 355.5 IJ) with a greater susceptibility (82.5%) of the grubs at pre-pupal stage was reported in 2014. Synergistic interaction of *H. indica* (1500 IJ) with imidacloprid (0.002%) against red palm weevil grubs indicated combined application of *H. indica* infected *Galleria mellonella* cadavers and imidacloprid (0.002%) would be an effective strategy in the field level management of red palm weevil in coconut.

Potential of trypsin inhibitors

Suppression of growth and endopeptidases of red palm weevil infesting coconut using proteinase inhibitors is a new development. Serine protease inhibitors like aprotinin (50 µg), soybean trypsin inhibitor (50 µg) and phenyl methyl sulphonyl fluoride (1700 µg) inhibited the gut proteinases of *R. ferrugineus*, affecting the digestion and nutrient uptake of the insect leading to an impaired growth and development.

Evolution of the integrated pest management

A chemical control with carbaryl (1%) and trichlorphon (1%) was recommended in the 1960s and 70s for the effective management of the pest. With the increasing awareness on ill-effects of pesticides on environment and non-target organisms, the emphasis was shifted to developing eco-friendly and sustainable technologies. The efficacy of prophylactic leaf axil filling with botanical cakes (neem cake and marotti cake @ 250g mixed with equal volume of sand) in reducing the pest incidence was reported in the beginning of the present century and thereafter included it in the IPM strategy. Curative treatment with safer molecules like imidacloprid (0.02%) or spinosad 0.013% was also found to be effective in the management of red palm weevil (RPW) infestation. Testing the efficacy of IPM strategy for management of red palm weevil in farmers' fields in Alappuzha District, Kerala proved that the systematic adoption of IPM practices could bring down the pest population to zero, devoid of any fresh incidence.

Proximity of the farmer and systematic scouting with a better understanding about regular physical changes in the palms in his farm will certainly lead to an early diagnosis. Maintaining optimal palm density supplemented with intercrops for diminishing volatile cues is a crop-habitat diversification strategy. Prophylactic measures for the rhinoceros beetle also safeguards the palms from invasion by rhinoceros beetle as palm injury incite RPW attack. The promising leads on the influence of the insect growth regulator, lufenuron, leading to defective morphogenetic moults and malformed adults, spur the long-term strategy for a bio-rational approach to RPW management.

Success stories

Integrated management technologies involving complete destruction of infested palm, close monitoring and sustained surveillance for early diagnosis, leaf axil filling of chlorantraniliprole sachet, curative management with imidacloprid (0.02%) and pheromone trap @1 trap/ha were found effective in pest suppression. Community level technology convergence and large-area adoption of IPM technologies conducted in 2150 ha in Kerala (Bharanikavu, Cheppad), Tamil Nadu (Palladam), Andhra Pradesh (Ambajipet) and Karnataka (Bidramamandi) could reduce the pest incidence to 56.8%. Palms at early stage of infestation completely recovered (80-85%) after curative treatment. Sustained surveillance, timely pest detection, sound awareness about the pest and perfect execution of curative management reduced the infestation level significantly.

Coconut eriophyid mite (*Aceria guerreronis*) becomes a major pest in the 1990s

History and Bionomics

Phytophagous mites occupy diverse plant niche, cause a wide array of feeding symptoms and also transmit diseases of economic importance in several crops. Coconut eriophyid mite, *Aceria guerreronis* Keifer (Eriophyidae: Acarina) is a microscopic creamy white, vermiform organism measuring 200-250 microns in length and 36-52 microns in breadth. The body is elongated, cylindrical, finely ringed and bears two pairs of legs at the anterior end. An adult mite lays about 100-150 eggs. The eggs hatch into protonymphs, deutronymphs and finally to adults. The total life cycle is completed in 7-10 days. The first report of coconut eriophyid mite infestation in India was in 1998 from Amballur Panchayat, Ernakulam, Kerala. Observations on the seasonal abundance of the mite during 2000-2002 showed the persistent nature of the pest with the population peak in summer months (April May). A period of high temperature with intermittent rains (causing high humidity) favoured multiplication and rapid spread of the mite.

As the sudden outbreak and spread of this invasive pest caused serious concern throughout India, the Government of India constituted a steering committee during 1999 for effective monitoring of research. A National Agricultural Technology Project on ‘Development of IPM package for eriyophyid mite for southern states’ functioned during 2000-2004 and later (2004-2007), an CFC/DFID/APCC/FAO funded project “Development and field testing of Integrated Pest Management strategies for Aceria guerreronis Keifer”.

Crop loss

A pilot sample survey on the incidence and yield loss due to eriophyid mite on coconut in Alappuzha district in Kerala estimated the loss in terms of copra to be 1962 tonnes (30.94%) and loss of husk was upto 41.74%. A roving survey in Kerala during 2004-05 showed the economic loss as having decreased from 30.9% during 2000 to 17.8% in 2003, and to 9.5 % in 2004. Mite infestation in Androth island of Lakshadweep during 2003 was found to be 19.82%. A snap survey undertaken during 2009-10 across major coconut growing tracts recorded the pest incidence as 44.77% in Hassan, 41.81% in Tumkur, 27.61% in Coimbatore, 41.40% in Thanjavur, 46.11% in Ratnagiri and only 4.06% inTrivandrum. Survey undertaken during April 2010 for assessing mite incidence in Lakshadweep Islands indicated a high infestation of 57.5% in Kavaratti, a moderate incidence of 23.2% in Kalpeni and a low infestation of 17.9% in Minicoy Island. Survey conducted in East and West Godavari districts of Andhra Pradesh during November 2011 revealed low to medium mite incidence (18.3 to 54.2%) in the coconut gardens.

Notwithstanding the higher mite incidence during the initial years of emergence (1999-2000), the percentage incidence of the mite diminished in subsequent years (2010-2012) with the population build-up of natural enemies, especially the predatory mites (*Neoseiulus baraki*) and the acaropathogen (*Hirsutella thompsonii*) in the ecosystem.

Management

ICAR-CPCRI has been pioneering research on the effective management of the pest ever since the pest was reported. A nation-wide sensitization drive reaching all stakeholders and an integrated approach were the hallmarks in the effective management of this pest.

Host plant resistance

A general observation on mite incidence was that varieties with round and orange nuts recorded limited damage, compared to those with oblong and green coloured nuts. Preliminary screening indicated coconut varieties such as Chowghat Orange Dwarf (COD), Laccadive Micro and Spicata recorded comparatively lower mite incidence in the field than that of West Coast Tall (WCT) and Laccadive Tall (LCT). WCT with green and oblong nuts recorded higher level of mite incidence as compared to WCT with reddish bronze colour and round nuts. The recently released variety, Kalpaharitha (a selection from Kulasekharam Tall), is relatively tolerant to mite attack.

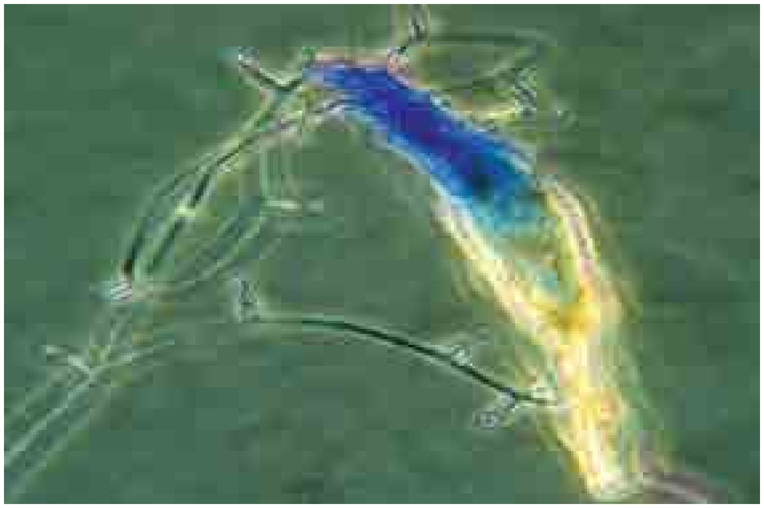
Chemicals and botanicals

Though most of the pesticides were effective in the field when given as spray/ root feeding / stem injection, none of the chemicals has been used for larger adoption due to environmental concerns. Even, wettable sulphur, recommended for mite management in the initial years, was withdrawn realizing its deleterious effects on the natural enemies of mite, particularly the entomopathogenic fungi. During 2000, the use of 2% neem oil-garlic mixture was proved effective and recommended in Kerala state for large scale adoption. Neem-based formulations with azadirachtin was also proved effective in managing mite population. During 2011-12, a significant reduction in mite incidence (70-81%) on fresh bunches could be observed in palms treated with palm oil (200 ml) - sulphur (5 g) emulsion. During 2015, Palms sprayed with coconut oil (200 ml)-sulphur (5 g L-1) emulsion, spiromesifen (1 ml L-1), neem oil (2%) and common salt (2%) plus adjuvant APSA (0.2%) were found effective in the suppression of coconut eriophyid mite.

Biological suppression

In India, the phytoseiid mite, *Neoseiulus baraki*, is the most dominant predator in the field. Other predatory mites include *Neoseiulus paspalivorus* and Bdella species. Conservation of predatory mites (*Neoseiulus baraki*) is quite successful in reducing the *A. guerreronis* population. Predatory mite population is registering an increasing trend of incidence and better establishment in nature over the years. From an initial occurrence recorded in 37.1% samples, predator population has increased to 62.3% in 2001 and 80% in 2011. The activity of the predators was high during June-December and frequently encountered in 4-6 months old nuts.

In search of its natural enemies, more than 40 isolates of the acaropathogenic fungus, *Hirsutella thompsonii*, were collected from all over the country and are being maintained in the biocontrol laboratory at Kayamkulam. Based on the bio-efficacy studies, one virulent isolate collected from Kayamkulam was characterized with molecular techniques, confirming the species identity. Spraying (three times a year) with the talc-preparation of this *H. thompsonii* (20 g/litre of water/palm containing 1.6 x 108cfu) resulted in 63-81% reduction in mite incidence. It was found effective in the multi-location testing across all AICRPP centres, despite the seasonal variation in its efficacy. Coconut water was found as an ideal medium for mass production of H. thompsonii, as evidenced by comparable growth rate (1.91 cm in 20 days), spore production (12.9 x 104 cm3) and yield of dry mycelium mat (1.017 g 100 ml-1) to that of standard fungal growth media.



A. guerreronis infested by *Hirsutella thompsonii*

Palm health management

It was generally observed that gardens where balanced NPK application and recycling of organic matter were practiced, incidence and intensity of mite showed decreasing trends. A unified recommendation was therefore formulated with IPM and INM components for adoption in all coconut growing tracts by the steering committee during 2003. IPM strategies involved phytosanitary measures in the coconut garden including crown cleaning, burning of fallen mite infested nuts and spraying azadirachtin (0.004%) on affected younger bunches thrice a year (during December-January, April-June and September-October). Wherever spraying is difficult for adoption, root feeding with azadirachtin 5% (7.5 ml+7.5 ml) or azadirachtin 1% (10 ml+10 ml) formulation thrice as in the case of spraying was recommended. In synergy with IPM package, adoption of INM including application of NPK fertilizers as per recommended levels, recycling of biomass or raising green manure crops in coconut basins, summer irrigation and moisture conservation by appropriate measures were also recommended for effective recovery from mite infestation.

Success stories

IPM technologies developed by ICAR-CPCRI involving 2% neem oil-garlic emulsion spray, root feeding of azadirachtin 10000 ppm @ 10 ml + 10 ml water and soil and palm health management practices reduced pest incidence to the tune of 71.4%. From an initial pest incidence of 58.6% observed in Kerala (Krishnapuram), Tamil Nadu (Kottur), Andhra Pradesh (Ambajipet) and Karnataka (Boranakoppalu) the pest incidence was reduced to 16.3% in a period of two years, indicating the success of the technology at the national level. Natural build-up of the predatory mites as well as the acaropathogenic fungus, *Hirsutella thompsonii*, could sustain in the field.

Coconut white grub, *Leucopholis coneophora* Burm. (Scarabaeidae: Coleoptera)

White grub, *Leucopholis coneophora*, is an annual pest of coconut and intercrops grown in sandy loam soils in south India. It damages seedlings and adult palms by feeding on roots, boring the bole and collar regions and severe infestation leads to death of the seedlings. In adult palms, they feed on roots impairing the conduction of water and nutrients, thus leading to yellowing of fronds and nut shedding, and eventually complete yield loss. *L. coneophora* also causes damage to arecanut, cocoa, and rhizomatous and tuberous intercrops raised in palm garden (banana, colocasia, cassava, elephant foot yam, yams, and fodder grasses).

Bionomics

L. coneophora has an annual life cycle with the adult emergence coinciding with the setting of south west monsoon. Emergence occurs daily in the evening hours, when illuminance falls below 124.37 ± 75.5 lx (around 6.35 pm IST) and 1.2 ± 0.4 lx (around 7.10 pm IST) in June and active swarming prolongs for about three weeks. On emergence, beetles feed on the leaves of weeds, mango, cashew and Ficus etc. Females lay eggs in interspaces, which hatch in 23 days. Larva is pestiferous and passes through three instars and prolonged for 260 - 270 days. Early instar larvae feed on organic matter and roots of grass, late second instar and third instar larvae move towards the root zone and start feeding on palm roots. Depending on the moisture in soil, larvae move deeper and deeper and it pupate during summer. During next monsoon season, aestivating pupae emerge out.

Integrated management strategy

An IPM strategy comprising of mechanical, chemical and biological methods is recommended for the management of white grubs.

Chemical control

Use of chemical insecticide is a vital component in IPM of root grub and it is successful when applied in the right stage and appropriate season. During 1950s to early 1970s, several organochlorine, orgnaophospherous and carbamates were evaluated and found effective in suppressing *L. coneophora* population. However, many of these persistent insecticides are phased out at present. Since then, drenching the root zone with chlorpyriphos (0.04 %) was found effective in the management of root grubs. In the first decade of this century, the efficacy of synthetic pyrethroids was tested against white grubs of coconut and arecanut, Most recently, a neonicotinoid insecticide (imidacloprid) (120 g ai/ ha) and the fourth-generation synthetic pyrethroid, bifenthrin (2kg ai/ ha) were found effective for the management of palm white grubs.

Biological approaches

A wide array of natural enemies is reported on *L. coneophora*. A solitary ecto-larval parasitoid, *Campsomeriella collaris* collaris Fab. on *L. coneophora* was studied in the laboratory for its efficacy. Parasitism by *Prosena* spp. nr siberita, a solitary endo-larval parasitoid was reported on *L. coneophora* grub for the first time from an organically managed coconut garden. An entomo-pathogenic bacterium, *Serratia entomophila*, causes "amber disease" to *L. coneophora* grubs. White muscardine fungus, *Beauveria brongniartii* and green muscardine fungus, *Metarhizium* spp. were obtained from infected *L. coneophora*. More recently, two species of entomopathogenic nematodes (*Steinernema carpocapsae* and *Heterorhabditis indica*) are used for the management of root grubs in palm. For coconut ecosystem application, drenching aqua suspension of the EPN (*Steinernema carpocapsae*) in the interspaces (1.5 billion IJ/ha at 5-10 cm depth) was very effective in reducing grub population.

Mechanical interventions

Hand picking and destruction of cockchafers between 6.35 pm to 7.15 pm for two-three weeks, commencing from the first day of monsoon, is advisable as a mechanical tool in IPM. As the peak swarming period is short and beetle congregate during swarming, this method can be most profitably practiced. It is found that, capture of beetle by hand picking is significantly efficient than light trapping.

Based on the field biology, toxicology and ethological studies of *Leucopholis coneophora*, a refined IPM strategy for white grub management in palms is proposed as:

- Hand picking and destroying adult beetles during peak emergence (during the month of August in hilly areas and in May- June in planes) continuously for three weeks, daily in the evening (between 6.30-7.00 PM).
- Blanket application of bifenthrin @ 2 kg ai / ha (Talstar 10 EC @ 20 litre / ha in 500 L of water) when first instar stage of grubs dominate in the field (in the month of Sept in hills and in July-Aug in plains).
- September-October is the window of time for EPN application in the interspaces. Second round of need-based root zone application of chlorpyriphos 20 EC @ 7 ml / palm after 45 days of first round insecticide application.
- November-December is the time for EPN application in the interspaces.
- Repeated ploughing to expose the grubs to predators / digging and removal of grubs during October-December.

Understanding life processes in coconut

Plant physiology is the branch of science concerned with all the primary life-processes in plants in its life cycle, from germination to senescence and eventual death. Building on this basic understanding, crop physiology (an integrative science drawing information from a wide range of scientific areas) unravels and possibly manipulates these life processes responsible for the growth, development, and production of economic yield in crop plants to our advantage. The history of physiology research in coconut exemplifies this transition from plant physiology to crop physiology, perhaps, with a greater emphasis on environmental (stress) and production aspects of the crop. The research in physiology of coconut is closely related to the overall R&D advancements of this crop.

Early days

The Coconut Station, when started in 1916 at Kasaragod under the Madras Presidency, did not have a plant physiologist then (*ultra-specialization was not a bane and holistic vision was a virtue in those days when generalists handled everything in science and medicine!*). But, realizing the importance of water and nutrients to the crop, a classical study was initiated to study the root system so as to understand the rate of water and nutrient uptake, zone of absorption and the depth and spread of root system. This understanding helped in deciding the place of manure application and effective root zone distance to be maintained between the trees.Subsequent observations on the amazing development of root system in a one-year-old seedling, even extending beyond 4.5 feet in radius from the stem, established the need for regular manuring of the coconut seedlings from the time of planting itself. Now, root architecture has become one of the important selection criteria, especially in the many environments characterized by low water and nutrient availability which influences productivity.

Another important observation made during the period (1918-19) was on the rate leaf production, its pattern in the crown and the appearance of flower in leaf axils. A mature coconut tree possesses approximately 35 leaves; from the bottom, leaf position up to 20 is fully opened, 21 to 29 is partly open and leaf buds from 30 to 37 could be identified, but the buds are too small to dissect. Leaf number 4 to 14 bear spathe with nuts, and at leaf position 15, spathe is yet to open. Spathe is just 3 inch long at leaf position 20, in which it is not possible to distinguish male and female flowers. However, flower buds have been formed in the axils of all the leaves from leaf position 21 to 29. From the above observation it was inferred that *"any treatment given to the tree will not show any change in female flowers in the case of bunches which ripen during the next 16 months. Any increase in production within that time will be found only in the increased proportion of female flowers which set their fruit"*. This finding refined the observations and inferences with regard to different treatments involving manurial, irrigation and various management trials in the subsequent years.

It is astonishing that such a basic information can have profound practical implications, influencing even policy decisions, as evident in the words of Shri C.M. John (the first Director of CCRS, Kasaragod). *"The analytical studies of the cabbage made us understand the reproductive phase of coconut; while dissecting the crown, the primordia could be located in the cabbage nearly 10 months prior to appearance. This is very important, since the manurial schedule was based on this fact that the response to manuring is manifest only after two years. And this made me to propose that advances from banks should be recovered only three years after disbursing the money"*.

During the 1950s, in the Central Coconut Research Centre at Kasaragod (under the Central Coconut Committee), the emphasis was on understanding factors governing productivity. Accordingly, correlation studies established between copra content of the nut and palm characters indicated that round nuts and trees with thicker petioles or larger leaf bases had nuts with higher copra content. In terms of season, trees yielded maximum quantity of copra during summer months from February to March and low in the months of August, September and October.

Another thrust area for the coconut committee (at the Coconut Research Station at Kayamkulam) and after the formation of CPCRI in 1970 and for several years thereafter, was the investigations on the root (wilt) disease of coconut. An Assistant Plant Physiologist was appointed at Kayamkulam to investigate the root (wilt) disease from a physiological perspective. Detailed observations on disease symptoms of trees in early, middle and advanced stage of the disease was made. Studies on the exudation of sap by roots and rootlets in different soil layers of healthy and diseased trees revealed the sap of main roots having been found to contain more total solids. Studies carried out on micronutrients, injection of nitrogen, hormones, chemotherapeutants etc., was the initial report to show the derailment of nutrients and hormones in diseased plants.

1970s: Plant Physiologist joined at Kayamkulam

The thrust in plant physiology research under CPCRI continued to be the root (wilt) disease. Dr. Ramadasan joined as the Plant physiologist. The failure to pinpoint the etiology of the root (wilt) disease and its complex nature and the realization that it might not be merely a pathological problem necessitated inter-disciplinary team research. This led to the appointment of a team of plant physiologists and biochemists and ultimately led to the creation of Plant Physiology and Biochemistry division at Kayamkulam.

Some of the predisposing soil factors associated with the disease was soil sickness caused by low pH, inadequate drainage, poor aeration, low microbial activity and nutrient imbalance. Plant roots are known to be very sensitive to oxygen deficit. Though the sensitivity of roots to O_2 deprivation is not studied in coconut, earlier workers observed rotting of roots and the root damage was found to be proportional to the intensity of the disease. It was further observed that the diseased plants had greater stomatal conductance and transpiration loss of water as compared to healthy palms. Roots of the 'wilt' affected plants were damaged, and leaf water potential was decreased. Biochemically significant change in sugars, amino acids, proteins, enzymes and hormones were observed. From the above understanding, it was postulated to be a 'root disorder', in which the soil-plant-atmosphere continuum is broken either due to biotic or abiotic factors.

1972: Plant Physiologist joined at Kasaragod

In 1972, Dr. Ramadas moves over to Kasaragod. Early on, many important contributions were made, but most of them additions to concepts already in existence. As seedling selection is of paramount importance in establishing a stand of superior yielders, criteria for selection of vigorous seedlings on the basis of a few easily measurable morphological characteristics such as girth at collar, total number of leaves, plant height, length and breadth of leaves or leaflets, and early splitting of leaves, were developed. Since growth is a function of leaf area development and dry matter (DM) production, the physiological approaches employed to identify superior seedlings are by correlating the phenotypic characteristics to the seedling vigour. Several regression equations were developed for non destructive estimation of leaf area and dry matter production. Breeders and physiologists, undoubtedly, benefited from a method of leaf area estimation that is fast, inexpensive, reliable, does not require destruction of the leaves, and is sufficiently manageable for use in field experiments.

The genotypic differences in crop yields was attributed to the variations in the amount of assimilates synthesized (source capacity), in the capacity for storage of assimilates (sink size), and in efficiency of the transport system. Methodologies were developed to quantify dry matter accumulation and partitioning of synthesized assimilates to different plant organs/economic products.

1980s and 1990s: period of rapid changes

The 1980s and 1990s had seen an unprecedented growth, both in terms of scientific manpower and research infrastructure. Many sophisticated equipments like the photosynthetic measurement system (IRGA), porometer, water potential system (Scholander's pressure chamber), spectrophotometers, centrifuges etc. were procured. They not only helped us in unraveling the basic processes contributing to the productivity, but also in characterizing important abiotic stresses like mositure deficit stress. Further, it helped us to dissect the biological and environmental constraints to adaptation, and for assessing the relative magnitude of the effects of individual genotype and/or environmental factors. It helped us to establish a robust screening method and set priorities and strategies for subsequent breeding and agronomic research.

Screening for moisture-deficit tolerance in coconut

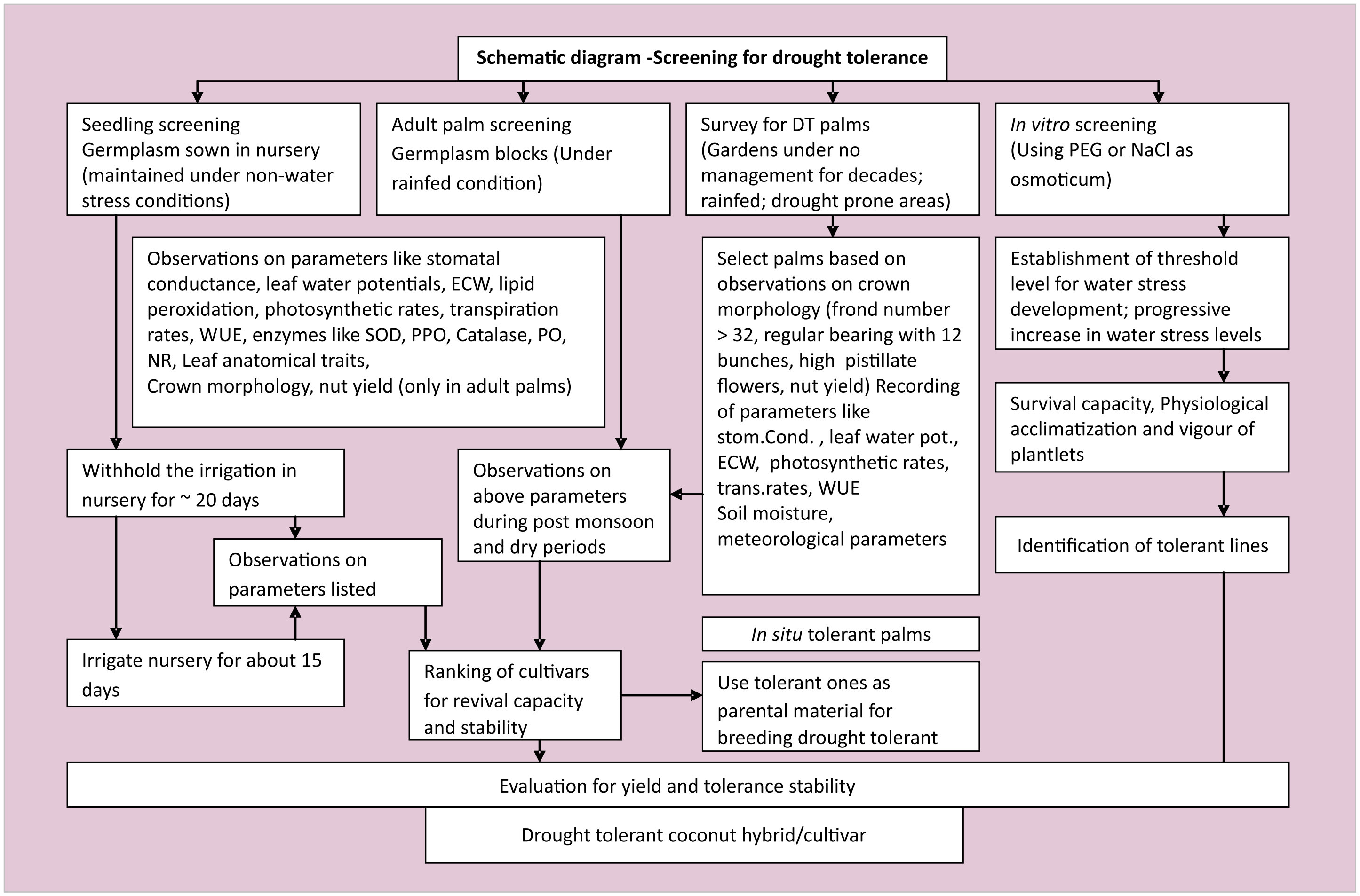
Coconut palms, being a rainfed crop mostly, are exposed to annual summer dry spells and frequent drought years of different intensities and durations across the vast coconut growing tracts in India. The impact of drought (*the more appropriate terminology currently used is 'moisture-deficit stress'*) on coconut persists for two to three years in view of the indeterminate flowering habit and perennial nature of the crop. As coconut yields are closely linked to favourable weather conditions, occurrence of drought leads to significant reduction in yields, thereby resulting in considerable economic loss to the growers.

Correlation of physiological and biochemical characters with nut yield and its integration with physiological/morphological (anatomical) responses to drought tolerance led to the identification of drought tolerant coconut cultivars. Extensive research work carried out in coconut has led to the development of screening methods for identification of drought tolerant genotypes. Screening of seedlings of parental lines and hybrids at the nursery stage indicated variations in stress responsive physiological characters like leaf water potential, lipid peroxidation, net photosynthetic and transpiration. High membrane stability, osmoprotection, osmoregulation and enhanced activity of antioxidant enzymes are characteristics often found in leaves of drought-stressed coconut trees.

Differences in leaf gas exchange, leaf water potential, water-use efficiency and stomatal behavior among cultivars and hybrids under water stress largely explain the agronomic performance of field-grown coconut trees under drought conditions.By employing screening techniques (as shown in flow chart) for desirable traits for drought tolerance, varieties were identified as suitable for planting in drought-prone areas. Some of the drought tolerant varieties/hybrids are WCT, LCT, FMS, WCT x COD, LCT x GBGD, LCT x COD.

Identifying the physiological and environmental constraints to productivity

Weather variables like rainfall, day/night temperature regimes, relative humidity, sunshine duration and vapour pressure deficits play a pivotal role in



crop growth, development and yield. Studies indicate the relationship between rainfall and other weather variables with nut yield in coconut. The influence of weather on nut yield in coconut, in fact, starts from inflorescence initiation and lasts till nut maturity. The time-lag between inflorescence initiations to nut maturity is 44 months, with 70% of this period in the pre-fertilization phase. The three critical stages during the nut development are initiation of inflorescence primordium, ovary development and button size nut. Coincidence of any of these critical sensitive period with unfavorable weather like a prolonged dry spell results in drastic reduction in yield. When recurrence of drought spells occurs once in 3-4 year cycles, or in consecutive years in the worst scenario, the results are devastating.

Short-term responses of coconut to water stress such as low stomatal conductance to water vapour (gs) and leaf water potential (Ψ) with negative consequences for the net photosynthesis rate (A) and transpiration rate (E) have been demonstrated. Stomatal closure is often considered as an early physiological response to water deficit, which results in decreased A, through limited CO_2 availability in the mesophyll. However, there are strong evidences that suggest that photosynthetic processes in the mesophyll such as Rubisco activity, RuBP regeneration, ATP supply, electron transport rate (J) and light capture efficiency in the photosystems are impaired as water stress increases.

Identification of the above physiological, biochemical and environmental constraints to adaptation and nut productivity assisted us in assessing the relative magnitude of the effects of individual genotype and/or environmental factors. It served to establish priorities and strategies for subsequent breeding and agronomic research. Thus, for example, irrigated coconut varieties of coastal tract like WCT or ECT might not be ideal in the dry season of Tamil Nadu, reminding that the limitations of the existing cultivars could not be readily overcome by agronomic management, underscoring the need for developing better adapted cultivars.

Optimizing the growth and development to the resources and constraints

In physiological terms, two complementary strategies are employed to improve genotypic adaptation to the variable and frequently stressful weather conditions. The first is to understand and match the growth and development of the crop to the resources and constraints of the environment and second is to select for tolerance or resistance to the impact of stressful extremes.

Moisture-deficit management

Studies reveal that moisture defict occurs once in 3-4 years with different intensities in major plantation areas. Depending on the length of dry spell and its coincidence with the critical stages of crop growth, the yield will be affected. In order to have sustained yields, it is important to have strategies to manage drought (which includes the soil as well as atmospheric droughts). Moisture deficit management strategies mainly include the conservation of available soil moisture and efficient use of available water resources for high production. Different agronomic practices can be used for soil management for conservation of water during drought periods such as adoption of organic farming technologies and tillage practices like summer ploughing, soil mulching and addition of soil stabilizers.

Improving genotypic adaptation

In addition to the traits identified as described above, the gene action with respect to drought responsive physiological traits was studied in a 2 x 4 line x tester mating design involving two dwarf (CGD and MYD) and four tall coconut cultivars (ECT, PHOT, LCT and FMST) with desirable characters. Analysis of variance for seedling transpiration rates and leaf water potentials showed higher specific combining ability (SCA) effects than general combining ability (GCA) effects, due to predominance of non-additive gene action, indicating heterosis for this character. The Pn under stress was additive with good combining ability, while the Pn during non-stress and recovery were governed by non-additive gene action that can be exploited for heterosis. In case of lipid peroxidation, gene action was unpredictable in non-stress with additive gene action being nil with low dominance. Whereas, during stress and recovery, non-additive gene action was observed. These results indicate the possibility of exploiting the nature of gene action governing drought sensitive traits in breeding for tolerant coconuts.

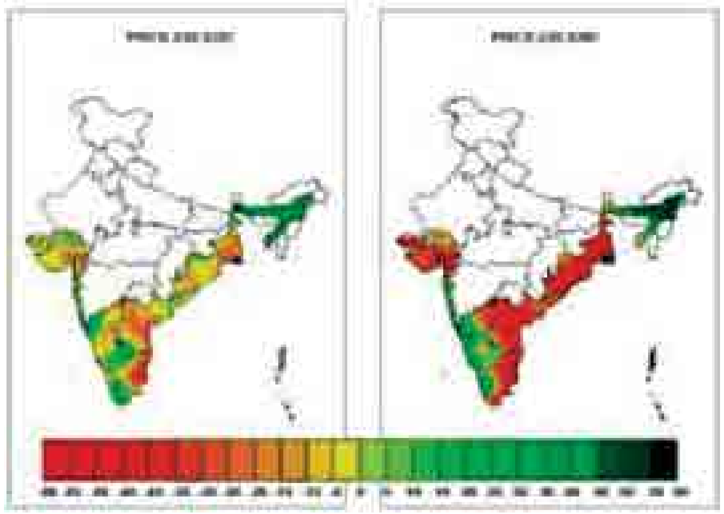
New tools for complex tasks

From the beginning of the present century, plant physiology had been increasingly integrated with molecular biology and information technology, enhancing the application of physiological advancements in crop improvement. Conversely, application of molecular genetics also contributed to a better understanding the basics of stress responses. Simulation models enhanced our ability to handle large amounts of data and to explore the dynamics of physiological processes and their complex interactions with the environment.

Simulation modeling: What the future portends?

Massive data on soil, plant and weather, across the major coconut growing tract and over the years, were collected and utilized to calibrate and validate a generic simulation model (Infocrop) for coconut. This Infocrop-coconut model showed a reasonably good fit with r^2 value of 0.86. The same model was later used to predict the coconut production under future climate scenarios.

As per the model projections, under the A1B scenario, 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.



Climate change: How will adapt to this reality?

Advanced studies under the open-top chambers (OTC) showed that seedling growth in coconut was promoted with elevated CO_2 [ECO_2], while elevated temperature [ET] 3°C above ambient reduced the growth. [ECO_2] 700 ppm increased plant height, leaf area and biomass production of coconut seedlings by 18%, 16% and 15%, respectively, as compared to the ambient (380 ppm). The higher root biomass accumulation indicated better CO_2 sequestration with [ECO_2]. Higher growth was due to both increased leaf area and photosynthesis. On the other hand, ET significantly reduced both photosynthesis and leaf area, and thus the plant growth. [ECO_2] and [ECO_2+ET] showed 23 and 9 % higher total soluble sugar content over the ambient as well as ET. [ET] on the other hand increased lipid peroxidation (16%) and reduced peroxidase enzyme activity (12%) but had no effect on polyphenol oxidase activity.

Now, the moot question is how coconut will respond to the combination of [ECO_2] and [ET], the most probable climate change scenario in the future?. In open top chamber (OTC) experiments, it was further observed that the stimulatory effect of CO_2 under drought was less, and it could increase the biomass by only 8% at 700 ppm CO_2. However, both under normal and water limited condition, there was a reduced stomatal conductance and transpiration with elevated CO_2. Thus, the water requirement to produce unit biomass in [ECO_2] treatment is less. This indicates that, at the present level of moisture available, coconut would produce more biomass under future climate. However, with the projected reduction in precipitation under future climate, the biomass production and nut production may be reduced, unless corrective measures are taken. Similar to the above ground biomass, the below ground biomass (root biomass) too increased with elevated CO_2. Thus, it is expected that there will be higher carbon sequestration under future climate, which is an important option to mitigate the climate change effect.

Coconut, the 'unsung hero' in carbon mitigation

Environmental benefits accruing from coconut plantations was always underestimated, till recently, as they are not easily measurable/quantifiable and not of direct financial benefit to the grower. Commercial plantations have an equal role as that of natural vegetations in carbon sequestration. Plantation crops has significant potential for offsetting and reducing the projected increases in green house gas (GHG) emissions and hence regarded as an important option for greenhouse gases mitigation. Coconut palm has a substantial C storage (sink) capability with the annually sequestered carbon stocked in the stem in the range of 0. 3 to 2.3 CERs (certified emission reductions). The above-ground biomass in coconut varied from 15 to 60 CERs, depending on the cultivar, agroclimatic zone, soil type and management, without taking in to account the substantial C sequestered in the soil through the soil organic matter.

Simulation results indicated that the carbon sequestered and stored in stem in coconut plantation in four states Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh is to the tune of 0.732 million tonnes of carbon every year. The potential social, ecological and economic benefits of coconut and coconut-based farming systems are largely underestimated.

Pre-and Post- Harvest Technologies

The two thrust areas for the 'Pre-and Post- Harvest Technology Unit' was developing efficient tools and machineries for mechanization of farming operations, and better proceeses and machineries for the traditional processing operations in the mandate crops. Tools, equipments, machineries and process protocols were developed for all the essential unit operations of traditional processing, considerably enhancing the ease of operation and labour use efficiency. However, the efforts at developing efficient and user-friendly tools and machineries for farming operations did not give the desired results, belaying expectations in this regard. Eventually, a third functionality was added to its ambit - developing processes and machineries promoting value addition and process diversification - opening up new vistas in agri-processing and entreprenuership development, thus essentially bridging the past and the future.

Machineries developed for every processing operation

Coconut de husking

Coconut de husking is the first unit operation in any coconut processing industries and even for domestic use. Traditionally, the de-husking is done manually using a spike fixed in the ground. However, it needs certain amount of skill. Efforts were started during 1977 to develop a simple de-husking machine that could be operated even by an unskilled person. Three prototypes were developed in the subsequent years and the final device was made available by 1985. The machine was driven by using the leg and the hand. Though the manual de-husking machine was suitable for house hold and small-scale processing units, the need of a mechanical device which is much faster than the manual one was felt when large scale coconut processing industries came in to existence. In fulfilment of this requirement, a mechanical coconut de-husker was developed in 2016, that has a capacity to de-husk 350 coconuts per hour, without the requirement of any human effort except for feeding the nuts.

Dryers for copra making

Traditionally, the major 'value-added product' from coconut in India has been the coconut oil. Quality of copra decides the coconut oil quality and its shelf life. Traditionally, copra is being made by drying coconut in open drying yards. However, dust accumulated in the copra and improper drying (for example, when the sky is cloudy) that lead to fungal growth, affects the quality of copra. During rainy season, with restricted sunshine, drying by artificial methods is the only possible solution. The direct type kiln dryers are not desirable for copra, as the products become inferior in quality due to smoking and improper drying. The other indirect type dryers using electricity or oil as fuel are uneconomical for small farmers. In such a scenario, developing an indirect type dryer suitable for small holders, using easily available low cost agricultural waste as fuel, for on-farm processing was the need of the hour.

Agricultural waste-fired copra dryer

The dryer is a 'batch type' having indirect heating and natural air convection arrangements. It has a drying chamber, a plenum chamber, the burning-cum-heat exchanging unit the chimney with regulators. The dryer is constructed from locally available materials and has a capacity to dry 400 coconuts in 32 hours of drying time. Another two dryers of capacity 1000 coconuts and 3000 coconuts have also been developed with the same drying principle.

Solar cabinet dryer

The solar cabinet dryer developed to dry 100 coconuts is the first attempt at harnessing the solar energy. This dryer is of a chamber type, having direct heating and natural air convection arrangements. Good quality copra with less than 6% moisture content could be made in 3-4 days using this dryer.

Electrical dryer

This tray-type dryer, with mixed flow and forced hot air circulation, was developed by the institute for drying a batch of 1000 coconuts. The dryer mainly comprises of a drying chamber, plenum chamber, the heating unit and the blower unit. Drying is accomplished in 30 hours in this dryer.

Shell-fired copra dryer

The agricultural waste fired copra dryer developed earlier had been utilized by the farmers and small entrepreneurs to make quality copra. However, the requirement to feed fuel to the dryer in every half an hour was a major limitation and for overcoming the same, another type of indirect dryer was developed. The shell-fired copra dryer is to dry coconut in 24 h, which works on indirect heating and natural convection principles using coconut shell as fuel. The unique burner generates heat for five hours without tending and the heat is retained for one more hour. Since the smoke does not come into contact with the copra, the copra produced is of good quality. About 100 grams of shell charcoal is also produced during the final phase of heating. Capacity of the dryer is 1000 nuts per batch. Another dryer having half the capacity, 500 nuts per batch, was also developed with the same technology.

Coconut de-shelling machine

Traditionally, after partial drying of the split coconut, the kernel/copra is separated from the shell using a traditional wooden mallet by holding the individual cups in hand. The batch type coconut de-shelling machine was developed to mechanically separate shell and copra after partial drying. Capacity of the machine is 400 half-cups per batch. Similarly, a machine for deshelling fresh coconut was also developed during 2015. This machine uses a tungsten tipped cutter wheel for deshelling and the power requirement of this machine is 1 hp. Now, with the same power, a double cutter wheel desheller has been developed.

Value-addition and product diversification

The price of coconut in the country is dependent on the prevailing price of coconut oil, which is characterized by recurring violent fluctuations. The behaviour of coconut oil price is highly dependent on the overall supply of oils and fats in the country. In many ways, value addition and by-product utilization play a crucial role in the stabilization of this coconut oil-driven domestic market and is essential for reorienting and engineering the Indian coconut industry to be cost-effective and globally competitive.

Coconut chips

CPCRI has also developed a complete technology package for production of coconut chips through osmotic dehydration along with a highly efficient manually operated coconut kernel slicing machine for ensuring uniform quality.

The non-satiated demand and a craving need for healthy snack foods led to the development of value added products from coconut. Coconut chips is a ready-to-eat, crispy, highly nutritious and non-fried snack-food, prepared by dehydrating the intermediate moisture in coconut kernel with flavours added. This high value natural product that can also be used as an ingredient in a

variety of delicious baked goods, snacks, desserts, and other dishes. Dried coconut chips contain 70% of fat with medium chain fatty acids (MCFAs) and rich in lauric, capric and capryolic acids. Coconut chips are also high in fibre, low in digestible carbohydrate and gluten-free. It can improve digestion and helps in weight control. The institute developed a processing technology for the production of quality chips (through osmotic dehydration) from matured coconut in 2000. The machineries for the production of coconut chips (coconut slicing machine, blancher and coconut chips dryer) were also developed in subsequent years. Two types of coconut slicing machines (power operated and sewing machine type manual coconut slicing machine) and both the electrical and bio-fuel used coconut chips dryers were also developed. The packaging technology ensuring shelf life up to six months for the coconut chips have been standardized during 2014.

Different types of coconut chips *i.e.* sweet chips with vanilla, strawberry, chocolate flavours, salt chips with tomato and pudina flavours, nutraceutical chips using coconut sap, carrot juice, beet root juice, turmeric, garlic and pepper base have been developed during 2013-2015. The process parameters like composition of sugar/salt, soaking time, drying time, drying temperature for high quality coconut chips have been standardized during 2013-15. It is an ideal micro-level enterprise suitable for Self Help Groups, which can be easily scaled up for large industries also. With a complete value chain for coconut chips production technology in place, several entrepreneurs have taken up this technology.

The pioneering efforts by the scientific team (K. Madhavan, S.J.D. Bosco, T. Vidhan Singh and A.C. Mathew) on developing value added products from coconut and technology packages, which are women entrepreneur-friendly and rural development oriented, was duly recognized with the prestigious ICAR Award for outstanding interdisciplinary team research in agriculture and allied sciences for the year 2003-2004.

Virgin coconut oil

Due to the present not so hygienic practices in the copra making and depletion of bioactive ingredients, there was an active search for a healthy and nutritious oil. Virgin coconut oil, extracted directly from the fresh coconut meat or from the coconut milk, fills this void. It is the purest form of coconut oil, crystal clear, containing natural vitamin E and with very low content of free fatty acids and has natural aroma intact. 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 depends to a great extent on the scale of operation, the degree of mechanization, the amount of investment available and the market demand. For decades, people in coconut producing countries like India and Philippines boiled coconut milk extracted from freshly grated coconut meat, with or without the addition of water, to produce coconut oil for hair and body massaging applications. The lauric acid present in VCO is converted to monolaurin, which provides disease-fighting ability to body and keeps infants free from getting viral or bacterial or protozoal infections. VCO is being used as an air and skin conditioner, an oil base for various skin and hair care products, a carrier oil for aroma therapy and massage, and a nutraceutical and functional food.

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.

The modified hot process method standardised during 2013 for producing VCO also follows the same principle, except for controlled heating to prevent the oil from turning yellow, and maintain the moisture content to less than 0.2 % to prolong its shelf life. The VCO yield was enhanced by using pulverizing and blanching operations.

There exists a big market for virgin coconut oil, especially in the Western countries, which ensures 3-4 fold price compared to coconut oil. Sri Lanka and Philippines are at present the major exporters. The institute has developed processing technologies for virgin oil production through hot, cold and fermentation processes, and evidently it is for the entrepreneurs to take advantage of these technologies.

The optimum utilization of co-products of virgin coconut oil (coconut water, coconut milk residue and VCO cake) generated in the process into various value added products were explored, for ensuring higher economic returns/viability for the VCO technology. Use of this low-fat desiccated coconut powder from the dried coconut milk residue was demonstrated in the bakery, confectionery and the extrudate food formulations. Recently, during 2014-16, coconut milk residue and VCO cake based extrudates have been made to enhance the protein and dietary fibre level of commercially available extrudates. Good quality coconut oil was extracted using the mixtures of coconut milk residue and dried testa powder. It is a great idea to mix the coconut milk residue flour with wheat flour and/or multi grain powder mix for enhancing the dietary fibre level. Similarly, muffin cakes and confectionery items were prepared from VCO cake. Good quality vinegar, squash type beverage and jelly type food was prepared from coconut water.

Neera, health and wealth in every drop

Coconut inflorescence sap, popularly called neera, is the natural health drink, traditionally collected from the coconut spadix and consumed largely by the rural population. The sap is highly prone to fermentation, being rich in sugars (15%) and therefore, collection of fresh and unfermented sap is a challenging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task. Lime is commonly used as a fermentation inhibitor, by coating it inside the collection container. Even with the lime, the sap gets partially fermented (as sugars get converted to alcohol) and becomes unfit to be marketed as a health drink. The unfermented sap and the fermented toddy are two different products, both chemically and nutritionally. However, the lack of a proper method of collection and suitable inhibitors to prevent fermentation hitherto led to the inclusion both the unfermented (neera) and fermented sap (toddy) under the category "toddy" (an alcoholic beverage), the production of which is strictly regulated under the provisions of the Excise Acts promulgated by the various Provincial/State Governments in India since the last several centuries.

The challenge of collecting unfermented neera has been largely resolved with the development of 'Coco sap chiller' by the institute and the unfermented sap thus collected ('kalparasa') is fresh, hygienic and non-alcoholic. In this method, a simple connector is attached to the cut end of spadix, instead of the application of clay or other materials, to ensure the free flow of hygienic sap and for the collection of sap, instead of the traditional earthen pot, a collection container housed inside an improvised ice-box (coco-sap chiller) is connected. Fresh sap collected is slightly alkaline in pH, golden brown or honey colour and sweet and delicious. Since, it is rich in minerals and vitamins, it is considered as one of the best natural health drinks. It can be promoted as an instant energy provider, and as a functional and nutraceutical food. It is good for post- operative care due to the high content of electrolytes. It is a body-cooler and is good for digestion. Frequent consumption of kalparasa is known to prevent diseases like jaundice and keeps one healthy.

Concerted efforts have been made to improve the shelf life or extend the storage period facilitating transportation to distant places for wider marketing. Since the quality of the fresh, unfermented juice collected through the CPCRI method is intact, it is relatively easy to improve the shelf life of Kalparasa. In this direction, a double pasteurized process has been developed during 2014 to extend the shelf life of coconut sap for 45 days under refrigerated condition (4°C to 6°C), which otherwise required to be stored at -1 to -3°C. Most importantly, for an increasingly health- conscious consumer, the bottled sap is devoid of any chemical preservatives.

Opposite: Value added products from coconut

Value-added products from neera

The coconut sap can be easily converted to various value-added products. Coconut sugar, jaggery and honey are obtained by evaporating the water of unfermented sap 100°C. The viscous and fairly thick hot sap (Brix 60 o to 70o) is cooled to get coconut honey or syrup. On further heating, the sap become more viscous and thicker in consistency, and is poured to moulds of either coconut leaf or steel to obtain jaggery. Thicker consistency of the syrup upon further heating, with continuous stirring to avoid charring, results in the formation of sugar granules. At this stage, the liquid will change into crystal form and is to be immediately cooled. While cooling, it is stirred continuously to break the lumps. The sugar obtained is sieved to get uniform particle size and to produce quality product. Similarly, pepper and ginger-based nutraceutical coconut sugars have been prepared. A process for the production of coconut sugar based Bengali sweets has also been made. In 2016, coconut sugar based dark chocolate was developed through the joint effort of CPCRI and CAMPCO, Mangalore.

Machineries and gadgets for value addition

Though technologies for the production of coconut chips and virgin coconut oil was available, industrial production could not make much headway, since all the unit operations involved in the production process was manual, time consuming and involves good amount of drudgery. Consequently, subsequent efforts were concentrated on developing labour-saving and gender-friendly processing machineries to help the processing industries to make these products in large scale at competitive price. By the year 2010, the institute has come up with a series of machineries that made processing of coconut chips and virgin coconut oil possible at competitive prices meeting international standards. Coconut testa removing machine, coconut grating machines, pulverizer, coconut milk expellers of different types and various capacities, virgin coconut oil cookers having different heat sources and fermentation tanks and fermentation chamber are the machineries developed for the production of virgin coconut oil. Manual and electrical slicing machines, blanching unit and coconut chips dryers make the coconut chips production competitive.

The Agro-Processing Centre: the 'must-visit' destination for entrepreneurs

The Agro-Processing Centre established under the AICRP on Post Harvest Technology (in 2005) is the preferred destination for all prospective entrepreneurs, where the prototypes of all machineries/ gadgets developed by the institute are showcased. The facility has been effectively utilized, ever since its inception, to impart hands-on training to entrepreneurs availing technologies (VCO, Coconut chips and Snow Ball Tender Nut) from the ITM Unit as part of the technology commercialization initiatives and demonstrating to the visiting farmers and other dignitaries.

A new perspective on validation, refinement and diffusion of technologies

Coconut plays an important and vital role in the socio-economic life of a large number of small and marginal farmers in various parts of the world. It is estimated that more than 10 million people in India are dependent on coconut, as they are engaged in coconut cultivation, processing, marketing and other related activities. Through the systematic research conducted during the last few decades, a substantial number of viable technologies related to crop improvement, production and protection have been evolved for enhancing coconut production. However, farmers are not able to exploit the production potential from these technologies to the extent desirable. The extent of adoption of the recommended practices plays a crucial role in improving productivity and income from coconut farming.

The real potential of the sector is not realized yet!

The present scenario of technology adoption in coconut calls for technology generation and dissemination programmes based on viable extension strategies with the active participation of beneficiaries. A comparison between the best managed gardens and national average of productivity of coconut crop reveal the fact that there still exists a wide gap between the technologies generated and their utilization by the growers in the coconut sector, especially in small holdings. The national average of coconut productivity in India is 8,303 nuts per ha per year and in Kerala state the productivity is 7,365 nuts per ha per year while the local West Coast Variety maintained in the HDMSCS experimental plot at the institute has an average yield of 30, 625 nuts per ha per year, not to speak of the still higher yield potential of the newly released varieties and hybrids. Evidently, one of the important reasons for this glaring yield gap in coconut is the low level of technology utilization at farmers' fields.

Extent and pattern of technology adoption

The process of research could be considered as successful, only when the results reach the ultimate users. However, the acceptance of a new idea by the members of a social system is rather slow and difficult. Each individual has to pass through different stages of adoption process. Various communication channels used by research and extension systems help him to pass through these stages in a rapid and positive manner. Studies have been conducted in different regions to assess the extent of adoption of improved coconut cultivation technologies. A survey conducted by the institute in 2002 among the coconut growers in northern Kerala in India indicated the low to medium level of adoption of various recommended technologies.

Technology utilization pattern among coconut growers in Kerala

25% and below	: Hybrids, fertiliser application in split doses, basin management with green manure plants, irrigation, systematic intercropping/mixed cropping, plant protection measures, biological control of pests, post harvest technologies
26-50%	: Regular planting with adequate spacing, application of organic manures, soil and moisture conservation techniques
51-75%	: Planting of seedlings, selection of seedlings, green manuring
76-100%	: Local WCT variety, planting method, mother palm selection, basin opening

Impediments in technology adoption

Coconut farmers experience many constraints in adopting the recommended practices for higher productivity and income from farming. The problems may be of socio-economic, technological, management or infrastructure in nature. Studies conducted at CPCRI show that even in a state like Kerala which prides itself on its impeccable achievement of 100 per cent literacy, there still exists a situation where many farmers do not possess sufficient knowledge about the available technologies for enhancing the production and productivity of coconut. Non-availability of location-specific technologies also poses an important hurdle in the improvement of coconut productivity. Low and fluctuating price of coconut is the most important problem faced by coconut growers. Lack of sufficient labour for climbing palms and high wage rate also create much problem to farmers. Incidence of pests and diseases is another important problem experienced by coconut farmers. High cost of inputs and lack of availability of quality planting materials are often reported as constraints in adopting the recommended practices of coconut cultivation.

Socio-economic problems faced by the farmers may slow down transfer of technology efforts as well as extent of adoption. Low efficacy of ToT and feedback system is another important constraint in improving technology utilisation by farmers. Majority of the coconut growers belong to small and marginal holding categories and the uneconomic holding size limits the adoption of recommended technologies for higher productivity and income from coconut farming. Planting coconut in unsuitable locations, poor spacing due to fragmented holdings, low availability and utilization of organic manure due to reduced adoption of livestock-integrated farming, lack of irrigation/drainage facilities etc also adversely affect effective utilization of technologies in coconut farming. Lack of an effective extension support system that responds in 'in time', the present system being inadequate in both quantity and quality, compounds the problem. Needless to say, the poor management and low adoption of recommended cultivation practices reduces income from coconut farming.

Conventional extension strategies

This low level of technology utilization at farmers' fields calls for formulating effective extension strategies suitable to the heterogeneous farming situations in coconut cultivation. Various programmes are implemented by research and developmental agencies on a regular basis, as part of their efforts to disseminate the research results among the cultivators. The important transfer of technology activities for coconut development implemented by CPCRI include training programmes, front line demonstrations, information communication through mass media like radio, television, newspapers and farm magazines, extension pamphlets, CD ROMs, video cassettes etc., arranging exhibitions, seminars, Kisan Melas and group meetings, providing consultancy through field visits and by replying to postal queries. Besides, few innovative extension approaches have also been pilot tested through action research with farmers' participation for improving technology utilisation by coconut farmers.

Imparting need-based training to farmers

Organizing need-based training programmes enhances the technology utilization and thereby, income of coconut farmers. Assessment of training needs of the coconut growers is to be done to streamline the training programme. Participatory methods can be effectively employed to unearth the areas of improved technologies, in which farmers require exposure. Depending on the techno-socio-economic situations of coconut farming prevailing in the locality, the training needs of farmers would be varying. Studies have shown that coconut farmers' topmost preference was for off-campus training, followed by institutional and other types of training. Off-campus training programmes are organised in villages in the most realistic situations for a short duration. Farmers' preferences with respect to the methodology, duration, venue, season and frequency of training are also to be given adequate attention while formulating training programmes for coconut farmers. For example, CPCRI offers various types of training programmes for farmers on topics such as "Production technology on coconut", "Management of coconut diseases", "Integrated pest management in coconut", "Nursery management in coconut", "Organic farming technologies for coconut based cropping systems" and "Post-harvest technologies". These training programmes are offered in regional languages like Malayalam, Kannada, Tamil, Telugu and Hindi, as desired by the farmers. Both Institutional training programmes and off-campus training programmes related to coconut farming are organised regularly at CPCRI and through the Krishi Vigyan Kendras (Farm Science Centres) at Kasaragod and Kayamkulam.

Training a 'labour-army' for coconut

Lack of availability of labour, especially skilled labour for coconut climbing, and high wage rate are important problems faced by growers in adopting timely crop management practices. To tackle this problem, the Coconut Development Board (a statutory agency under the Ministry of Agriculture & Farmers' Welfare, Govt. of India) has initiated an innovative training programme,'Friends of Coconut Trees (FoCT)' to develop a professional group of youth for harvesting and plant protection operations in coconut. The training targeted the group of unemployed youth in developing technical skills, entrepreneurship capacity, leadership qualities and communication skills to address the needs of the coconut growers. More than 5000 rural youth have been trained in the Kerala state alone under this programme, started during 2011.

Knowledge-empowerment and skill development of extension personnel has multiple effects

Extension personnel of different organisations are directly involved in organising various technology transfer programmes and implementing development schemes to improve the income generation from coconut farming. Training of extension personnel enhance their knowledge and skill, inculcate appropriate attitude, provide on-the-job experience and develop professional behaviour, thus enabling them to extend better service to clients (the farmers), which is the ultimate aim of all training interventions. Taking into cognizance the importance of technology transfer, systematic training programmes catering to the needs of extension personnel engaged in the development of coconut are organised at research organisations such as CPCRI. Short duration training courses for research, teaching and extension staff provides opportunities for sharing of information and experiences at different levels, apart from imparting knowledge and skill. The study conducted among extension personnel who had participated in the training programmes conducted at this organization during 1995-98, indicated that the efforts for organising the training programmes were highly successful in achieving the objectives as reflected by the high Training Effectiveness Index (TEI) values.

In all the training programmes, there was a significant improvement in the knowledge, skill and attitude of extension personnel involved. The study also revealed that lack of essential teaching and communication equipments, lack of adequate transport facilities to reach farmers and lack of training in extension methods and communication skills were perceived as the most important constraints faced by the extension personnel in implementing educational programmes on the topic of training they attended to benefit the ultimate users (the farmers). Unless effective measures are taken to overcome these difficulties, as experienced by the extension personnel, the training programmes organised may not serve the basic objective of disseminating the latest technologies evolved at the research institutes to the farmers.

Demonstrations are effective in convincing and motivating clients

Demonstration is a very effective method of transfer of technology in a community. It is a group method of extension usually conducted to educate and motivate groups of farmers. Demonstration may stimulate farmers to try out innovations themselves, or may even replace a test of the innovation by the farmer. A great advantage of demonstration is seeing how an innovation works in practice. Demonstrations, to be effective, should be integrated with the total extension programme. Result demonstration attempts to motivate the people for adoption of a new practice by showing its distinctly superior result. A method demonstration is given before a group of people to show how to carry out an entirely new practice or an old practice in a better way. It is essentially a skill training, where the emphasis is on effectively carrying out a job, which shall improve upon the result. It involves seeing, hearing, participating and practicing in a group which shall stimulate interest and action. Method demonstration is sometimes used as complementary to result demonstration. Frontline demonstration of various improved coconut production technologies with the active participation of farmers has been proved to be an effective method of transfer of technology for improving the yield and income from coconut farming.

Demonstrations on thematic areas related to hybrids and high yielding varieties, agro techniques, cropping/farming systems, integrated pest and disease management in coconut can be effectively laid out as an important ToT activity. CPCRI has been organizing front line demonstrations in farmers' fields on different coconut cultivation technologies such as coconut based farming systems, management of root (wilt) affected coconut gardens. Such demonstration programmes have proved to be effective in convincing the farmers of the technical feasibility and economic viability of the technologies. Further, these demonstration programmes have multiplier effects in the dissemination of recommended technologies among cultivators at large. The adoption of the integrated root (wilt) management practice was effective in improving the average yield of root (wilt) affected palms in farmers' fields. The average yield of the palms increased from 24.17 to 46.3 nuts/palm/year after three years, recording an improvement of 91.4 per cent. Observations on yield of coconut revealed an increase in productivity of palms from a pre-demonstration yield of 95 nuts per palm per year under mono crop situation to 122 nuts per palm per year in coconut based High Density Multi Species Cropping System.

Innovative extension approaches

Low efficacy of transfer of technology and feedback system is an important constraint in improving technology utilisation by farmers. The low level of utilisation of technologies in farmers' fields calls for formulating effective extension strategies suitable to the heterogeneous coconut farming situations. Some innovative extension approaches have been pilot-tested through action research with farmers' participation by the Central Plantation Crops Research Institute (CPCRI) for improving technology utilisation by farmers.

Research-Extension-Farmer Interface facilitated through cyber extension programmes

Cyber extension envisages the effective use of information and communication technology (ICT), national and international information networks, internet based expert systems, multimedia learning systems and computer based training systems to improve information access to the farmers, extension workers, research scientists and extension managers. CPCRI has been implementing various cyber extension activities as part of strengthening the technology transfer programmes of the Institute in mandate crops (coconut, arecanut and cocoa).

As part of the cyber extension activities, a group video conferencing system through ISDN was installed at the Agricultural Technology Information Centre (ATIC), CPCRI, Kasaragod in 2007 to facilitate interaction between various stakeholders for enhancing technology utilization. Facilities at the District Collectorates for videoconferencing were utilized for the interaction through the collaboration with State IT Mission. Since then, the Institute has been organizing interface programmes involving different categories of stakeholders at regular intervals to strengthen the technology transfer efforts.

In the year 2010, the videoconferencing facility for organizing interface programmes was strengthened by procuring a mobile CODEC. The mobile CODEC enhanced the scope of interface programmes by linking the scientists at the Institute headquarters with farmers and other stakeholders in distant locations (which do not have videoconferencing facility) either through ISDN or IP-network. This facility provided more opportunities for the researchers

at the Institute to have interactions on field problems with farmers and other stakeholders located in distant places. A total of 55 interface programmes facilitated through videoconferencing were organized by CPCRI during the period from April 2007 to October 2012.

Effective linkages are established with various agencies such as ICAR institutes, Commodity Boards like CDB, State Department of Agriculture/Horticulture, State IT Misssion, NGOs like MSSRF, people's representatives and farmer organizations for the effective conduct of the interactive videoconferencing programmes to strengthen technology transfer programmes under the cyber extension project.

Since launching the facilities, interactive videoconferencing involving various stakeholders have been conducted between CPCRI headquarters at Kasaragod and various locations in the country. All the four southern States *viz.*, Kerala, Tamil Nadu, Karnataka and Andhra Pradesh where the mandate crops of the Institute are mostly cultivated have been covered through the interface programmes besides other states such as Assam, Bihar and Orissa.

Facets of Interphase

The interface programmes facilitated through videoconferencing organized by CPCRI can be broadly categorized in to five types.

Type 1: In this type of interface programme, scientists of the institute interact on themes related to production technologies of the three mandate crops and palm based cropping systems with extension personnel and farmers located in distant places. Mostly this type of interface programmes have been initiated in collaboration with commodity boards such as Coconut Development Board (CDB), State Department of Agriculture/Horticulture and Krishi Vigyan Kendras (KVKs).

Type 2: In this type of interface programme, scientists of the institute interact with farmers located in distant places. Mostly this type of interface programmes have been initiated at the request of commodity based farmers' groups such as coconut farmers groups.

Type 3: Here, scientists of the institute interact with extension personnel attending training programmes at other horticultural research institutes on topics related to palm based cropping systems.

Type 4: In this type, interaction is facilitated between extension personnel attending training programmes at CPCRI and scientists at other horticulture research institutes on themes related to improved varieties and agro techniques of horticulture crops suitable for inter/mixed cropping in coconut/arecanut gardens.

Type 5: Here, interaction between SHGs are facilitated mainly to share their experiences in production and marketing of value-added agro-based products and also to facilitate demonstration of techniques involved in the production to benefit the members of SHGs at the other end of the interaction.

Empowering community based organizations (CBOs) in coconut communities for sustainable income enhancement

Livelihood of a substantial number of families in rural poor communities in India depends on coconut farming. Many a times, the income generated from coconut farming in small and marginal holdings does not provide enough for meeting the requirements of such families. Technology options for enhancing income from coconut farming in such poor rural communities do exist, but not fully realised in field situation. The fragmented holdings don't render themselves viable for the optimum utilization of resources and the adoption of improved technologies by the cultivators. To augment the production and productivity of such small and marginal holdings, it was suggested to have group management of resources which helps to overcome the inherent weaknesses of the fragmented holdings. The concept of organizing coconut farmers into 'Community Based Organisations' (CBO) for sustainable income enhancement with the objective of efficient management of farmers' resources to reduce cost of cultivation and to increase productivity through integration of technologies even in very small farm holdings have been demonstrated by CPCRI in selected localities.

A project sponsored by IPGRI for developing sustainable coconut based income generating technologies in poor rural communities was implemented by the CPCRI in two selected coconut communities, at Pallikkara in West Coast region and Ariyankuppam in East Coast region. The three-pronged strategy for the project included growing suitable inter/mixed crops in coconut gardens and integrating animal husbandry and other subsidiary enterprises with coconut farming, cultivating high yielding cultivars of coconut to enhance the yield and income, and promote the diversification of coconut products. The implementation of the strategies envisaged in the project was routed through Community Based Organisation of coconut growers in the selected communities. Micro-credit for introducing the interventions envisaged under the project was through the CBO. Joint participatory analysis of the coconut farming scenario in the community was undertaken by the team of scientists and farmers under the CBO to design the technological interventions to be implemented. A close linkage was developed between the CBO and scientists from CPCRI for the effective implementation of interventions. Arrangements for procuring planting materials, inputs and organising training programmes on CBO management and relevant technologies were done through the CBO with close collaboration with CPCRI and other agencies. Monitoring and evaluation of the interventions implemented in farmers' field were done through CBO. This innovative extension methodology was subsequently adopted for the implementation of other similar projects also.

Under the project on 'Cluster approach among coconut farming community for improving productivity and income from small and marginal coconut based homesteads' in the root (wilt) affected coconut area, the farm family members of 25 hectare area clustered together for deciding the farm strategies (both individual and group ventures) for improving productivity and income. The average yield of coconut was doubled after implementation of the technology package over a period of three years.

This cluster approach has been scaled up by other agencies like Coconut Development Board (CDB) among coconut farming communities through their development schemes. The Board has initiated the formation of Coconut Producer Societies (CPS) by associating 40-100 coconut growers in a contiguous area with a consolidated minimum of 4000-5000 palms. The objective is socio-economic upliftment of the farmers through productivity improvement, cost reduction, efficient collective marketing and processing and product diversification. A farmer equity contribution is also proposed to be mobilized. A matching equity contribution will be sought from the state Government as a one-time assistance for making the CPS effective.

Under the NAIP project on 'Value chain in coconut', a methodology was evolved for participatory group approach through Community Based Organisations (CBOs) for sustainable income enhancement in small and marginal coconut holdings. The methodology involves facilitating CBOs of farmers and women SHGs for effective integration of production and processing technologies in coconut holdings for higher income. Under this project, 10 CBOs comprising of 534 farmers, in clusters of 25 ha each, were formed. Technological interventions on soil and water conservation, soil health management, INM, inter/mixed cropping, IPM and IDM were implemented in farmers' gardens. Four women SHGs were facilitated to take up microenterprises on production and marketing of coconut value-added products like coconut chips. The group approach in coconut farming for income enhancement in small holdings is being scaled up by other agencies like Coconut Development Board, State Department of Agriculture and Local Self Governments.

Promoting women self-help groups

It is generally agreed that there is immense scope for introducing interventions related to the promotion of women's self help groups for processing of

diversified coconut products at the farm-household and community level. Hence, entrepreneurship development programmes can be organised for women to train them on the various opportunities for value addition in coconut. Concepts and practices of entrepreneurship development, group approach for micro level interventions on product diversification in coconut, and technologies for production of quality copra using copra dryers, coconut kernel based food products, preparation of coconut candies, production of snow ball tender nut, production of coconut chips, oyster mushroom cultivation on coconut wastes and production of vermicompost using coconut leaves are the ideal subjects to be dealt in these entrepreneurship development programmes.

The experiences and the perceptible impact of organising the Entrepreneurship Development Programme on value addition in coconut for women under the COGENT-IPGRI project on "Developing sustainable coconut based income generating technologies in poor rural communities' in different coconut growing countries" clearly indicate the scope for enhancing the income of resource-poor coconut farmers and socio-economically disadvantaged rural women through product diversification in coconut. One of the most significant outcome of the interventions under this project was that women members of the CBOs could increase their income by 3-5 times, through the production and marketing of coconut high value products compared to their previous income from copra, securing a steady source of additional income for them and helping them rise above poverty line. Equally important, this project intervention provided employment opportunities to formerly unemployed and under-employed rural women resulting in enhanced self esteem, and economic and social empowerment.

Subsequently, under the NAIP project on 'Value chain in coconut', four women SHGs were facilitated to take up microenterprises on production and marketing of coconut value added products. The SHG members were trained on technologies for the production of coconut chips, VCO and a range of other coconut based value added products. Capacity development programmes were also organized for the SHG members on good processing practices, quality control, procurement of raw material, maintenance of machinery, marketing and maintenance of accounts and audit etc. Besides the economic empowerment, the members of women SHGS also benefited from better recognition in the society, improvement in communication skills, knowledge in financial management through their involvement in the management of coconut based microenterprises.

Farmers' participation in coconut research

Ensuring farmer participation in research and extension invariably enhances the extent of technology utilisation at farm level. There is immense scope for participatory technology assessment and refinement in coconut for achieving higher productivity. Indian Council of Agricultural Research (ICAR) implemented a project in 1995 for "Technology Assessment and Refinement through Institution-Village Linkage Programme" (IVLP) under National Agricultural Technology Project (NATP). IVLP is a novel front line extension programme, the implementation of which begins with the selection of a suitable village, that is followed up with a detailed agro-ecosystem analysis of the selected village, diagnosing the problems of each production system and prioritising these problems, identification of technological interventions based on problem-cause relationship, the development of action plans and their implementation; and detailed socio-economic evaluation including farmers' reactions and perceptions about the interventions. This exercise was carried out using various PRA tools and techniques. In all these stages, the active participation of farmers was ensured.

The TAR-IVLP project was implemented by the institute in three villages (Pady, Edneer and Nekraje) in Kasaragod district of Kerala, with coconut as one of the important crops in the production system of the villages. Keeping the problem-cause relationship as the basis, action plans were prepared for each technological interventions with the active participation of farmers facilitated by the IVLP Core Team. Each intervention was either in the form of on farm trial (OFT) or verification trial (VT). For those problems, wherein solutions are experimentally proved elsewhere, were taken as VTs and for those technology for which the results are yet to be confirmed under farmers' field conditions are taken as OFTs. Farmers' practice was included as control in all the trials undertaken. The action plan gives an account of the micro-farming situation, problem and its causes, intervention points, potential solutions, nature of intervention, treatments, critical inputs etc. At each and every stage of the trial, the participating farmers are involved in assessing the interventions using various performance indicators such as technical observations, economic observations, farmers reaction etc.

Implementation of the project revealed the effectiveness of participatory approach in the performance assessment of various technologies related to high yielding varieties, intercropping, nutrient management and crop protection in coconut.

Participatory community extension approaches for technology refinement and utilization:

A case study of area wide management of coconut pests

Adoption of plant protection technologies in coconut was reported to be very low (below 5%). Coconut, a perennial plantation crop being cultivated in contiguous areas mainly in small and marginal land holdings (average holding size of 0.2 ha), provides congenial conditions for pest and disease incidences throughout the year. Technology delivery among farming community with varied resource base, socio personal and psychological variables is a challenging task. Obviously, the extension approaches/ mechanisms needs a paradigm shift from individual farmers to area wide or groups/community based for improving efficiency Time, cost, impact, economic / environment benefits and resource efficiency could be achieved through linkages, appropriate technology choices, participatory approaches and implementation.

The coverage and efficiency of the present extension set-up (Krishibhavans at Panchayath level with one agricultural officer and 2-3 agricultural assistants) in reaching out to farming community may be much lower to the expectations, due to its multifunctional responsibilities. The initial efforts on extension approaches for improving adoption of GMF among coconut farmers started in 2007 in two panchayaths of Alappuzha district elicited poor field responses. Hence, in 2008, farm level production (FLP) unit (with a qualified person) was initiated, but it did not sustain for long, and the area wide campaign for treatment of breeding sites of rhinoceros beetle taken up in an area of 1500 ha, was proved to be time consuming/less efficient. Inadequate availability of bio agents and inability to achieve full coverage were the problems experienced. In this backdrop, the institute took up a pilot effort in Edava panchayath during 2010- 2013 and evolved a tested extension approach which was scaled up in several districts subsequently.

The learning experience asserted that technology package supported with appropriate extension mechanisms based on socio-economic situations and technical parameters, results in wide spread awareness, adoption and demand for technology. The model community extension approach evolved in the

Opposite: Farmers from Coconut Cluster interacting with the Scientist study also underscores the role of linkages with peoples' representatives, farmer organizations, farmer leaders, co-operative societies of farmers and co-ordination with various extension departments and research institutions. The critical component of the extension approach was the decentralized option for technology facilitation *viz*. capacity building of women farmer groups as master trainers and farm level producers of Green Muscardine Fungus (GMF) and targeting the 'potential and critical adopters' of the bio control technology. The non adoption of the technology by the 'potential or critical adopters' could render the community level adoption of the technology by other coconut farmers ineffective. Another lesson learnt was integration of indigenous technical knowledge (ITK) like incorporation of Clerodendron plants in breeding sites, leaf axil filling with salt/sand/ash mixture with recommended technologies.

The scattered breeding sites of rhinoceros beetle in the panchayath like livestock farms, vermicompost units, coir pith heaps were mapped in the panchayath, indicative of the locations in each ward. These potential /critical adopters were reached through coordinated efforts of peoples representatives, extension units of Department of Agriculture and Animal husbandry, milk cooperative societies (in which 85 percent of livestock farmers are members) and women Self help Groups (SHGs). Through this approach more than 90 percent of the potential adopters were reached within 2 months and post intervention data indicated 75.8% reduction of fresh pest infestation. The farmers revealed that grubs were infected by fungus after a week of treatment and infected grubs could be collected from all wards indicative of reduction of pest population

Participatory technology transfer approach for technology assessment with participation of farm families: A case study of coconut root (wilt) disease management practices

Under this approach, the farm families of manageable contiguous area (50-100 ha) will be the participating farmers and this approach suits well for the first-line technology assessment and transfer. Multi-disciplinary team of scientists, extension officials, farmer representatives, local village representatives, women, youths and groups form the stakeholders. Participatory rural appraisal tools were employed for pre-implementation, periodical appraisals at six monthly intervals and also post-implementation of the project. The awareness, knowledge, adoption and attitude of farmers towards the technology package for the integrated root (wilt) disease management technologies were improved by 40-85 per cent over the pre-implementation level. The monitoring, appraisal and evaluation of the technology implementation and its impact were done with the stakeholder participation and documented in 'farmer–scientist-extension dialogue session' for further scaling up by other agencies.

Need for convergence of extension machineries in the coconut sector for better efficiency

As there are various agencies, both from research and extension systems, striving for the development of coconut, invariably, some overlaps do occur in their functioning. But, taking into account the enormous number of farm families with small holdings, the duplication will only have a multiplier effect in dissemination of technologies for enhancing coconut production. For better impact, the extension activities of the research and extension/ development agencies are to be co-ordinated at different levels. Technology dissemination process will be accelerated if concerted efforts are made by the different agencies having proper co-ordination among them. The experiences of CPCRI in implementing the interface programme to strengthen the research-extension-farmer linkage in coconut sector indicate the relevance of strengthening research-extension-farmer linkage in coconut sector.

Interface programme for coconut is an approach for strengthening the transfer of technology efforts for the development of coconut sector in Kerala state. In this approach, the research and extension personnel and farmers are brought on a common platform to streamline activities for the sustainable development of coconut. The programme was implemented during the year 2001-02 and 2002-03. Thematic sessions relating to crop improvement, crop production, crop protection and post harvest processing technologies were included in these interface programmes, in which scientists from CPCRI and KAU, extension personnel from Department of Agriculture and Commodity Boards, people's representatives and selected farmers participated.

The results of impact analysis indicated the effectiveness of the interface programmes in enhancing the awareness and knowledge about the technologies for improving coconut productivity and income of farmers.

The impact study also revealed that there is a vast scope for planning decentralized schemes based on improved coconut production technologies dealt in the interface programme for implementation under decentralized planning programme. The experiences gained during the district level interface programme and the results of analysis of the impact of interface programmes, revealed that the concept of research-extension-farmer interface is sure to enhance the adoption of technologies ultimately leading to coconut growers' own benefit. Similar ventures may have to be initiated in other states as well to serve as a catalyst in the promotion of coconut technologies.

Evidently, the problems and challenges in the coconut sector are unique; it is natural that solutions also have to be specific; the delivery mechanism also has to be specific and tailor-made to meet the requirement. As coconut farmers, predominantly small scale and marginal farmers are resource-poor, it is ideal if the delivery mechanisms are not targeted at individual farmers, and a group or cluster approach is adopted. It is most important that we should do the 'packaging' or 'bundling of appropriate technologies' suitable for a given cropping environment or target group and make it available at the doorstep of the farmer at the right time when he needs it the most.

Economic, marketing and policy aspects of coconut sector in India

Coconut assumes considerable significance in the national economy of India in view of rural employment and income generation. The traditional coconut farming in India is an integral part of its life, culture and identity. The coconut palm exerts a profound influence on the rural economy of the many states where it is grown extensively and provides sustenance to more than 12 million people in the country. The processing and related activities centred on the crop, generate employment opportunities for over three million people in India. Production and marketing of diversified high-value coconut products from all parts of coconut - the kernel, husk, shell, wood, water and leaves - are a potential source of income and employment for the rural people. In addition, the crop contributes ₹ 92,000 million annually to the Gross Domestic Product (GDP) of the country. The coconut sector contributes to foreign exchange earnings to the tune of ₹ 21,385 million, through the export of coconut and coir products. Over 90 percent of coconut farmers in India are small holders and are considered resource-poor.

Of late, apart from price/market related constraints, coconut growers face many other challenges like scarcity of skilled labour, high wage rate, low productivity of coconut, depletion of natural resources in coconut gardens and soil related constraints, inadequate irrigation facilities, crop loss due to incidence of pests and disease and natural calamities. A substantial number of technologies have been developed for enhancing productivity and income from coconut farming. These include high yielding varieties and hybrids, water management and irrigation techniques, integrated nutrient management, coconut based cropping/farming system models, integrated pest/disease management practices and technologies for value addition through product diversification. However, due to various factors, the level of adoption of these technologies is comparatively low. Hence, it is highly imperative that a favourable pro-poor policy environment is evolved to protect the interests of coconut growers in the country and appropriate development/extension interventions are implemented to enhance the efficiency of coconut sector.

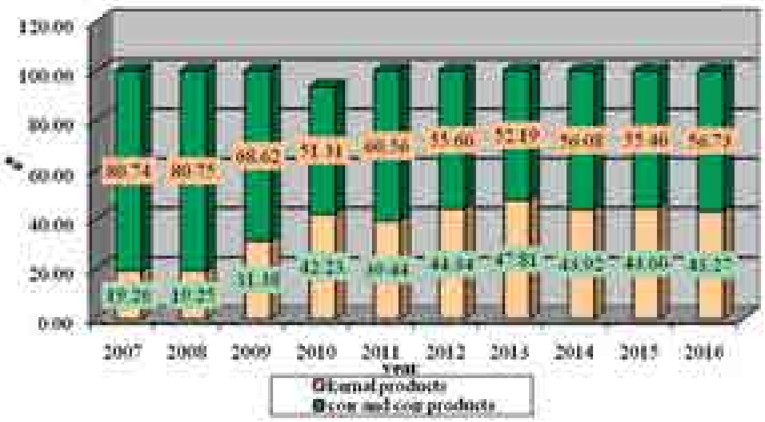
Global and National Scenario

Among the plantation crops, coconut palm is the major crop grown both under plantation and homestead management system. It provides livelihood security to several millions of people across the world, and capacity of coconut in providing improved nutrition, employment and income generation are well known. Although coconut is widely dispersed in most of the tropical regions, and grown in 93 countries in the world, out of 12.5 million hectares of global area under this crop, close to ten million hectares is contributed by only four countries, namely Indonesia, Philippines, India and Sri Lanka and they contribute 79.09% of the total area under coconut and its production in the world.

India has produced 20439 million nuts in the year 2014-15 from an area of 1.97 million ha with a productivity of 10345 nuts per hectare. Tamil Nadu is the major producer of coconut, contributing around 34 per cent of the total production in the country. Coconut is predominantly cultivated in small and marginal holdings in the country. Most of these holdings neither provide gainful employment opportunities for the family labour throughout the year nor generate sufficient income to meet the family requirement. Presently coconut growers are more exposed to economic risks and uncertainties owing to the high degree of price fluctuations. In this context it is needless to emphasize the importance of crop diversification in coconut gardens.

Export-Import scenario

During the year 2015-16, export of coconut products (excluding coir items) was valued at ₹ 1,45,024 lakhs as against ₹ 1,31,238 lakhs during the previous year, showing an increase of 11 percent in terms of value. Government of India has notified Coconut Development Board as the Export Promotion Council



Break-up of export earnings from coconut sector

(EPC) for all coconut products, other than those made from coconut husk and fibre, with effect from April 2009. During the year 2015-16 import of coconut products (excluding coir items) in terms of value was ₹ 38,326 lakhs, that is around 11 percent less than that of the previous year's import (₹ 42,166 lakhs in 2014-15). Coconut oil cake and coconut oil were the major two coconut products imported into India, of which coconut oil cake accounts for 86 percent and coconut oil accounts for 11 percent in terms of value of imports. During the period the quantity of coconut oil imported amounted to 1001.88 MT as against 2663.03MT imported during the previous year. The striking benefit derived from the notification CDB as EPC is reflected in tremendous increase in the export share of coconut kernel products since 2009-10.

It may not be feasible to arbitrarily maintain the edible oil prices high, considering the interest of consumers and the fiscal prudence of curtailing inflationary tendencies. India, being deficient in edible oils, import of palm oil becomes a 'necessary evil', as governments have to do the balancing act, safeguarding the interests of farmers, consumers and industry alike. The price of coconut oil is closely linked with the prices of other edible oils. Among the vegetable oils imported in the last year, palm oil and its fractions accounts for 73.10 percent and palm kernel oil (crude and refined) accounts for 1.40 percent. Being a lauric oil, imported palm oil seems to be the major competing oil for coconut oil and often beats down coconut oil prices in the domestic market. The excessive import of edible oils especially palm oil that too during the peak coconut production season would definitely trigger price crash of coconut oil. A closer look at the price movement of coconut oil reveals that import of large quantity of palm oil has invariably resulted in crash of coconut oil price. Although in the very recent times, the coconut prices have become attractive, the confidence of coconut farmer can be elevated only when a stabilized price regime is experienced for a reasonable time frame.

Market related challenges

The studies on marketing margins and costs are important as they reveal many facets of marketing and the price structure as well as the efficiency of the system. The term 'price spread' refers to the difference between the price paid by the consumer and the price received by the producer. Price spread involves not only ascertainment of actual prices received at various stages of the marketing channel, but also the cost involved in the process of the movement of the product. The impact of risks is more severe in the case of perennials, in which heavy initial investments are made. Price spread analysis of coconut marketing revealed that near about 70 percent of the farmers sell their produce through the village traders as raw coconuts.

Less marketable surplus due to small and marginal holding size is the major reason for the farmers for not undertaking copra/oil production for sale. The marketing channel consists of village traders, whole sellers and retailers who in turn sell their products to oil millers and retailers and send some of their lots to upcountry markets as raw nuts, edible or ball copra. Predominant marketing channel identified is 'Producer-Copra maker-Oil miller-whole seller-Consumer'.

In Kerala conditions, the producers share in consumer rupee is just around 64 percent and the market chain consumes as much as 36 percent share in the total value chain. Higher price spread always indicates a lower share of the final price to the producer. In other words, it reflects the low marketing efficiency of the market channel. The price spread and marketing efficiency can be improved only through collective and constant efforts in terms of adoption of higher value addition technologies at individual or group level.

The tender coconut market scenario in India was examined through a case study mode in Kerala. The marketing pattern, market structure and marketing efficiency in the tender coconut chain were examined. It has been observed that the sector is in the nascent stage and experiencing an evolving market regime. However, the perceived consumption trend of the tender coconuts in the country is undoubtedly on an augmented growth trajectory. The producer (farmer), as a matter of fact, enjoys very little bargaining position in the chain. Although there were multiple modes of governance and power relations in the chain, it is predominantly a middleman driven one. Direct deliveries from farmer to the retail outlets will decrease the transaction cost and also improves the market intelligence in terms of pricing and consumer demand. Contracts combined with transparent and formal credit facilitation between vendors and retailers may be the best guarantee for sustainable tender coconut sector in the future. But there are two necessary conditions applicable for such an arrangement. Firstly, the marketing should be a group activity wherein a group of farmers come together to form a sort of producer's society and actively engage in the production and marketing in a sustenance manner. Secondly, the government (institutions) should play a much stronger role in enforcement of legislation that supports this development. However, there is a huge potential for the organized development of the tender coconut sector in the country.

Plantation crops are vulnerable to the market related challenges especially in the context of trade liberalization and free trade agreements. In the present scenario of frequent fall in market prices and unsteady markets and the absence of a very responsive mechanism/agency for prompt market interventions to ensure remunerative prices in the sector, it would indeed be a herculean task to motivate the farmers to continue with the cultivation and adopt resource-demanding modern technologies. Besides, attracting women and youth to agriculture, skilled man power and infrastructure and input support for secondary agriculture are the major challenges. Further, preserving and sustaining the economic viability of all the members of the commodity chains of mandate crops is a major challenge, and requires research support for small scale, diverse and sustainable enterprises and should improve the economic and social capital of local communities.

The problems of low income from the coconut holdings due to decline in the prices of coconut and its products necessitated the need for development of appropriate coconut based farming systems to enhance the farm level income and development of broad based processing technologies for the sustainable growth of the industry. Consequent to the liberalization of the Indian economy, the domestic industry has not been able to catch up with the growth of other world leaders in the coconut sector. However, new vistas could be opened up in value addition and product development through infusion of technologies and emergence of a variety of products in the edible and non-edible sector. Now, the coconut industry in the country has realised the imperative need to become competitive. Consumer demands for varied high value products have also started recording an increasing trend.

Coconut prices in India have been historically integrated with the coconut oil prices. Therefore, indubitably the coconut prices received by the farmers are integrated with the MSP of copra. In general, the farmer prefers to sell fresh coconut when the price of coconut is attractive, as he receives a remunerative sum in his hand immediately and he can get rid of processing and transportation charges. Contrary to this, if the copra and oil prices are lucrative, farmer prefers to do at least primary level processing which would augment farm level copra production. Therefore, the MSP for copra fixed at higher levels would certainly influence and act as an incentive for the primary value addition in coconut.

Having said this, the procurement system of copra in India was always ineffective, and it never elevated the market prices to a higher level. From the NAFED's point of view, the agency, though could procure large quantum of copra and has the capacity to convert the copra into coconut, never find the market to push their product with at least a minimum margin. It should be in such a way that the MSP ensures an incentive for processing to the coconut farmers when compared with that of selling fresh coconut. Other pertinent factors in this context of discussion are lack of effectiveness and efficiency in copra procurement by the agencies and inadequate infrastructural facilities for the storage of copra. It is noteworthy that for the most part of the year copra is traded below MSP.

Coping up strategies

In the evolving trade liberalization regime, sustaining coconut cultivation as a profitable enterprise is extremely challenging. Hence, the policies should focus more on competitiveness through higher productivity. One way to achieve this goal is through reduction in cost of production increasing the net returns. There are possibilities of increasing the productivity and net returns from coconut gardens by raising compatible subsidiary crops and/or integrating with live stocks. The farming system models of CPCRI have conclusively proved that the scientifically designed coconut-based farming system is not only capable of generating higher income, but also generates additional employment for small-holders. In a scientifically laid out coconut based farming, unlike the traditional ones, the resource use efficiency gets considerably enhanced from crop interactions in the system. Moreover, farming systems are capable of improving the financial status of the smallholder, while permitting him to use the available resources more efficiently.

It is categorically proved that, scientific coconut based farming systems will mitigate the price risks of coconut monocropping by providing adequate additional returns. The recent field results from ICAR-CPCRI shows, the coconut based cropping system, using multi species cropping of coconut with pepper, banana, nutmeg, pineapple, ginger, turmeric and elephant foot yam generated a net income of ₹ 3, 62,595 per ha, which is 150% higher than that of coconut monocrop (₹ 1,41,505), while the and coconut based mixed farming system (CMFS) wherein the components are coconut, pepper, banana, crossbred cows, poultry birds, goat, and pisciculture generated a net return of ₹ 5,50,214 which is 288% higher than that of coconut monocrop.

It is of paramount importance to develop an exclusive policy by each coconut growing state for production and supply of elite planting materials to the farmer. Each state should have a separate policy frame for the area expansion and rejuvenation programmes and for the generation of required planting material of suitable varieties. There also should be separate development schemes for the execution of the programmes according to the policy frame.

Community based organizations (CBOs) of coconut farmers at different locations may be identified for establishing certified coconut nurseries for the production of elite planting materials. The ongoing decentralized planning programme in states like Kerala can support such initiatives for farmer participatory schemes for production and distribution of elite planting materials. The decentralized seedling production programme can be strengthened by, maintaining a centralized pollen storage and supply mechanism to ensure the quality of the pollen parent. Accreditation should be made mandatory for all coconut nurseries as a regulatory mechanism and to ensure control in the production and distribution of planting material.

CPCRI being the pioneering national research involved in developing improved varieties of coconut can provide breeder seed/source material for establishing nucleus seed gardens. Besides, CPCRI can also play a vital role in the capacity development programmes on nursery management to be organized for the benefit of technical personnel of CDB and state Agri/Horticulture Departments. Collaborative programmes involving stakeholders representing private sector nurseries are also important in formulating viable strategies for ensuring production of sufficient quantities of elite planting materials. CPCRI has already supported such initiative by imparting training on hybridization technique to the technical personal of private nursery groups.

There exists a huge scope for coconut based agribusiness in India with reference to processing and value added products. The crop provides employment opportunities to more than 10 million people in the country. Agribusiness management on a mission mode approach aims for maximization of farmers' income, employment and sustainability. Technologies are available for individual processing for the production of snowball tender nut, coconut chips, copra, vinegar, desiccated coconut (DC), coconut shell charcoal, packed tender coconut water, coconut cream and milk powder. The economics of production of coconut based value added products indicates fairly high level of capital requirement towards establishment and operation of these enterprises. The attractive returns from the business will, act as the motivating factor and moreover, coconut farmers are expected to realize better price stability in long run.

Due to the growing consumer demand for desiccated coconut (DC) across the world, there exists an immense export potential for the product. The capital investment required to start up a Desiccated Coconut production unit, of capacity to process 15,000 coconuts per day, amounts to Rs 1.29 crores. It is noteworthy that there are attractive export promotional schemes initiated by the Government of India under the new Foreign Trade Policy (2015-20), wherein (under Merchandise Export from India Scheme), five percent export subsidy can be availed on Free on Board (FoB) prices. There is also a Duty Draw Back scheme wherein up to one percent of the FoB prices are refunded for the service taxes paid for raw materials and other input services for the production of desiccated coconut.

Virgin coconut oil (VCO) has received much attention globally in the recent times. The popularity of VCO is growing among consumers in all the continents due to its myriad properties including potential health benefits. Feasibility analysis of the project on commercial production of virgin coconut oil revealed a Benefit Cost Ratio of 1.12, and an Internal Rate of Return of 21.5 %. Thereby, we may conclude that the commercial production of virgin coconut oil could turn out to be a profitable venture. Though the market of VCO is expanding in the domestic and International front, as a matter of fact, India is yet to realize the potential benefit that the country holds in this segment. It is imperative to establish good quality, technically advanced VCO units across the country so as to realize the competitive market share of VCO in the global market.

As a matter of fact, the processing and value addition in the coconut sector has to be scaled up manifold. India is lagging far behind in processing for value addition and export even in comparison with countries like Sri Lanka. The coconut industry will revive dramatically if it is made part of the Prime Minister's 'Make in India' campaign. This can be made possible through formation of coconut parks across the major hubs, which can provide new impetus to the coconut industry by ensuring economic enhancement of the farmers and other stakeholders through large scale activities.

Future Scenario

It is envisaged that globally well connected and highly interlinked commodity chains will evolve in the future, requiring a reorientation of the scope of the research and developmental Institutes to accommodate the restructured commodity chains and changing concept of commodity markets. The Institutes should take a lead role to re-engineer and revitalize the coconut sector in the country by providing adequate emphasis on product diversification and creation of neo-market platform to promote coconut as an organic health drink with Good Management Practices (GMP), Good Agricultural Practices (GAP) and Hazard Analysis and Critical Control Points (HACCP). Institutes should facilitate co-creative, innovative, vibrant social enterprises which will enable to pass on the value creation in the coconut sector to farmers in an appropriate manner which reduces the social disparity. With the growing realization of lesser profitability in small farm holdings, producers/farmers should be encouraged to get together and form into small cooperatives or crop based organizations to develop and utilize community facilities for farm operations, post harvest processing and marketing to economize on production as well as marketing costs. Further, research orientation will lead to an increase in the number of economically viable coconut farms of different sizes and increase in the number of processing enterprises. For the vision of developing a sturdy and vibrant coconut industry which does not depend on copra/oil/ to come true, we need to come up with a breakthrough coconut product which is strong enough to capture the niche export market segment.

ARECANUT: IT'S TIME TO REDEFINE ITS FUTURE

Like coconut, arecanut (*Areca catechu* L.) is another important plantation crop, which plays a prominent role in the religious, socio-cultural milieu and economic life of people in India. Chewing arecanut with betel leaf (or paan) with some other ingredients is an old habit still prevalent in India, especially in the Central, North and Northeast India. Arecanut provides a decent livelihood for more than three million people and assured employment of 10 million mandays annually.

The present production of arecanut in the world is about 0.854 million tonnes from an area of 0.702 million hectares. Arecanut is primarily grown in India, Bangladesh, China, Indonesia, Sri Lanka and Myanmar. India ranks first in both area (49%) and production (50%) of arecanut. In India, arecanut is cultivated in an area of 396.8 thousand hectares with an annual production of 559 thousand tonnes, mainly confined to states of Karnataka, Kerala, Tamil Nadu, Maharashtra, Assam, West Bengal and Meghalaya. Stagnating market prices and increasing cost of production, especially the skilled labour charges in the recent times, have generated livelihood concerns of arecanut farmers in India. Surging imports, which is around 12 percent of the domestic production, certainly has a significant role in price volatility. Market studies reveal that around 75 percent of the arecanut trade is in the hands of private traders, which certainly provide ample scope for market manipulations and low price realization. From a long-term perspective, low priority in area expansion and more priority for encouraging adoption of scientific methods of cultivation, especially the arecanut based cropping/farming systems, by strengthening the ToT activities would certainly benefit the arecanut farmers in terms of long-term sustainability and livelihood security.

Presently, research in arecanut is conducted by the ICAR- Central Plantation Crops Research Institute at its Regional Station at Vittal and Research Centres at Kidu (both in the Dakshin Kannada district of Karnataka), Mohitnagar (West Bengal) and Kahikuchi (Assam) while the developmental portfolio rests with the Directorate of Arecanut and Spices Development (a subordinate office under the Ministry of Agriculture & Farmers' Welfare, Government of India), Kozhikode in Kerala. In fact, comprehensive R&D efforts in arecanut started as early as 1947 with the establishment of an ad-hoc arecanut committee by the ICAR to study the problems of arecanut industry and subsequently, the Central Arecanut Research Station (CARS) was established at Vittal in 1956. Consequent to the establishment of the CPCRI in 1970, the CARS became the Regional Station of the Institute.

R&D efforts in arecanut: In the colonial period and beyond

In fact, initial efforts on improvement of the arecanut sector in India began as early as in 1914 under the Mysore Agriculture Department at a government farm at Marthur in the malnad area of Shivamogga district of Karnataka, with the main objective of tackling the fruit rot disease. Experiments on manuring and selection were also taken up at this farm. Unfortunately, researches were discontinued with the closure of this farm in 1939. Later efforts, mainly concentrated on the control of diseases like fruit rot (koleroga in kannada or mahali in Malayalam) and Anabe were carried out by the Agricultural Departments of erstwhile Madras, Mysore and Bombay States.

Opposite: Mangala

Institutional Timeline

1947 : Ad hoc Arecanut Committee formed

1949 : Government of India constituted Indian Central Arecanut Committee (ICAC)

1951 : Nursery schemes initiated by ICAC

1952 : Establishment of a Research Station for investigation of stem-breaking disease of arecanut at Vittal

1955 : Land taken possession for establishment of Central Arecanut Research Station

1956 : Establishment of CARS at Vittal

1958 : RARS, Peechi, RARS, Hirehalli and RARS, Mohitnagar came into existence

1959 : RARS, Kahikuchi and RARS, Palode came into existence

1959 : Arecanut Technology Unit started functioning at CFTRI, Mysore

1961 : Construction of laboratory buildings of RARS at Palode, Peechi and Mohitnagar completed

1962 : Construction of laboratory building of RARS Hirehalli completed

1962 : Arecanut Technology unit of ICAC at CFTRI got merged with CSIR-CFTRI

1964 : Construction of laboratory building, guest house and 11 quarters at CARS completed

1966 : The Central and Regional Arecanut Research Stations came under direct control of ICAR

1970 : The Central and Regional Arecanut Research Stations and the Central Coconut Research Stations got merged to form the Central Plantation Crops Research Institute with its headquarters at Kasaragod; CARS Vittal becomes the Regional Station and the five RARS become Research Centres under the CPCRI

1975 : Construction of the administrative building and 35 additional quarters completed

1999 : CPCRI Research Centre, Palode merged with ICAR-IIOPR, Pedavegi

2002 : CPCRI (RC) Hirehalli station handed over to ICAR-IIHR

2007 : CPCRI (RC) Peechi (Kannara) station phased out

Field-level management of the fruit rot prevalent in all the arecanut growing tracts with Boreaux mixture spray was an important activity of the Agriculture Department under the Madras Presidency. The Report of the Madras Agriculture Department for 1922 expresses disappointment over the recurrence of the disease and blames the lack of concerted efforts on the part of the growers for the same. *"A serious recurrence of the disease was reported by the garden owners of Honnaver of the Coondapur taluk in South Kanara district* -----. *Very* *careful demonstration work was carried out at this place by the Mycological section in the years prior to 1913, when the methods of dealing with this disease were fully demonstrated and understood, and it is disappointing to note that further help should again be required in an area where the garden owners are fully conversant with the necessary remedial measures".*

The report for 1923 analyses the direct relation between the heavy rain fall during monsoon and the severe incidence of the disease, the need for prophylactic spray, and some of the unhealthy practices prevalent at that time. *"This disease in South Malabar has occupied the attention of the Department for many years. Recently, there has been a succession of seasons unfavourable to the disease and the damage caused by it has decreased in consequence. This year, however, the early rains at the end of June and the beginning of July favoured the disease and it made its appearance again and caused a great deal of damage. It is necessary that, if this disease is to be controlled, to do the spraying before the fruit bunches are attacked by the fungus; that is to say, the spraying is a preventive measure. Too often the ryots spray only after the attack has begun, and also try to save money by applying the spray with brushes instead of proper machines and by using a weaker solution than is necessary. Necessary educational propaganda was undertaken to eliminate these mistakes".*

Another document, "A Popular Account of the Work of the Madras Agricultural Department" (1922) by HC Sampson, the then Director of Agriculture of Madras Presidency, while making an account of its activities and the economic impact of these interventions, claims to have undertaken spraying arecanut bunches with Bordeaux mixture as a preventive measure against Mahali disease covering 42,953 palms in 1916-17 at the cost of 2 annas per tree resulting in an economic gain of ₹ 5,400. This report also makes an empirical projection of potential economic benefits of a larger initiative covering 5.200,000 palms in the entire arecanut growing tracts of Malabar and South Canara, if undertaken, would have given an economic benefit of ₹ 6.50,000. Incidentally, this report also gives rare insights on the state of affairs of arecanut in those days. *"The disease is common in South Malabar, especially in the Ponnani taluk where it formerly caused a loss of some 50 per cent of the crop. A tree bears on an average 200 nuts, the value of which at present (in 1922) prices is 8 to 12 annas".*

However, the organized research on the all-round improvement of the crop encompassing all aspects of the crop was started only with the establishment of the Indian Central Arecanut Committee (ICAC) in 1949 and with the opening of a network of research stations in the important arecanut growing belts of the country. The work initiated by the ICAC was subsequently taken over by the ICAR in 1966 and then the CPCRI (under ICAR) since 1970.

Turbulent times of the 1950s

Arecanut industry in India was also passing through a crisis when the second World War broke out. By 1945, representations were made to the Central Board of Revenue regarding its deplorable plight, the heavy cost of cultivation and poor return mainly due to the absence of scientific research to improve cultivation and augment production, the heavy crop loss due to fruit-rot and the ill-developed marketing system in vogue. The unrestricted imports of arecanut at low prices from the East Pakistan (now Bangla Desh) in the aftermath of the partition in 1947, further aggravated the problem. There was demand from arecanut farmers for immediate protection in some form or the other for the local industry for its survival.

Indian Central Arecanut Committee, the 8th and the last Commodity Committee in India

As a first step towards the improvement of the arecanut industry, the Government of India sets up an ad hoc Committee under the Indian Council of Agricultural Research to formulate co-ordinated schemes for the purpose. On the recommendations of this ad hoc Committee, the Government of India, constituted the Indian Central Arecanut Committee (ICAC) (the youngest of the eight commodity committees) in May 1949, with headquarters at Kozhikode in Kerala. The ICAC was entrusted with the responsibility of assisting the Government in the improvement and development of production and marketing of arecanut and arecanut products and all other matters incidental thereto. The Committee was mandated to work in collaboration with State Governments and co-ordinate its activities in this sector.

Cognizant of its responsibilities, the ICAC initiated various programmes aimed at increasing production of arecanut to make the country self-sufficient in the commodity, by putting it on a sound scientific footing and also ensuring adequate protection to the indigenous industry. For achieving this objective, a three-pronged approach was envisaged: initiating research on production and (post harvest) technology aspects, adopting novel strategies for reaching out to the farmers, and putting in place a better marketing structure.

One of the landmark decisions (taken in its second meeting in 1948) of the ad hoc Arecanut Committee was to undertake an all India arecanut survey on the agricultural practices adopted in different parts of the country. Shri K. K. Nambiar, the Secretary of the Committee in his comprehensive survey report, besides presenting the details of arecanut cultivation in various parts of the country, also came out with some path-breaking recommendations, which paved the foundation for the later research and development programmes initiated by the Indian Central Arecanut Committee. Subsequently, K.K. Nambiar was also deputed to Malaysia and Singapore for a month (from 10-8-1953 to 9-9-1953) under the Colombo Plan (funded by UK) to study the cultural practices and methods of processing of raw nuts (from where it is extensively imported at cheap prices) so that it could be profitably utilized in India.

The basic strategy enunciated was that production of arecanut in India to be enhanced to meet the deficit by increasing both the yield per unit area and the area under the crop. Emphasis should be on intensive cultivation by adopting more effective cultural and manurial practices and on control of pests and diseases. For strengthening the research infrastructure, a central research station to be set up for undertaking fundamental and applied studies along with four or five regional research stations in important arecanut growing regions of the country for solving location-specific problems. It also recognized the need for collecting correct statistics regarding area and production of arecanut in the country, establishment of arecanut nurseries to supply quality seedlings and extension programme targeting the growers.

Research Stations on Grant-in-Aid Basis

In furtherance of the committee recommendations, the ICAC in 1951 approved schemes formulated by the Governments of the major arecanut growing states (on the basis of equal sharing of expenditure between the state and the Central Arecanut Committee) for establishment of regional research stations in the erstwhile Bombay, Mvsore, Madras and Travancore-Cochin States. The first station was established at Vittal in South Kanara district on 1st August, 1952, under the scheme proposed by the then Madras Government, for investigation on the stem-breaking disease of arecanut palm. A second station was established at Ollukkara near Trichur in erstwhile Travancore-Cochin State on 17th October, 1952. A third station was started at Yadehalli near Thirthahalli in the Mysore state and a fourth at Sakigopal in November 1957, sponsored by the Government of Orissa (Odisha). Unfortunately, all these stations could not sustain itself beyond 1955/1963, except the one at Yadehalli (this too subsequently taken over by the Karnataka State Horticulture Department in 1966).

Change of Strategy: Establishing Research Stations directly under the ICAC

The failure of the grant-in-aid stations forced a rethinking of the strategy. Then, it was envisaged to establish Regional Stations (directly under the ICAC) first and then later convert one of them as a Central Station. Since the above programme also did not materialise, the ICAC decided in 1953 to establish a Central Arecanut Research Station (CARS). During the Second Five Year Plan period (1956-57 to 1960-61) setting up of Regional Arecanut Research Stations (RARS) constituted a major item of work under ICAC.

Central Arecanut Research Station (CARS) established at Vittal

On the recommendations of a special sub-committee, the ICAC decided to locate the CARS at Vittal (in the erstwhile Madras State) in the Dakshina Kannada district of Karnataka. Shri P. A. Srinivasan was appointed as Special Officer in June 1955, to arrange for the acquisition of the required land and attending to preliminary works connected with the starting of the Station. The CARS finally came into existence in April, 1956, with an area of 6.7 ha of land acquired for the purpose. The terrain of the Station was of hillocks and a shallow valley embedded within it, with the winding rivulet 'Vokkethur' running placidly along the north-eastern boundary and then through the middle of the Station.

Regional Arecanut Research Stations for location-specific research

Regional Arecanut Research Stations (RARS) were established in five different agro-climatic regions of the country with the objectives of improving the quality and yield of arecanut in the region, evolving suitable manurial, cultural and irrigation schedules for adoption by the farmers, formulating, and organising control measures against pests and diseases affecting arecanut in the region, and raising quality areca seedlings from selected mother palms and supplying to farmers in their respective region. The RARS were located at Hirehalli (representing the low rainfall maidan), Peechi and Palode (representing the coastal and southern Kerala with more uniform distribution of rainfall), Mohitnagar (representing the alluvial types of soil of West Bengal) and Kahikuchi (representing north-eastern India).

CARS on the developmental path

It was extremely difficult days in the beginning, as the station was bereft of all basic amenities like roads, electricity, permanent buildings to house laboratories and offices, and living accommodation for staff. For crossing the flooded river during monsoon to reach the location, the station maintained its own country boat initially, then built a bamboo foot-over-bridge in 1961, and finally a bridge-cum-vented dam was constructed in 1967-68. The first building constructed was a small farm shed with a tiled roof in 1958-59, followed by one more shed for a field laboratory during 1960-62.

The first major construction consisting of one laboratory building, guest house and staff quarters was initiated in 1961-62 and got completed during 1963-64. Between 1970 and 1975 (after the formation of CPCRI) another set of 35

quarters for scientists and other staff besides an administrative block were constructed. In subsequent years, other facilities like a dispensary, a club room and a canteen were also constructed. In the third stage, construction of additional rooms for the Guest House, a farmers' hostel and more staff quarters was undertaken in 1978-1979.

The first field planting in the Station was the progeny garden of 2.23 ha in 1957, followed by a spacing trial garden in 1958. Till 1970, all the experimental plantings were only on arecanut or crops associated with it as inter or mixed crops. From 1971, two other crops, cashew and cocoa were also included in the different studies.

As per the scheme, the research work at the Central Arecanut Research Station, Vittal was started from 2-4-1956 (scheduled to be terminated by 31-3-1966) with a total budget of ₹ 6,66,976 (with a recurring component of ₹ 5,47,526 and non-recurring share of ₹ 1,19,250) over a period of 10 years. However, with the abolition of the Arecanut Committee and ICAR taking over the CARS in April 1966, financial position improved considerably. The sanctioned budget estimates of CARS along with its Research Stations for 1969-70 alone was ₹ 14,89,500.

The original scheme had only five scientists including an Arecanut Specialist who was also the administrative head of the Station. Initially, there were three sections (agronomy, botany and pathology) and during 1963-64, two more sections, statistics and soil chemistry, were added. Separate sections on entomology and plant physiology were established during 1964-65.

Research collaboration at national and international levels

Right from the beginning, strong linkages and collaborations were struck with the Central Coconut Committee and the two Central Coconut Research Stations (CCRS) under it. As a rational measure of sharing resources and utilizing the expertise and facilities available nearby, some research activities envisaged in the technical programme like anatomical studies on structure and development of fruits in areca were taken up at the Central Coconut Research Station, Kasargod. Physiological studies on studies on fruit setting and shedding and salt resistance experiments with areca seedlings were mandated to be taken up at CCRS, Kasargod, while the physiological studies on germination of arecanut at the CCRS, Kayamkulam.

Collaboration with Commonwealth Institute of Biological Control, Bangalore was obtained for the supply and rearing of predators for the biological control of mites. Some specimens were also got identified by the Commonwealth Entomological Institute, London. Dr. F. J. Simmonds, Director, Commonwealth Institute of Biological Control, Trinidad along with Dr. V. P. Rao, Entomologist-in-charge, Commonwealth Institute of Biological Control, Bangalore had visited CARS in 1969 for fruitful discussions.

Pioneering research and development in arecanut

The country's pressing problem in the early fifties with respect to arecanut was one of acute shortage in the supply of the commodity. The research stations were therefore mandated to provide the know-how for increasing the production of arecanut both by expansion of area under the crop as well as by intensifying the production in the existing areas through intensive research and development programmes. Considering the initial difficulties in establishing the research stations, the long time-duration for obtaining experimental results leading to meaningful inferences and recommendations (on account of the long gestation period and other inherent peculiarities of the crop), the progress made in developing suitable technologies and its transfer to the farmers were substantial.

Empowering the nation for a quantum jump in production

Obviously, the first step was developing suitable techniques for selecting seed and raising seedlings, and procuring, raising and distributing seeds and seedlings both for use in the research stations and to the farmers. As a result of a series of nursery trials conducted at the research stations, the nursery techniques were standardised. Farmers were also trained in the correct technique of raising seedlings.

Concurrently, research programmes in crop improvement were taken up, which involved introducing and testing the performance of arecanut varieties from different countries besides evaluating the types available within the country. A fruitful result of these investigations is the high yielding variety, Mangala, released to the areca growers in the early seventies. It has three important characters like early bearing (within 3-4 years), semi-tall stature and higher yield (75 per cent more than the local). The variety has gained popularity among the farming community within a short span of 5 to 6 years after its release for general cultivation. An important collection made in the earlier years was the dwarf arecanut palm located in Hirehalli area of Karnataka which has about $^{1}/_{3}$rd the height of normal type of equal age, available presently for cultivation.

The third aspect in the research programme was to determine various agronomic requirements like spacing, planting, manuring and irrigation. The spacing trials have suggested that the arecanut palms when planted as sole crop require a spacing of 2.7m x 2.7m or slightly closer, with an average of about 7.3 m^2 space per palm for highest yield per unit area. The cultural experiment done under the maidan conditions of Hirehalli indicated that digging the garden twice a year gives higher yield. In central Kerala, digging had no advantage, but a clean cultivation without weeds was ideal. In slopy lands of southern Kerala, clean cultivation and planting palms along the contour was the best. Mulching the gardens with organic matter like chopped areca leaf, arecanut husk or dry leaves from forest lands was found to conserve moisture, besides suppressing weed growth.

The manurial experiments definitely proved the advantage of application of green leaf besides determining the optimum N, P and K requirements of the palm. The recommendation emerged out of these studies is application of 12 kg each of green leaf and cattle manure, besides nitrogen (N) 100g, phosphoric acid (P_2O_5) 40 g and potash (K_2O) 140 g per palm per year.Irrigation experiments elucidatd the water requirement and scheduling of irrigation intervals for arecanut. In southern Kerala, where gardens are not commonly irrigated, irrigation alone has been able to increase yield by two to three times. The water requirement of arecanut in central Kerala during the dry months was found to be 82.5 cm. At Vittal, irrigation requirement was worked out based on evapo-transpiration. An irrigation of 30 mm depth when the evaporation is 30 mm has been found the best. Labour saving methods of irrigation like sprinkler, perfo and drip systems were recommended in view of economy and efficient use of water.

The need for utilising the available natural resources (land, water, sunshine etc.) as well as the inputs to the maximum were realized early. Studies on the rooting habit and growth (spread of crown) of the palm have indicated that both the soil as well as the above ground space is not fully utilised by the areca palm when it is raised as a pure plantation, especially during the early 4-5 years of pre-bearing growth period. From this realization, systematic trials with a large number of annual and perennial crops as inter and mixed crops in arecanut gardens were initiated. Among the annual crops or crops of similar nature, elephant foot yam, arrow root and banana were found to be ideal. For the requirement of green fodder, Guinea grass was recommended for cultivation in the interspaces. Among the perennials, pepper, cardamom and betel vine were suggested, depending upon the locality and the needs of the market. The most notable introduction is that of cocoa as a mixed crop with arecanut. By the late 60s/early 70s, cocoa had established as a successful mixed crop with arecanut. With cacao as a mixed crop it is possible to double the income of arecanut farmers. In the existing arecanut gardens with the normal spacing of 2.7 m x 2.7 m for arecanut, the spacing recommended for cocoa is 2.7m x 5.4m. From the spacing trial running at Vittal, a spacing of 3.3m x 3.3m for both the crops is indicated as optimum for the combined cropping system.

Research efforts were also made on studying the various pests and diseases of arecanut prevailing in different areas. The most important of the pests are root grubs (*Leucopholis burmeisteris* feeding on roots, spindle bug (*Carvelhoea arecae*) harbouring in the leaf angles and feeding on the tender unfurled spindle, and mites of various species, damaging the leaf surface and green fruits. For all the pests, appropriate chemical control measures were evolved and recommended. Diseases like the fruit rot and bud rot (both caused by *Phytophthora meadii*), Anabe (caused by *Ganoderma lucidum*) and the yellow leaf disease (YLD) were found to be damaging the palms to varying extents.

Spraying Bordeaux mixture continued to be the most effective preventive measure for fruit rot (Koleroga or Mahali) disease based on extensive multilocltional trials. Covering of arecanut bunches with polythene covers, which was the modification of "Katte" or "karda",before onset of the monsoon ensures complete protection from the disease. The yellow leaf disease (YLD), which has extended to about 32,000 ha in Kerala and a few isolated pockets in Karnataka by the 1980s, was another area of research attention. Studies on the disease were initiated as early as 1958, with the establishment of the Research Centre at Palode. By the 1980s, several biotic factors like fungi, bacteria, virus and phytoplasma (MLO) were reported to be associated with the disease, though the pathogenicity of these associated organisms were not conclusively proved. The palms grown in low-lying areas with high water table are found more vulnerable for the spread of the disease. However, intensive efforts made in the later years has contributed in elucidating the phytoplasmal etiology and developing integrated management practices for this malady.

Initial efforts on post harvest technology and value addition in arecanut

Though the original plan was to locate the Technological Research Unit on arecanut also at Vittal, the Unit was 'temporarily' located at the Central Food Technological Research Institute (CFTRI) Mysore, since basic facilities like electricity were not available at that time at Vittal. Unfortunately, this unit which started functioning from February 1959, later got 'permanently' merged with the CFTRI with effect from July 1962. Important achievements of this unit were developing a method for storage of ripe arecanut fruits for off-season use, developing a drier for processing and drying of arecanuts, chemical analysis of various trade varieties of arecanut with a view to prescribing quality grade standards and utilisation of arecanut husk for manufacture of paper, etc.

Supplementing the work of the Technology Unit, the ICAC also arranged several schemes for technological research on arecanut and its by-products under various universities and R&D laboratories on a grant-in-aid basis. These schemes were helpful in elucidating the basic quality, chemical constituents and certain pharmacological properties of arecanut.

Developmental and Marketing Initiatives

As part of the developmental activity, the ICAC launched several programmes encouraging area expansion under arecanut and adoption of improved cultivation practices for higher production from the existing gardens. Two important interventions were the supply of various inputs like quality planting materials through its extensive network of regional nurseries and making extensive extension activities for popularizing the scientific methods of cultivation. Excellent extension materials like a Picture Book (Flip Book) on "Arecanut Cultivation" and a documentary film on "Growing Arecanut" are worth mentioning.

The lack of adequate marketing facilities for arecanut and the exploitation of arecanut growers by traders was realised even from the early days. The ad hoc Arecanut Committee, in its first meeting itself, resolved to appoint a Cooperative Marketing Officer to study the problems of arecanut marketing and organise cooperative societies for the proper marketing of arecanuts. The ICAC, as a matter of policy, took up several steps to organise and develop cooperative marketing units in important arecanut producing states of Karnataka, Kerala, Assam and Maharashtra. The Committee also played a proactive role in the successful working of the 'Regulated Markets' for arecanut established under the "Agricultural Produce Markets Act" in the important assembling centres, where the areca growers generally sell their produce. Regulated markets were established in all the important arecanut assembling centres in Karnataka state and arecanut was included as a notified crop under the Act. In Kerala too, a Regulated market for arecanut was established in the erstwhile Malabar district.

Conscious of the repercussions of the unrestricted imports of arecanuts on the domestic industry, one of the earliest resolutions of the Committee was to recommend for restricting the unabated imports. Accordingly, arecanut imports were regulated from 1949-50 onwards, by imposing protection duty on imports, besides a ceiling on the monetary value and quantum of imports. These measures, undoubtedly, gave a boost to the indigenous production of arecanut.

The concerted efforts of ICAC (from 1949 to 1965) and later by the ICAR/CPCRI and the Arecanut Development Council through the planned research and development programmes brought the country to the threshold of self-sufficiency in arecanut by the early seventies, probably a few years earlier than anticipated. However, the internal marketing system was not sufficiently evolved commensurating with the rapid rate of increase in production, which has resulted in lowering of arecanut prices in the production centres creating a panic among the growers by the end of 1971. The decline in the prices was as much as 30-40 per cent in 1973 from that of 1969-70 levels.

On the representations of the growers, the Government of Karnataka constituted a Committee in 1972 led by Shri T.T. Paulose to examine the causes of declining prices and suggest suitable means to improve the condition. The Committee in its report submitted to the Government in March 1973, recommended among other things, setting up of a central organisaton for procurement of the bulk of the produce, for its proper storage and timely release for sale as and when there is demand. A fruition of this initiative was the establishment of the Central Arecanut Marketing and Processing Cooperative Limited (CAMPCO) in July 1973, with the growers and the two state governments of Karnataka and Kerala joining hands for a worthy cause. Within a short period of 2-3 years after its establishment, the CAMPCO could exert an impressive impact in stabilising the arecanut prices.

Impact of R & D Programmes in the Arecanut Sector

The concerted research, development and marketing programmes had a spectacular impact on the production of arecanut in the country in the first three decades since the inception of an R&D system. There was both an increase in the cultivated area and productivity. The area under arecanut increased by nearly 100 per cent; the production recorded a raise of about150 per cent and productivity per ha increased by over 30 per cent. While the increase in area might be attributed to the developmental measures taken up by various agencies, the productivity per unit area can be attributed to the scientific endeavours and its adoption in the farmers' fields. The farmers are motivated towards scientific cultivation because of the enhanced returns and fairly steady market condition.

Reorganization and devolution of functions

With the dissolution of ICAC in 1965, as in the case of all the eight Commodity Committees, ICAR took over the research responsibilities directly under it *(a fallout of the recommendations of the Agricultural Research Review Team of 1963 on ICAR reorganization)*, and the developmental and marketing programmes were entrusted to the Indian Arecanut Development Council and later the Directorate of Arecanut and Spices Development, Kozhikode from April 1966 onwards.

Subsequently, the CARS with its regional arecanut research stations (RARS), along with the two Central Coconut Research Stations (at Kasaragod and Kayamkulam) were merged together to form the unified Central Plantation Crops Research Institute (CPCRI) in January, 1970 with its headquarters at Kasaragod. The CARS at Vittal was redesignated as a Regional Station and Regional Arecanut Research Stations were converted as Research Centres of CPCRI.

Strengthening of research under CPCRI: emphasis on developing technologies

Since its inception, the institute has made significant achievements in improving the arecanut production techniques and thereby increasing the farm income and improving the living conditions of arecanut farmers in the country. The arecanut production techniques such as planting material production, planting, irrigation, fertilizer application, plant protection, cultural operations etc. are standardized for optimising the production condition. Also suitable inter/mixed crops for arecanut gardens for different agro-climatic regions were identified to enhance the net return from unit area.

Enhancing the genetic base

Base/primary collection of arecanut resources is maintained in field genebanks, as in crops like arecanut with recalcitrant seeds (seeds which cannot be dried and frozen without killing the embryos), seed genebank is not a viable option. The institute maintains world's largest arecanut gene bank comprising 169 accessions with 146 indigenous and 23 exotic ones. The exotic accessions are introduced from other areca-growing countries in the South-East Asia like Fiji, Mauritius, South China (Taiwan), Sri Lanka, Indonesia, Saigon, Singapore, British Solomon Islands, and Australia representing four areca species (*Areca catechu, Areca triandra, Areca normanbyii* and *Areca concinna*) and one related genera (*Actinorhytis calapparia*).

Development of varieties through selection

The high yielding Mangala variety of arecanut, which is semi tall and an early bearer, was released during the year 1972. It gives an average yield of 3.00 kg chali (dry kernel)/palm (30 tonnes/ha) compared to the 2.00 kg chali/palm (20 tonnes/ha) of SK Local variety. At present rate, the gross return from Mangala variety is ₹ 7.5 lakhs/ ha compared to 5.0 lakhs/ha by the local variety. A field survey conducted in Dakshina Kannada showed that about 12% of the arecanut gardens were occupied by Mangala variety by 2004.

Since then, the institute has released seven more high yielding arecanut varieties, Sumangala (VTL-11 from Indonesia), Sreemangala (VTL-17 from Singapore), Mohitnagar (VTL-60), Swarnamangala, Madhuramangala, Nalbari

Nalbari

Madhuramangala

Mohitnagar

Arecanut varieties released by CPCRI

Variety	Year of release	Yield (kg/palm)	% increase over local
S.K. Local	-	2.00	-
Mangala	1972	3.00	50
Sumangala	1985	3.28	64
Sreemangala	1985	3.18	59
Mohitnagar	1991	3.67	84
Swarnamangala	2006	3.78	89
Kahikuchi	2010	3.70	85
Madhuramangala	2006	3.70	85
Nalbari	2014	4.15	108
Shatamamgala	2016	3.98	99

and Kahikuchi through selection, which gives 50 to 100 per cent more yield than the local varieties. The initial performance of these recently released varieties in farmers' gardens is very encouraging, resulting in very high demand of planting materials of these varieties.

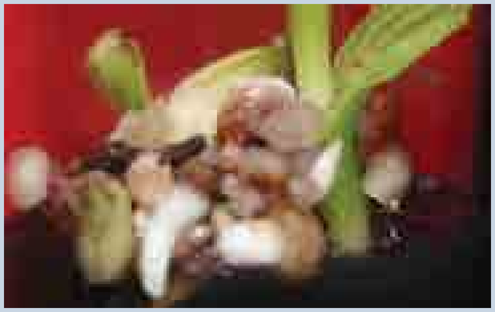
Dwarf hybrids of arecanut

High yielding dwarf hybrids involving Hirehalli Dwarf (HD) and released varieties were developed through hybridization, evaluation and selection. These hybrids were evaluated for about fourteen years in the field for their

VTL-AH1

VTL-AH2

Arecanut tissue culture: A success story



Protocols for somatic embryogenesis and plantlet regeneration from leaf and immature inflorescence explants in arecanut have been developed at ICAR-CPCRI. Optimization of culture media, type of explant, plant growth regulators and their concentrations, other additives and sub-culturing schedules have paramount significance in developing a reliable tissue culture protocol. Murashige and Skoog (MS) medium was found to the best and picloram most suitable callogenic agent. Serial transfer of explants from higher to lower auxin concentratio to hormone-free medium at 30–35 days interval was essential for sustained growth of callus and somatic embryo induction. Hormone-free MS medium was used for somatic embryo formation. Germination of somatic embryo was achieved in half strength MS medium supplemented with cytokinin BA was found to be the best. For rapid germination of somatic embryos, MS liquid medium supplemented with BA was used. Plantlets with 2-4 leaves and fairly good root system were transferred to potting mixture, consisting of sterilised sand and soil in the ratio of 5:1. This protocol for mass multiplication of elite arecanut palms is being utilized for propagation of palms field-resistant to yellow leaf disease (YLD) and dwarf varieties. Recently, this technology has been transferred to an R&D laboratory in the private sector for commercial exploitation.

performances in terms of yield attributes and dwarfness. Among the hybrids, HD x Sumangala and HD x Mohitnagar were found to be superior for yield performance along with the dwarf stature. As a natural culmination of these efforts, these two dwarf hybrids were released as VTL-AH1 (Hirehalli Dwarf x Sumangala) and VTL-AH 2 (Hirehalli Dwarf x Mohitnagar) during 2006/2007. The average yield of VTL-AH1 is 2.54 kg dry kernel (chali) per palm per year, while VTL-AH 2 gives 2.64 kg dry kernel (chali) per palm per year. Being dwarf in stature, the cost of cultivation particularly for spraying and harvesting can be reduced by about 40%. Also the problem of non-availability of skilled labours (climbers) can be solved to a great extent by planting dwarf types.

Multiple benefits of an arecanut based multispecies cropping system

Adoption of a cropping system approach is indispensable to increase the productivity per unit area and to avoid risks due to soil, climate and economic constraints. This is more so in arecanut, which has long pre-bearing period leading to high investment and low returns in the initial period. But, the success of a cropping system depends on the relative shade tolerance of component crops. It also becomes necessary to grow value-added and export-oriented inter/ mixed crops in this era of WTO-mediated trade agreements/regional FTAs, as arecanut has limited alternative uses and export potential. In the tropical countries, where the farm holdings are small and perennial crops like arecanut and cocoa occupy the land for several years, a small farmer cannot afford to lose the crop due to any of the climatic disasters or pest and disease attack as he is wholly subsistent on it.

A High Density Multi Species Cropping System (HDMSCS) is the single-point answer to all these multiple concerns. It is a system of growing more than two crops having different stature and rooting habits grouped to form compatible combinations so as to enable interception and utilization of light at different vertical intervals and facilitate foraging the soil at different layers and columns. Realizing the prime importance of this concept, research on the theory and practice of HDMSCS was initiated in 1980s at CPCRI. Initial studies showed that approximately 60 per cent of the incident light is only intercepted by an adult areca palm and that this could be increased to about 95 per cent by growing intercrops. The root distribution studies in arecanut reveal that at the recommended spacing arecanut uses only about 35 per cent of the space and the remaining 65 per cent of the space can be used for raising inter/ mixed crops.

Intercropping also leads to increased availability of organic matter for recycling. In arecanut and cocoa mixed cropping, the higher litter fall and prunings of cocoa improves the organic matter content, soil fertility and increased microbial activity. Initial period of 5-6 years is ideal for growing annual and biennial crops. In later years, mixed cropping with other shade tolerant crop species is advocated. Short statured crops like tuber crops, rhizome crops, vegetables,

Opposite: Shata Mangala

flower crops can be successfully grown in arecanut during pre-bearing stage. Perennial crops like cocoa, banana, black pepper, acid lime and cardamom are ideal component crops for grown up arecanut plantations. Value added crops like vanilla and medicinal and aromatic crops come up very well in arecanut. Efficient high density cropping models involving component crops like cocoa, banana, pepper, acid lime, cardamom etc. have been developed for different arecanut growing regions in India.

The comprehensive study on arecanut based high density multispecies cropping system (HDMSCS) for over 20 years has led to developing HDMSCS models with cocoa, banana and pepper, ideal for the coastal regions and plains of South India. Cocoa and black pepper or banana, betelvine and lemon crops are found to be profitable mixed crops for Maidan parts of Karnataka. It was observed that arecanut yield increased by up to 20 % in the arecanut based cropping systems, besides progressive increase in yields of intercrops. For Assam and Sub Himalayan Terai region, arecanut based HDMSCS models with inclusion of lemon and spices (arecanut + black pepper + banana + lemon + clove or alternatively, arecanut + black pepper + banana + lemon + nutmeg) are highly profitable with a high benefit cost ratio of 3.2-3.6. It has also been found that other crops like turmeric, ginger, cowpea, banana and citrus also grow well in arecanut gardens, offering good options catering to specific family requirements.

Arecanut based multispecies cropping system helps the farming community to effectively utilize the unit area of land available to realize higher income and employment opportunities. The initial results (for first three years) from the demonstration plots on arecanut based cropping system in Kasaragod and Dakshina Kannada districts showed an increase of arecanut yield (dry kernel or chali) from 2135 kg/ha to 2550 kg/ha. Also, on an average, additional income of ₹ 1,06,753 per hectare was realized from banana intercrop alone during the initial three year period. A survey conducted in Karnataka during 2015 indicates that about 65-85% of arecanut gardens are presently covered with intercrops, a living testimony to the necessity and versatility of a such a system.

Arecanut based mixed farming system is a profitable and sustainable family enterprise

A judicious mix of cropping systems with associated enterprises like dairy would bring prosperity to the arecanut farmer. Arecanut based mixed farming system (ABMFS) model of one hectare comprise of arecanut+fodder grass in 0.75 ha, fodder grass sole in 0.1 ha, dairy component in 0.1 ha and fishery component in 0.05 ha. From this system, about 56-72 tonnes of green fodder could be obtained which is sufficient for maintaining 5-7 cows. This system can meet the requirement of N (1.5 ha), P (2.5 ha) and K (0.66 ha). ABMFS provides about 55% of higher gross income and 25% of net income over arecanut sole cropping. The benefits are directly associated with increased productivity, increased income and improved sustainability.

Technologies for higher sustainability, profitability and value addition

The institute has recommended the fertigation technique (application of fertilizer through irrigation) which reduces labour and also the requirement of fertilizer by 25-50%. The technology for recycling bio-wastes available from arecanut garden provides about 80% recovery of vermicompost and it is sufficient to meet 100 per cent requirement of N and P and 37 per cent requirement of K.

Value-added technologies are now available for arecanut byproduct utilization such as production of edible oyster mushroom (*Pleurotus sajor-caju*) rich in proteins from the leaf and bunch wastes, making of eco-friendly disposable plates and bowls from areca leaf sheath, leaf sheath fodder etc.

Integrated Disease Management for arecanut diseases: Challenges ahead

Fruit rot caused by *Phytophthora* and YLD caused by Phytoplasma are currently the most important yield-limiting factors in arecanut. The increasing incidence of other diseases like inflorescence dieback and basal stem rot are the other concerns. Control of yield loss (10-90%) due to Phytophthora diseases is a huge challenge. The *Phytophthora* causing fruit rot was identified as *P. arecae* by E.J. Butler in 1910. Later, Dr. Chowdappa and his team reclassified *P. arecae* as *P. meadii* based on morphology and molecular crtiteria. However, it is not clear whether, *P. meadii* infecting rubber, cardamom and nutmeg and arecanut are identical or different. Heavy rainfall, non-availability of skilled climbers for spraying during rainy season, absence of machinery for effective delivery of fungicides, variability and occurrence of more virulent strains of the pathogen are the most important constraints in the adoption of the recommended control measures. Elucidation of resistance mechanism of certain wild *Areca* species to *Phytophthora* and identification of the genes governing resistance, and exploring the possibility of using resistance genes to develop improved arecanut varieties with resistance to fruit rot disease require greater focus.

Yellow leaf disease (YLD) is taking a heavy toll of areca palms every year and the disease has rendered arecanut cultivation in diseases tracts unremunerative to the farmers due to severe reduction in yield. Yellow leaf disease caused by Phytoplasma is characterized by inter-veinal foliar yellowing commencing

Impact of research on arecanut production

With the introduction of high yielding varieties and the improved crop production and crop protection technologies, the net return from mono arecanut (₹ 3.80 lakhs) and arecanut based cropping system with cocoa, banana and black pepper (₹ 8.8 lakhs), and arecanut based mixed farming system with dairying,aquaculture and fodder grass (₹ 6.6 lakhs) has greatly enhanced during the last four decades and consequently the arecanut farming has become more profitable now (than ever before) compared to many other crops. The area under arecanut in India has increased from 0.167 million hectares during 1971 to 0.468 million hectares by the year 2015. During the same period, the production has increased from 0.141 million tonnes to 0.726 million tonnes and the productivity showed a quantum jump from 843 kg/ha to 1553 kg/ha. This has reflected in the increase in area, production and productivity of arecanut in the country as well as the very high demand for the planting materials as well.

Planting material production in arecanut since 1970

from the tip of the leaflets of the outer leaves and necrosis at later stages. Non-availability of curative measures and YLD resistant varieties is another major challenge. The strategy for disease management includes adoption of recommended management practices, removal of the diseased palms in the mildly affected areas to prevent the spread of the disease and identifying disease tolerant palms and utilizing them in hybridization programmes. It is of significant importance to develop efficient multiplication protocols for large-scale production of disease-free planting materials. Besides, it is vital to evolve a robust diagnostic kit for identification of the disease well in advance.

Studying the diversity of *Colletotrichum* species involved in causing inflorescence die back is required in order to develop an integrated management tool for combating the disease. Apart from this, it is important to study and monitor the effect of change in temperature, rainfall pattern and cropping systems on outbreak of the disease and develop effective forecasting and management strategies.

A look at the value chain dynamics in arecanut

An area of utmost concern is streamlining the market and marketing system in arecanut. Recent studies show that more than 75% of the domestic arecanut trade is in the hands of private traders, wherein cooperatives have little bargaining position. This eventually results in frequent fluctuations in prices due to poor market intelligence, market hoarding and associated problems. The price spread analysis of arecanut has indicated only a meagre share of producer in the consumer price, a situation none too desirable.

Distortions in the present value chain in arecanut not favourable to the primary producers need to be straightened to the extent possible. Emphasis also needs to be given for organizing village level farmers groups, primary processing/ grading units, marketing and storage units. Adequate steps should be taken to explore international markets for arecanut and its value added products and provide facility for online trading by farmers and farmers groups.

Arecanut-based agri-business: Potential largely unrealized

Even though, several value-added technologies are available for arecanut by-product utilization such as making of eco-friendly disposable plates and bowls from areca leaf sheath, leaf sheath fodder, oyster mushroom production from leaf and bunch wastes and vermicomposting, there are only very few commercial (small-scale) ventures operating at present. About 3.5 billion arecanut leaves and leaf sheaths are produced every year and have the potential to facilitate production of 0.3 billion kg of mushroom and ₹ 7 billion worth areca leaf sheath plates and bowls. Production of vermicompost from arecanut wastes is also done only on a very limited scale by farmers. Vermicomposting of arecanut leaf wastes per hectare can generate a net income of ₹ 20,000 and this can be taken up as a microenterprise, instead of the prevailing unscientific dumping of wastes in the plantations.

Production of value added products through small scale industries/Women Self Help Groups should be encouraged by providing credit facility for initial investment. What is most needed is, perhaps, skill development/capacity building for women SHGs and rural youth for efficient by-product utilization in arecanut ensuring value addition and income generation. Initiating village level mushroom and vermicompost production units in arecanut with the help of local manpower and establishment of large scale enterprise by integration of plate making, mushroom production and vermicomposting on a single platform and ensuring online trading facilities are also strategic considerations for supporting entrepreneurship development in the arecanut sector.

Prospects for value addition and product diversification

Arecanut is, at present, mainly used for chewing alone (in many forms of supari) or in combination with betel vine leaf/slake lime/ and other ingredients. In recent times, a debate has been set in motion in a considerable section of public opinion and policy makers as to whether arecanut should be promoted any further in view of its limited uses and should the farmers be not encouraged to grow other remunerative crops as alternatives.

Research efforts in the seventies on exploring alternate uses of arecanut / developing commercially viable products and processes in collaboration with various R&D laboratories (Cancer Research Institute, Bombay; Central Drug Research Institute, Lucknow; Indian Drug Research Laboratory, Poona; Regional Research Laboratory Hyderabad; Oil Technological Research Institute, Anantapur: Central Leather Research Institute, Madras) and Industries like Punalur Paper Mills Ltd. had given promising leads. Chemical analysis showed that arecanut contains 10-12 per cent fat, 27-32 per cent polysachharides. 16-20 per cent polyphenols, 7.0 per cent protein and 1.5 per cent alkaloids (arecoline, arecaidine, guvacine and guvacoline). Among the alkaloids, arecoline is the most potent and active constituent. Arecanut is also a good source of flavonoids, polymerized leucocyanidins and tannins, besides containing small quantities of catechin, leucopelargonidin and leucocyanidin.

Identification of arecanut varieties with less arecoline content and stages of harvest at which low content of arecoline needs serious consideration. Another area of promise is to employ the modern thermal and non-thermal processing techniques/methods based on traditional knowledge for reducing the content of alkaloids and other bioactive compounds in arecanut kernels of different maturity stages. It is desirable to develop commercially-viable methods to fractionate alkaloids/polyphenols from arecanut to obtain alkaloid-free polyphenols and explore its use for nutraceutical/therapeutic purposes. Multi-disciplinary collaborative studies involving medical/pharmaceutical R&D laboratories are required to develop viable pharmaceutical products like toothpaste and herbal mouth wash. The polymerised polyphenolics in arecanut can also be used as a natural colouring matter in food and non-food industries.

Bio-softened arecanut husk fibres can be exploited commercially for the production of furnishing fabrics, textiles etc. by blending with cotton, viscose and polyester. It has been found possible to make plyboards from arecanut leaf-sheath and use them in making tea chests. But, efforts for developing commercially-viable technologies for products like tooth brush, paper boards, plyboards, hardboards and plastics from arecanut husk mixed with conventional raw materials has to be taken up in collaboration with industrial R&D institutions.

From a long term perspective, the fact remains that, in spite of early leads, not much progress has so far been made in taking them forward in to developing commercially-viable products/processes/business enterprises, which can change the destiny of this crop. Unfortunately, the only small consolation is the development of few small-scale industrial units making plates and cups from arecanut leaf sheath.

Making eco-friendly plates from areca leaf sheath

COCOA: THE 'FOOD OF GODS' AND CHOCOLATE, THE GOURMET'S DELIGHT

Cocoa (*Theobroma cacao* L.) originated millions of years ago in South America, to the east of the Andes. The genus Theobroma encompasses twenty two species, of which *T. cacao* is the most widely known. The generic name in Latin for cocoa, *Theobroma*, literally means 'food of the gods' (derived from the Greek words, theos, meaning 'god,' and broma, meaning 'food'). The specific name *cacao* is derived from the native name of the plant in indigenous Mesoamerican languages.

There are two different theories as to their origin: One school holds that it came from southeastern Mexico and was carried to the Amazon basin and the other theory points to it as native to the Amazon, from where it spread to Central America and Mesoamerica. However, recent molecular studies linking the area of greatest cacao genetic diversity, has further refined the area of domestication to a bean-shaped area that encompasses the border between Brazil and Peru and the southern part of the Colombian-Brazilian border.Though Africa is the world's largest cocoa producers today, cultivation there began only by the mid 1800s by the European colonial powers in their erstwhile colonies, realizing the economic prospects from the explosion in demand for chocolate.

Trans-continental journey of cocoa from its South American home to Europe: Not a delicious taste of history

Throughout its 3000-year history, chocolate has been celebrated as a precious health-giving drink and it was not until the 20th century that the sweetened chocolate confectionery and bars replaced the 'real chocolate'. Cocoa was so prized that it was once used as currency in Colombia and offered by the Mayans to the gods in worship. Christopher Columbus first discovered cocoa in 1502 during his voyages searching for a sea route to the spices of the East, though it was the Don Hernan Cortés, leader of a Spanish expedition in 1519 to the Aztec empire looking for the 'fabled gold treasures', who brought the cocoa beans back to Spain.

The legend has it that Montezuma, the Aztec King, showered gold on the guests and in all native hospitality and served the Spaniards so fine a beverage that they immediately realized its delicious potential. The Spaniards returned the 'hospitality' by brutally eliminating the Aztecs and with that an ancient civilization was wiped out from the face of earth. But, luckily, cocoa and the secret of chocolate still survived this act of extermination. By the middle of the sixteenth century, the chocolate drink became popular with the Spanish royalty and it spread throughout Europe within a century. Cocoa beans and the top-guarded secret of 'chocolate' was a prized possession of the marauding Spaniards, as gold was, returning from their conquest of the Incas and the Mayans of the South America. In another twist of history, Antonio Carletti, the Italian traveller, discovered the closely guarded secret of chocolate in Spain and took it to Italy in 1606 and the rest is 'sweet chocolate' history, as it spread to other European countries.

Cultivated throughout the tropics, both the Old and the New world

This commercial beverage crop is grown in 58 countries in around 10 million hectares with a production of four million tonnes. The four West African countries (Côte d'Ivoire, Ghana, Cameroon and Nigeria) accounted for 63% of worldwide cocoa production, whereas Côte d'Ivoire alone contributed about 33%. Adding the production of Indonesia in the South East Asia also to the output, these five countries command the lion's share of 80%. Latin America, where the cocoa plant originated, presently accounts for only 13% of worldwide cocoa production.

The average world productivity is 500 kg/ha, whereas Côte d'Ivoire, a major country has the highest productivity of 660 kg/ha. With the exception of Brazil, cocoa production is mainly concentrated in small-scale farms. Cocoa production is therefore highly important for many households, as it is a key source of income and livelihood. During the last ten years (2004-13), world production has increased by 3.3% per annum with Africa's production expanding at a slightly higher rate of 3.7%.

The Indian Cocoa Story

The original 'landing' of cocoa in India was on the Tamil Nadu coast by the British, though there is another version of history that natives of Indonesia's Maluku islands brought cocoa to Tamil Nadu by 1800, as it was already growing in Asia and the Pacific Islands since 1560. The British East India Company brought Criollo cocoa beans to present day Tamil Nadu and Kerala from the Amboyna Island of Indonesia. Post-Independence, the Central Government launched a joint initiative with Cadburys (presently Mondelez) of England to expand cocoa cultivation in India. At first, Criollo beans were cultivated and later when Forastero cocoa plants were brought in from West Africa, these Criollo trees were removed to avoid cross pollination. In the early 1970s, global cocoa prices soared and many plantations in Kerala began cultivating the trees. But, when the prices suddenly dropped within a decade or two, most of the cocoa planters moved to rubber and other crops. In recent times, history is repeating itself, as with the not so remunerative prices of rubber, many farmers have started looking for alternative crops, especially coconut/arecanut based cropping systems with cocoa as an important component.

Cocoa is mostly grown in India as a mixed crop in arecanut,coconut and oil palm gardens. In the global production scenario, India is a very small player with the production share of a meagre 0.3%. It is mainly cultivated in four major southern states of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. The cocoa industry in the country has expanded to a considerable extent in recent years, with a production of 15,133 tonnes of cocoa from an area of 71,335 hectares and contributing about ₹ 2,000 million annually to the national GDP.

Although the per capita cocoa consumption in India (0.04 kg/head) is meagre in comparison with major cocoa consumers, the consumption has been steadily increasing over the last 10-15 years, reflecting the increasing purchasing power of the expanding middle class segment in India. Taking into consideration the

present day consumption patterns and growth of confectionery industry in India at around 15-20 %, the demand for cocoa is likely to increase in coming years.

Global consumption scenario

The African region, accounting for 70% of net world exports, is by far the largest supplier of cocoa to the world markets. Côte d'Ivoire is the world's leading exporter of cocoa beans, representing 28% of global net exports, followed by Nigeria (21%) and Ghana (19%). Between 2004 and 2013, world cocoa consumption expanded by 24% with most of the increase coming from higher consumption in the traditional cocoa consuming countries of Europe (up by 17%) while consumption increased by 22% in the Americas over the same period.

The most dynamic regions in terms of cocoa consumption were the Asian region (up by 50%) and the African region (up by 74%). European countries recorded higher per capita consumption of cocoa in selected countries and major net imports of cocoa beans, followed by the USA (14%) and Malaysia (10%). The world per capita consumption of cocoa has increased from 0.60 kg in 2004 to 1.09 kg in 2013. Switzerland recorded the highest per capita consumption (5.9 kg/ year) while the per capita consumption of India is a meagre 0.04 kg.

Indian Scenario

Domestic production aspects

In India, cocoa is cultivated mainly in the states of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. At present, demand for cocoa beans far outstrips the local production, necessitating large scale imports to meet the national requirements. India produces 15,100 tonnes of cocoa from an area of 7,100 hectares. Tamil Nadu has the highest area under cocoa (34%) while in the case of cocoa production, Kerala has the major share (42%). The all India growth rate in area of cocoa in the recent period was an impressive 14.2%.

Domestic import-export scenario: At a glance

The import (value) of cocoa and cocoa products increased at a compound growth rate of 31% during the ten year period of 2002- 11, which shows a surging domestic demand for cocoa and cocoa products. Cocoa beans and chocolate products together constitute around 70% of the value of cocoa imports to India. On the other hand, the export growth was almost stagnant which accounts for only around 9% of total value of exports during the period under consideration.

Opposite: Cocoa Hybrid

Demand and supply forecast

The demand for cocoa by 2050 is projected at 212 thousand tonnes against the estimated supply of 121 thousand tonnes. Evidently, there would be a demand-supply gap of 90 thousand tonnes of cocoa beans by 2050. To achieve this target, the cocoa production in the country should increase at an annual growth rate of 7.68 per cent considering the market growth at 20%, underpinning the great potential this sector has in the near future.

Research in cocoa at CPCRI

The cocoa industry in the country has expanded to a considerable extent in recent years. At present, more than 15 industrial entrepreneurs and firms are existing in the field demanding nearly 30,000 tonnes of cocoa beans of which the present domestic availability is only about 40 percent. Considering the market growth in the chocolate segment in India, which is about 20 percent per annum, cocoa has a great potential to develop in future years.

ICAR-CPCRI is the pioneering research organization which introduced cocoa in the country. Until the early 60s, cocoa was known in India only as an ornamental or museum tree in some of the botanical or horticultural gardens and backyards of bunglows and religious institutions. Cocoa was introduced to this country during 1960s and the systematic research on cocoa production technologies were started during 1970 at the Regional Station, Vittal. Introduction of cocoa as a mixed crop of arecanut and coconut has provided sustained production models.

Genetic enhancement

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 under the University of Reading in 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. 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 evaluation and conservation, making the total cocoa germplasm collection at 321. These introductions include 20 accessions for larger bean size, five white bean accessions for flavour characteristics, four accessions for canker resistance, 25 accessions for black pod disease (BPD) resistance, three accessions for vascular streak disease (VSD) resistance and two 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 accessions tolerant to moisture-deficit stress from Shiradhi Ghat in the State of Karnataka have been collected and conserved.

Improved cocoa varieties and hybrids released

Research in CPCRI has resulted in releasing four high yielding hybrids (VTLCH1, VTLCH2, VTLCH3 & VTLCH4) and two selections (VTLCC1 &

VTLCC2). The yield of cocoa increased from 1.0 to 2.5 kg per tree due to the adoption of these high yielding varieties and improved agro-techniques.

Vittal Cocoa Selection 1: A precocious, stable and high yielding clone with medium canopy and red to orange coloured pods; possesses biotic and abiotic stress tolerance; pod yield of 54.5 / tree/ year and 2.52 kg/ tree/ year dry bean yield (1700 kg/ha)

Vittal Cocoa Selection 2: An early, stable and high yielding type both under arecanut and coconut canopies with green to yellow coloured pods having bold and bigger beans, less incidence of pests and diseases and yielding 55 pods/ tree/ year with a dry bean yield of 2.7 kg/ tree/ year (1850 kg/ha)

VTLCH1: A vigorous, early and heavy bearer with green to yellow pods; yielding 50 pods/tree/year with 42 beans per pod and a dry bean yield of 1.48 kg/tree/year (1014 kg/ha).

VTLCH2: A heavy bearer with medium canopy, green to yellow coloured pods and tolerant to black pod rot disease; annual yield of 70 pods/tree/year with 40 beans/pod and 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. Yield 45 green to yellow coloured pods/ tree/year with a dry bean yield of 1.45 kg/tree/year (993 kg/ha).

VTLCH4: Another hybrid suitable for both rainfed & irrigated gardens with red to orange coloured pods; yields 40 pods/tree/year with a dry bean yield of 1.25 kg/tree/year (856 kg/ha).

Canopy arectechture engineering

Cocoa in its native zone is grown as an under storey crop either under permanent shade or under temporary shades. In India, cocoa cultivation is widely undertaken in palm-based cropping systems. Cocoa, with its typical growth habit of branching in tiers, tends to grow high which is considered as unfavourable in the cropping system models. There are genotypes with erect, intermediate and pendulous branching habits in which intermediates are considered compatible in the inter-cropping systems. Different spacing under arecanut, single and double hedge systems of planting under coconut, triangle system of planting under oil palm are being followed in cocoa cultivation with canopy modifications. Formation pruning and training in young plants, structural and sanitary pruning in matured trees, canopy architectural engineering in both grafted and seedling plants are developed, standardised and are being practiced regularly in cocoa plantations. The challenge is to expand these methods in different cropping systems and agro-climatic zones and to maintain optimal canopy area for achieving productive yield of cocoa.

Tailor-made agronomic practices: suitable to arecanut, coconut and oil palm plantations

The cocoa production techniques including planting, spacing, irrigation, fertilizer application and cultural operations suitable to palm based cultivation are standardized. Mixed cropping of cocoa in arecanut / coconut gardens fetches an additional income of ₹ 1,00,000/ha. Besides increasing income, cocoa cultivation also helps in conserving moisture, reducing weed growth and improving soil health by adding leaf litter to the tune of 7 to 10 tonnes per hectare.

Enhancing productivity by reducing crop losses due to disease and pests

Presently, cocoa cultivation is facing threat of Phytophthora related diseases in seedlings, trees and pods, manifested through seedling dieback, stem canker and black pod rot, in the traditional high rainfall zones. Sowing before the onset of monsoon, soil solarization, biopriming measures, and adequate drainage facilities will reduce the incidence and spread of disease in the nursery and facilitate the healthy growth of seedlings. Stem canker is seen mostly in young plants and flood irrigated gardens of Tamil Nadu and Andhra Pradesh as compared to drip irrigated gardens. Shade regulation, timely harvest of pods, removal and destruction of infected pods, systematic annual pruning, smearing with Bordeaux paste on cut ends, spraying with copper fungicides are the remedial measures. Clones exclusively resistant to black pod rot and VSD have been collected. Though Phytophthora diseases are amenable to disease management and is controlled to some extent, it is still considered as a major challenge for cocoa cultivation.

Mealy bugs and tea mosquito bugs are the major pests affecting cocoa, primarily during the summer season. It is observed that unscrupulous cutting of trees has aggravated the pest problems in the recent years. Screening of cocoa germplasm has identified clones tolerant to tea mosquito bug based on grades of damage levels in flushes, cherelles and fruits.

Risk of accidental introduction of exotic pests and diseases

World cocoa is severely affected by few debilitating diseases such as cocoa swollen shoot virus (Africa), witches' broom disease (Latin America), frosty pod rot (Latin America), cocoa pod borer (South East Asia) and *Phytophthora megakarya* (West Africa). Indian cocoa is presently safe and no significant economic loss is experienced even with Phytophthora diseases. Since cocoa pod borer is a major threat in the South East Asian region, the country needs to be alert and vigilant. At present, exotic collections of cocoa germplasm are routed through Intermediate Cocoa Quarantine Centre, University of Reading, UK and through NBPGR, India and exports are controlled by National Biodiversity Authority (NBA). Continuous surveillance over imports is a challenge with respect to germplasm collection from international gene banks and major cocoa producers.

Processing: enhancing bean and flavour quality

Cocoa is considered as a functional food because of its richness in terms of polyphenols and antioxidant properties. Genotypes, growing conditions, seasons, pre and post harvest handling etc. decide the quality of beans. Bean size with respect to bean indices, moisture content, shelling percentage, nib recovery and fat contents add value to the marketable bean. Elite clones and hybrids are developed with rich bean qualities. Clones rich in polyphenols, procyanidins, fat, antioxidant properties etc. have been identified. Fatty acid

profiles obtained from clones and hybrids are high in stearic acid. In the recent years, flavour improvement have been given importance in order to develop specialty chocolates with a blend of Criollo and Forastero beans. Bean size is highly varying with genotypes, changes in climate and processing which are to be taken care of in order to maintain the quality of the cocoa beans.

Trnasfer of technology efforts gives ample fruits!

Front line demonstrations (FLDs) on cocoa as a mixed crop in arecanut/coconut garden in farmers’ fields across all cocoa growing states were established to convince the farmers about the feasibility and advantages of growing cocoa as a mixed crop in arecanut/coconut garden. Seedlings, grafts and hybrid seeds materials were distributed to the regional nurseries, Cadburys and CAMPCO for distribution to the farmers. Recently, 50 cocoa demonstration gardens were established in Andhra Pradesh alone under coconut in collaboration with DCCD to convince the farmers about the advantages of growing cocoa in coconut and oil palm gardens. Besides, need-based training programmes are being conducted for farmers, agricultural/ horticultural officers and Self Help Groups. The area under cocoa in India has increased from 27,810 ha in 2004-05 to 78,000 ha in 2014-15 and production from 9,250 MT to 16,050 MT in 2014-15. As the expansion of area under cocoa has taken place only recently, it may take few years to reach the exact production potential of these newly established gardens.

Challenges of mitigating market risks and sustaining farmer-confidence

Too many price-shocks too often dents the investor-confidence of the farmers. But, with the spatial integration of cocoa markets, the risk of price volatility is inherent in the system. Hence, it is of paramount importance that risk minimization mechanisms should be adequately taken, while advising the area expansion programmes on cocoa, wherein we should discourage the mono cropping of cocoa. There is an urgent need to come up with a clear market intelligence mechanism which could provide price signalling in advance. Cocoa is an important commodity traded in the international stock exchanges. In the domestic level, we may formulate a producer consortium to facilitate the futures trading and stock investment of cocoa beans, and thereby can combat the speculative price movements to a large extent.

Domestic supply chain of cocoa in India is still in rudimentary stages. CAMPCO and Cadbury India Ltd (now Mondelez India) are the major procuring agencies in India, who are directly procuring the cocoa beans from farmers. The value share of the producer/farmer is a meagre 32%, as most of the farmers sell the produce as wet beans, even without doing minimal processing. Urgent steps should be taken to establish village level primary processing units and capacity building for fermentation and drying of cocoa beans with the formation of strong farmer aggregates, women SHG’s and rural youth. Development of exclusive market yards and assembling places for cocoa beans along with the adoption of high quality food safety standards would be a pro-active step for better realization of bean prices. Assured buy-back systems developed in the framework of contract farming under the stake of government (tripartite arrangement) can help the growth and stability of the sector. State machineries should go for long-term agreements with the leading chocolate manufacturers for appropriate marketing arrangements and supply chain development ensuring an equitable profit share for the farmers.

True potential of Indian cocoa sector to be unleashed yet!

The procurement strategy of the major buyers in India is at present focussed on the domestic sphere where they can save the transaction costs. But as a matter of abundant caution, it is prudent to always keep in mind that the domestic cocoa prices are highly integrated with the international prices and the chances for price instability are very high, as any supply shock in the international arena may influence the domestic prices as well. The growth of purchasing power in emerging markets and the confirmation of the health/ nutritional benefits of cocoa have led to a significant increase in the global demand for cocoa. At the same time, the market has become more stringent in terms of quality requirements particularly with regard to pre- and post-harvest bean handling. From an overall perspective, cocoa for India is a high potential crop, but with too many external factors loaded against the sector as a whole. We are, as of now, a very small player in the international arena, and need to explore the possibilities to make cocoa sector a dynamic and vibrant one.

A long-term vision of self-reliance in cocoa sector in India

Taking in to consideration the past growth trends, the demand for cocoa beans in India by the year 2050 would be about 220 thousand tonnes and the projected supply is expected to be only 120 thousand tonnes, thereby forming a huge supply deficit of around 100 thousand tonnes of cocoa beans. The steadily increasing per capita consumption of cocoa in India is the basis for this optimistic projection. A desirable situation of demand and supply movement is one in which the supply deficits are very small during the projected periods and eventually the deficit becomes surplus.

Through a combination of area expansion by way of potential intercropping in existing coconut/arecanut/oil palm plantations (estimated to be about 25 lakh ha area available, of which around 35% of this land is under irrigation) in the states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Odisha, coupled with setting realistic targets for increasing the present below par productivity level, a much happier scenario of near self-sufficiency in production can be achieved by 2050.

To make cocoa farming more profitable, farmers need to produce more cocoa. For that to happen, farmers need to be reasonably assured of long-term prospects of a steady market, since scientific cultivation of cocoa demands long-term and heavy investments in terms of land, labour and financial resources. The need for building investor-confidence in the farmers is a bitter lesson learnt from the experience in the 1980s. Monopoly of one or two procurement agencies should be discouraged and there is ample scope for new players in the procurement and processing sector, pre-empting cartel formation and deliberate market manipulation by the multi-national players.

Average productivity increases when entrepreneurial farmers are motivated and empowered to use inputs such as better varieties, fertilizers, irrigation and other production and protection technologies. To attain the production matching with the projected bean demand, it is essential to focus on building long-term equitable partnerships and reinforced capacities across the cocoa sector. Meaningful partnerships should be evolved among all stakeholders, namely governments, cocoa farmers, and the cocoa industry to boost productivity and strengthen the cocoa community development in the country.

Opposite: Cocoa garden from Andhra Pradesh

SPICES: THE PRIDE OF THE EAST

If there is one single commodity which turned history of the mysterious Orient upside down, it is the spices. The traders turned conquerors and eventually the rulers with the vast British colonial empire, sitting on the destiny of most of Asia by the late 19th century. In its hey days, the spice trade was the world's biggest industry; it established and destroyed empires, led to the discovery of new continents, and in many ways helped lay the foundation for the modern world.

Elaborating on the 'power and glory', the mystical charm that spices exercised in history, 'Gantzer & Gantzer' in "Spicestory" (2014) writes, *"More than the legendary beauty of Helen of Troy, they launched a thousand ships, created the world's greatest empire, discovered a New World, and, following the charge of a mutant called CTM (referring to the spicy chicken tikka masala, the iconic Indian food getting popular in cosmopolitan London, acquiring a place next to the traditional English foods), breached the established bastions of British tradition"*.

The amazing diversity of spices

'Spices' is a mixed bag of crops with varying plant habits/stature and life span from fleshy rhizomatous and herbaceous annuals to perennial trees, varying in morphology, constituents/ active ingredients, and useful parts/uses. Some of them are native to India and others from its Asian neighbours made India their adopted home. Morphologically, a spice is a dried seed, fruit, root, bark, berry, bud or other vegetable substance primarily used (in small quantity) for flavouring, colouring or preserving food. They are distinguished from herbs, which are parts of leafy green plants used for flavoring or as a garnish. Many spices have antimicrobial properties. Spices are commonly used in traditional/ Indian systems of medicine like Ayurveda, religious and social rituals, cosmetics and perfume industry.

Present spices scenario

During 2010-11, spice production in India was 5350.47 thousand tonnes from 2940.39 thousand hectares of area. During the last three decades, the production has steadily increased, nearly three times, due to both area expansion and higher productivity. Total area under spices has increased by 46.8% and production by 182.4% during the decade from 1991-92 to 2010-11. The consumption of spices is growing in the country with the concomitant increase in purchasing power. With the forecasted population increase of up to 1619 millions in 2050 and with increased GDP and per capita food spending, approximate per capita consumption of black pepper, cardamom, turmeric, and ginger is expected to be about 148 g, 54 g, 1.6 kg and 1.2 kg, respectively. In such a scenario, the productivity in black pepper must increase from the present level of 260 kg to 943 kg/ ha. Similarly the cardamom, turmeric, and ginger should yield 0.98, 10.0, 9.3 t/ ha respectively. Taking in to account the anticipated export commitments also, production levels to meet the local and global demand have to be increased by 2.7 - 5.7 folds from the present levels.

Spices are high-value and low-volume commodities of commerce in the world market. All over the world, the fast growing food industry depends largely on spices as taste and flavour makers. Health-conscious consumers in developed countries prefer natural colours and flavours of plant origin to cheaper synthetic ones. The estimated growth rate for spices demand in the world is around 3.19%, which is just above the population growth rate. Of the total domestic production, nearly 10% is exported. Share of export in total production varied from a mere 0.2% in large cardamom to about 42% in chilli. Value of spices exports from the country has experienced a 5-fold increase during the period, 1991-92 to 2010-11. During 2010-11, export in terms of value was all time high at US $ 1.5 billion, with chilli contributing 42%, followed by seed spices (21%), turmeric (14%), black pepper (5%), ginger (4%) and other spices (7%). As the international trade barriers are steadily coming down, India will have to develop a very competitive edge in all respects, if it has to retain and increase its present position in the international trade in spices.

Higher productivity, clean spices through improved post harvest techniques and reasonable threshold prices affordable to food industry are key to future spice trade. Over the years, India's share in world spices market has not appreciated much and its monopoly as a supplier of spices is threatened by countries like China, Brazil, Vietnam, Pakistan, Egypt, Turkey and other African and Caribbean countries. India also faces shortage of exportable surplus because of increasing domestic demand. Sharp fluctuations in the quantum and value of exports and in the unit value realization have characterized the spices trade in recent years.

A taste of spicy history

Historians and archaeologists estimate that from as far back as 50,000 B.C.E., humans had used the sweet-smelling spices to help flavour their food, primarily meat taste better. They would have also offered all sorts of aromatic herbs to propitiate their gods and also used the spices for healing properties. From that moment on, spices played an important role in human existence. It may seem strange and unbelievable that once upon a time spices were valued as highly as gold and silver. Not surprisingly, black pepper was the 'black gold' in those days.

Spice Trade in the Ancient World

Trade in the ancient world included the use of caravans with a long retinue of camels carrying spices, the treasures from the East, on the winding land routes across continents from the west coast of India to the lands of the Romans and the Greeks and the rest of Europe through the gateway of Constantinople. For hundreds of years, traders also used ships which sailed along the Indian coast, past the Persian Gulf, along the coast of South Arabia, and finally through the Red Sea into Egypt, braving the great risks in the high seas. Spices were in such great demand (especially during the highly developed Greek and Roman eras) that the profits outweighed the risks. The Arabians were the first traders and they used all their mercantile guiles to hide the true sources of the spices in protecting their monopoly on the spice trade.

The Portuguese in India

But, all that changed forever when Vasco da Gama landed on the coast of Calicut of India in 1498. Under the wealth from the spice trade, Portugal expanded territorially and commercially. By the year 1511, the Portuguese were in control

Opposite: Intercropping of cocoa under coconut

Vasco da Gama on the spice trail

of the spice trade of the Malabar Coast of India and Ceylon. In the 16th century, over half of Portugal's state revenue came from West African gold and Indian pepper and other spices. As inevitable in history, the Portuguese also could not cling on to their monopoly for long. The floodgates were flung open with all the major European powers set out to claim a pie of this lucrative trade.

The Dutch and the English follow suit

With the waning power of the Portuguese apparent, the Dutch and the English saw their opportunity to gain an upper hand in the spice trade with India. The Dutch entered the competition in earnest at the end of the 16th century. The Dutch explorers, established trading posts which eventually gave Holland the monopoly in the early 17th century.

England was an immense threat to the Portuguese and later the Dutch, because they were a superior power at sea. In 1600, the British East India Company was chartered by Queen Elizabeth I, and its major objective was obtaining spice cargoes. The British worked slowly in their attempt to gain the power away from the Dutch, and finally in 1780, England and Holland started a war which severely weakened Dutch power in India. By the 1800s everything that once belonged to Portugal and Holland was controlled by the British.

The Pepper Empire and the Gift of Monsoon

Vasco da Gama at the court of Zamorin

On the dawn of May 21 1498, Vasco da Gama and his crew landed at the Kappad beach in Calicut on the southern Malabar Coast of India after the first direct sea voyage from Europe to Asia. With this adventure on the sea, began the direct engagement of Europe with the exotic and mysterious East in trade, culture and history for ever.

For several centuries before Gama and hundreds of years thereafter, the secret of the spice trade was simple: great demand and highly controlled supply. In some cases, that control was enforced through political power or mercantile guile. Some was simply a gift from the gods of nature and pepper of Kerala, the 'God's own country', is one such case. Legend has it that, while leaving, Gama asked the Zamorin of Calicut whether he can have a pepper stalk with him. The Zamorin readily agreed, to the consternation of his court. Assuaging his advisors, he calmly reasoned that he has given only the pepper cuttings and not the *'thiruvathira njattuvela'* (the fortnight commencing from the second half of June in the Malayalam calendar with heavy monsoon showers, the most ideal time for planting pepper cuttings) and hence no potential danger to his pepper empire. He knew how important the region's unusual twin monsoon, both phases of which bring heavy rain, was to the crop. To this day, though regions elsewhere grow pepper, Kerala pepper with its supreme quality, has a niche-market of its own. In the present day, the geographical indications for exquisite crop specialties make sense in this context.

Genesis of Spices Research in India

Spices research has its beginning under the combined Madras Presidency in 1949, with the establishment of Pepper Research Scheme at Panniyur in Present day Kerala and research on cardamom at Mudigere in present Karnataka and Pampadumpara in Kerala during the early fifties. Realizing the need for research and development of spices in the country, Govt. of India in 1951, constituted a Spices Enquiry Committee and based on the Committee's recommendation, the spices research was entrusted to the Indian Council of Agricultural Research in 1953. A Central Spices and Cashewnut Committee was also set-up to assist the ICAR in advising, planning and co-ordinating the implementation of the recommendation of the Spices Enquiry Committee.

All India Co-ordinated Research Project on Spices

Improvement of spices research in the country was intensified with the initiation of All India Coordinated Spices and Cashewnut Improvement Project in 1971 with its headquarters at the Central Plantation Crops Research Institute, Kasaragod. The main mandate was to increase the production and productivity through evolving high yielding varieties, standardization of fertilizer and management practices and control measures for pests and diseases of black pepper, cardamom, ginger and turmeric. The seed spices like cumin, coriander, fennel and fenugreek were included during the V Plan period.

The project was bifurcated and the All India Co-ordinated Research Project on Spices was shifted in 1986 to the newly established National Research Center for Spices, Calicut (which was originally the regional Station of Central Plantation Crops Research Institute). The scope of the spices project gradually enlarged through the plan periods and at present the project has 19 regular centers, 10 co-opting centers and 9 voluntary centers spread over 24 states devoted to R&D work on spice crops. At present, AICRP on Spices conducts and coordinates research on 12 spice crops (black pepper, small cardamom, large cardamom, ginger, turmeric, cinnamon, clove, nutmeg, coriander, cumin, fennel, fenugreek) with specific mandate for each centre.

Indian Institute of Spices Research, the baby of CPCRI, grows up

During the fifth Five Year Plan, the ICAR realized the need to initiate basic and applied research on major spices (black pepper, cardamom, ginger and turmeric) and also tree spices and accordingly, a Regional Station of CPCRI for spices was established at Calicut on 10th November 1975.

Just after a decade of its establishment, spices research was delinked from CPCRI and the regional station was upgraded as the National Research Centre for Spices (NRCS) during April 1986. The Cardamom Research Centre, Appangala (which was transferred from Indian Institute of Horticultural Research, Bangalore to CPCRI, Kasaragod earlier in 1974) was also merged with the National Research Centre for Spices. This NRCS was further upgraded to the ICAR-Indian Institute of Spices Research (ICAR-IISR) in July,1995 based on the recommendation of the Parliamentary Committee. The institute presently works on black pepper, small cardamom, ginger, turmeric, vanilla, paprika, cinnamon, clove, nutmeg and garcinia, with an objective of providing a scientific and technological base to make the Indian spice cultivation, industry and trade profitable, sustainable and equitable.

The laboratories and administrative offices of the institute are located within the city limits of Calicut (Kozhikode), Kerala, at Chelavoor (50 m above MSL), 11 km from the city on the Calicut-Kollegal Road (NH 212) in an area of 14.3 ha. The research farm is located 51 km North East to Calicut at Peruvannamuzhi (60 m above MSL), in the foothills of Western Ghats, on the Peruvannamuzhi-Poozhithode Road in Quilandy Taluk, Kozhikode District, in an area of 94.08 ha. The Cardamom Research Centre, Appangala (920 m above MSL) is located in Hervanad Village of Madikeri Taluk, Kodagu District, Karnataka on the Madikeri-Bhagamandala Road, 8 km from Madikeri, in an area of 17.4 ha. The headquarters of All India Coordinated Research Project on Spices is also located at Indian Institute of Spices Research.

CPCRI pioneering the research in spices

CPCRI had been carrying out a number of research programmes in priority areas pertaining to spice crops from the 1970s. In the 1980s, the research efforts in plant protection especially investigations on wilt diseases and quality aspects of pepper were intensified under the Kerala Agricultural Development Project funded by the World Bank. Research work on spices was primarily carried out at the Regional Station at Calicut and the experimental farm at Peruvannamuzhi under it, Research Centre at Appangala (for cardamom) and some of the investigations, especially the feasibility of growing pepper and other spices as components of the multi species cropping system were undertaken at Kasaragod and Vittal.

The systematic investigations/long-term field trials initiated in the 1970s and 80s were subsequently taken to their logical conclusions, invaluable scientific data/information were generated, and several high yielding varieties and technologies developed in the later years to the benefit of the farming community by the IISR.

Collection and management of plant genetic resources

In just over a decade since its establishment in 1975, an amazing diversity of collections in pepper and other spice crops including tree spices were assembled. The germplasm holdings in 1984 consisted of 84 of black pepper, 124 of ginger, 172 of turmeric, 219 of cardamom, 135 of cinnamon, 298 of nutmeg and 140 of cloves. Eighty eight accessions of *Piper nigrum* and related species were added to the germplasm bank during 1984 alone.In pepper, 28 cultivated types and 7 wild types were further added to the germplasm collection in 1985. The prized collections include the forty wild *Piper* types collected from Silent Valley forests.Descriptions of *Piper* spp. from Silent Valley areas andvarietal description of several cultivars were carried out. The cytological studies established the somatic chromosome number of five cultivars studied as 2n=52.

During 1984, 48 accessions (predominantly of Vazhuka variety) were collected from Wayanad District of Kerala. During the germplasm survey, individual clumps reported to be yielding over five kg of green capsules/clump/year were located and clonal materials were col1ected from from Waynad.In cardamom, seven more accessions werecollected from Pampadumpara, Saklespur and Mudigere in 1985.These collections were maintained and evaluated at Calicut (all spices except cardamom) and Appangala (cardamom).A duplicate set of 100 accessions of cultivated types in pepper were also maintained at the CPCRI Research Centre, Kannara for conservation.

In turmeric evaluation trials, three selections (PCT 2, PCT 5 and PCT 8) gave an yield over 17 t/ha compared to 9 t/ha in control. PCT 8 with 18.7% curcumin content was approved for release by the Seventh All India Coordinated Project Workshop on Plantation Crops.Ginger yield for 1985 showed the highest yield of 9.5 kg/3 sq.m. bed in PGS 35, a collection from Pottangi (Odisha).

Collection, conservation, cataloguing and evaluation of germplasm in tree spices also received due research attention. A nutmeg clonal progeny trial was laid out with 15 epicotyl grafts, 15 side grafts, 15 budded plants and 15 seedlings in a completely randomised block design. The morphological characters of *Myristica malabarica* were recorded.Based on the quality evaluation of 290 cinnamon accessions six Indian and five Sri Lankan cinnamon accessions were selected for clonal multiplication and bark yield evaluation.

Evolving high yielding varieties by selection and hybridisation

For breeding in black pepper and cardamom, the thrust was not only on yield improvement, but also in evolving lines with built in resistance against pathogens. Selection in segregating populations, inter-cultivar hybridization and induction of mutation through irradiation were attempted to evolve resistant lines in these crops.

In vitro propagation

Investigations were started in 1977, primarily aimed at developing suitable tissue culture procedure for rapid clonal multiplication of elite genotypes in spice crops. Multiple shooting (as many as 8 from a single bud)was induced in cultures of floral and vegetative buds of cardamomin a period of 3 months from the initiation of the culture. Cardamom plants produced *in vitro* from the vegetative and floral buds were successfully transferred to the field. Tissue culture work in ginger was also initiated and plantlets could be produced throughregeneration of callus from ginger rhizome.

Nutritional requirement of pepper

A nutritional experiment with three levels each of N (50, l00, and 200), P (20, 40 and 80 g) and K (70, 140, 280 g) / vine was initiated in 1979 to determine the optimum NPK requirement of pepper variety Panniyur-l. a series of spacing-cum-varietal trials on pepper were laid out at Peruvannamuzhi (Calicut) and based on the these trials, optimal spacing and manurial requirements were worked out and recommendations made.

Management of quick wilt and slow wilt diseases of black pepper

Black pepper cultivation in India is affected by the two wilt diseases, quick wilt and slow wilt. Though studies on these diseases were initiated in 1972 itself, a concentrated multi-disciplinary effort to solve these maladies was started only around 1980. Some of the initial research findings include identification of the quick wilt pathogen as *Phytophthora palmivora* MF4 (as confirmedby University of California, Riverside, USA), the splash dispersal of the pathogen from soil resulting infections in lower region of the vine, selection of a few seedlings as resistant/tolerant to the quick wilt pathogen and the constant association of plant parasitic nematodes in slow wilt disease incidence.

Further studies carried out on quick wilt and slow wilt diseases yieldedpositive results on their etiology, epidemiology, identification of tolerant varieties for *Phytophthora palmivora* and *Meloidogyne incognita* and the efficacy of metalaxyl in controlling *Phytophthora* infections. The pathogenicity of plant parasitic nematodes in slow wilt complex was conclusively established.

Rhizome rot and bacterial wilt of ginger

Rhizome rot or soft rot of ginger caused by *Phythium* sp.was a severe disease problem affecting the crop yield. A comprehensive field control trial involving fungicides coupled with various management practices was undertaken during 1983 and 1984. Simultaneous application of neem cake, metacid and Bordeaux mixture at the time of planting, and spraying metacid and drenching Bordeaux mixture three months after planting resulted in lower disease. In addition, various seed storage practices for ginger were also tried to identify the best storage method. The recovery of seed ginger was more in rhizomes treated with 0.3% Dithane M-45 and stored in pits lined with sand under Kasaragod conditions.

Studies were also undertaken on bacterial wilt of ginger caused by *Pseudomonas solanacearum* which has become serious in many of the ginger growing tracts.

Katte disease of cardamom

Investigations on strainal variation, epidemiology and characterization of 'Katte' agent of small cardamom received prime attention.EM studies showed the presence of flexuous rod shaped virus particles in all the six 'Katte' virus strains. No morphological differences in shape of the virus among the different strains were observedand serological studies revealed that all the six strains are related. However, the concentration of the virus particles were found to be more in strain CKV-18 which is very severe than the other strains. The virus associated with 'katte' disease was found to be belonging to poty Y' virus group.

Studies conducted from 1982-1984 on 'Katte' disease management in three severely affected plantation through phased replanting programme clearly showed that the disease can be economically managed by phased replanting programme.

'Azhukal' or clump rot of cardamom in the High Ranges of Kerala could effectively be controlled with 2 sprayings of 1% Bordeaux mixture.

Pest management

Investigations on the bionomics of major pests of pepper and evolving effective control measures against them received due attention. Field trials for chemical control of pepper 'pollu beetle', *Longitarsus nigripennis,*was initiated. Studies onseasonal fluctuationsin population, screening of pepper cultivars against pollu beetle,working out economic thresholds for pollu beetle infestation and standardizing standards for estimating insecticide residues were carried out under this programme.

Production of quality planting materials

In pepper, single nod rooted cuttings of high yielding Karimunda selections and Panniyur-l were raised by rapid multiplication technique and distributed to seed gardens and developmental agencies.The high yielding clones of cardamom were multiplied and seed capsules from the high yielding selections were distributed to farmers. Planting materials of elite lines of ginger and turmeric, and tree spices were made available in large numbers to the needy farmers.

Research Accomplishments of IISR

ICAR-Indian Institute of Spices Research (ICAR-IISR), which started out as a Regional Station of Central Plantation Crops Research Institute in 1975, has now grown into a full-fledged institute of international standing. The institute during the last three decades has developed an impressive array of high yielding varieties and efficient technologies for the spice farmers of India. Research activities on spices has resulted in establishment of world collection of spices germplasam, development of 25 improved varieties of spices, integrated nutrient, disease and pest management, post-harvest technologies for major spices like black pepper, cardamom, ginger, turmeric and tree spices, contributing to increase in production, productivity and sustainability in spices.

Genetic enhancement

The institute holds the world's largest germplasm collection of spices that are being characterized for various traits. The collections include 2300 black pepper accessions besides 1400 hybrids, 439 cardamom, 700 ginger, 924 turmeric, 484 nutmeg, 225 clove, 408 cinnamon, 116 garcinia and 79 vanilla accessions. Utilizing this reservoir of PGR, several improved varieties endowed with high yield, quality attributes and resistance to pests and pathogens have been developed.

Improved varieties of black pepper

Sreekara: A selection from Karimunda, adaptable to various climatic conditions and with high quality attributes like high essential oil (7%)

Subhakara: Another selection from Karimunda suitable for all black pepper growing tracts with wide adaptability. It has high content of oleoresin (12.4%).

Panchami: A selection from Aimpiriyan with high fruit set and a late maturing type.

Pournami: Selection from Ottaplackal; suitable for all black pepper tracts; tolerant to root-knot nematode

IISR Shakti: An open pollinated progeny of Perambramundi; tolerant to Phytophthora; high dry recovery (43%)

IISR Thevam: A clonal selection of Thevamundi suited to both high altitudes and plains; field tolerant to Phytophthora, yielding 2481 kg/ha (dry)

IISR Girimunda: A hybrid between Narayakodi x Neelamundi giving high yield and suitable for high elevation tracts

IISR Malabar Excel: A hybrid between Cholamundi x Panniyur-1 suitable for high elevation; high oleoresin content (14%)

PLD–2: A clonal selection from Kottanadan suitable for Trivandrum and Quilon districts of Kerala; high oleoresin content (15.5%)

Improved varieties of cardamom

Appangala-1: This variety is suitable for intensive cultivation (high density planting) under both mono cropping and mixed cropping conditions. Being an early maturing variety and highly adaptive, producing 89% bold capsules, is suited for Karnataka and Kerala.

IISR Avinash: Suitable for Karnataka, especially for planting in valleys, and produces 51% bold, dark green capsules. The great advantage is that it is resistant to rhizome rot disease.

IISR Vijetha: Suitable for Kodagu, Hassan, Chikmagalur and North Wayanad, especially suitable for katte-prone areas, as it is resistant to katte disease. It is adapted to moderate rainfall and moderate to high shade areas.

Improved varieties of ginger

IISR Varada: A germplasm selection with plump rhizomes and wide adaptability. Crop duration is of 200 days with a dry recovery of 20.7%. This variety has 4.5% crude fibre, 6.7% oleoresin and 1.8% oil.

IISR Mahima: A selection with bold rhizomes, crop duration of 200 days and a dry recovery of 23%. The variety has 3.3% crude fibre, 4.5% oleoresin and 1.7% oil. More importantly, it is resistant to Meloidogyne incognita and M. javanica.

IISR Rejatha: A germplasm selection with round and bold ginger. Crop duration is of 200 days with a dry recovery of 23%. The variety has 4% crude fibre, 6.3% oleoresin and 2.3% oil.

Improved varieties of turmeric

Suvarna: A germplasm selection suitable for Kerala, Karnataka and Andhra Pradesh; a short duration variety, with the rhizome deep orange in colour and with good quality attributes (curcumin 4%, 13.5% oleoresin and 7% oil).

Suguna: A selection suitable for Kerala and Andhra Pradesh; early maturing and field tolerant to rhizome rot; with 4.7 % curcumin, 13.5% oleoresin and 7% oil.

Sudarshana: Another selection suitable for Kerala and Andhra Pradesh. This is an early maturing type field tolerant to rhizome rot with high curcumin (7.9%), 15% oleoresin and 7% oil.

IISR Prabha: An open pollinated progeny selection, suitable for all turmeric growing tracts of India; rhizome reddish yellow in colour with curcumin content of 6.5%, besides 15% oleoresin and 6.5% oil.

IISR Prathibha: An open pollinated progeny selection with reddish yellow rhizome. Crop duration is 188 days, a stable yielder across environments and suited to all turmeric tracts across India. it is renowned for its high quality, with a dry recovery of 18.5%, curcumin 6.2%, oleoresin 16.2% and essential oil 6.2%.

IISR Kedaram: A selection suitable for Kerala and Andhra Pradesh with 18.9% dry recovery, curcumin content of 5.5%, and 13.6% oleoresin; resistant to leaf blotch disease.

IISR Alleppey Supreme: This high quality turmeric variety is a selection from the local cultivar, 'Alleppey Finger turmeric'. The crop duration is 210 days. It is resistant to leaf blotch disease. The variety has a curcumin content of 6.0%, 16% oleoresin and 4.0% oil, with a dry recovery of 19.3%.

Improved varieties of cinnamon and nutmeg

IISR Navashree: It is a high quality line of cinnamon with good bark recovery (40.6%) and shoot regeneration, good aroma and taste, and grows well in both plains and high elevations. Bark oil is up to 2.7% with high cinnamaldehyde content (73%), eugenol (6.0%), oleoresin (8.0%) and leaf oil of 2.8% with cinnamaldehyde (15.0%) and eugenol (62.0%).

IISR Nithyashree: This cinnamon variety yields 200-250 kg of dry bark/ha (good bark recovery of 30.7%) and has shoot regeneration capacity along with good aroma and taste. Bark (2.7%) and leaf (3.0%) oleoresin contents are also high.

IISR Vishwasree: A high yielding nutmeg variety developed through selection from clonal population and suited for all nutmeg growing areas of Kerala. Economic yield starts from the sixth year itself with 35% mace and 70% nut recovery. Myristicin and elemicine are also high in nut and mace oils.

IISR Keralashree: A high yielding nutmeg variety, developed through farmers' participatory breeding programme. The variety has bold nuts with entire and thick reddish mace. Economic yield starts from the fifth year with 35% and 70% mace and nut recovery. Mace and nut are rich in sabinene and have low myristicin and elemicin content.

Nursery techniques for spice crops

Rapid methods for production rooted cuttings of black pepper: A method for rapid multiplication of black pepper rooted cuttings using split bamboo method was standardized in the 1970s itself, with a multiplication ratio is 1:40 per annum. The well developed root system ensures higher field establishment. Besides, a novel 'serpentine method' for production of planting material in black pepper has been developed in recent times. The highlight of this technology is the high multiplication ratio of 1:60, higher field establishment with the well developed root system and the ease of adoption for the farmers/nursery men.

The column method is a novel method of producing orthotropic, plagiotropic (rooted laterals) and single node cuttings of black pepper in soilless medium. Growing black pepper plants on columns makes the cling roots also take up the role of absorption and consequently the rate of growth is enhanced. Each column can give 10 orthortropic shoots of 5 nodes each, 20-30 lateral branches that can be made into bush pepper and 100-120 single node cuttings in four months time.

New rooting media for black pepper cuttings: Substituting sand with granite powder (a waste material from stone quarries) in nursery mixture in the ratio of 2:1:1 (soil: granite powder: FYM) and addition of *Trichoderma* sp. and applying nutrient solution (urea, superphosphate, potash and magnesium sulphate) at monthly intervals produced healthy rooted cuttings. This innovation ensures multiple benefits like lesser production cost, healthy cuttings with higher root biomass (20% more) and up to 80% reduction in pathogen infection in nursery cuttings.

A soilless nursery mixture with decomposed coir pith (fortified with *Trichoderma* sp.) and vermicompost (3:1 ratio), has been standardized for mass production of rooted black pepper cuttings in plug trays. Healthy cuttings with higher establishment and easy transportability are the benefits. The cost of production works out to only ₹ 6.50/plant.

Nursery medium for nutmeg seedlings: Nursery mixture with soil: sand: coir dust: vermicompost in proportion of 1:1:1:1 is a better medium that supports seed germination and seedling growth in nutmeg.

Pro-tray nursery for ginger: A microrhizome technology for production of disease-free planting materials in ginger has also been developed. A transplanting technique in ginger by using single bud sprouts (5 g) raised in soil-less nursery mixture, coir pith with *Trichoderma* sp. and vermicompost (75:25 ratio) in pro-trays was standardized. Reduced ($\frac{1}{4}^{th}$) seed rhizome requirement, reduction in seed rhizome cost, disease free planting material, employment generation and increased cost benefit ratio. Cost per planting unit is ₹ 0.70.

Planting material production technique in cardamom: Techniques for rapid clonal propagation of cardamom suckers through trench method by close planting at a spacing of 1.8m x 0.6m has been developed. Advantage of this method is production of large number of true-to-type materials with a multiplication ratio 1:20 per annum at 50% lesser cost, besides being very easy to adopt.

Vegetative propagation methods in tree spices: Epicotyl grafting and budding in nutmeg and air layering in clove and cinnamon have been standardised. These propagation techniques give >90% success and are being widely used for production of quality planting materials from released/disease-tolerant varieties.

Crop production technologies for black pepper

Irrigation schedule for black pepper: Drip irrigation (7 litre per vine per day) between October to March has recorded higher fresh yield per vine of 3.36 kg, increasing the yield by 200%. Irrigating bush pepper grown in coconut garden with drip irrigation (8 l/plant) from October to May is recommended to get maximum income.

Intercropping medicinal plants in black pepper gardens: Intercropping medicinal plants in juvenile black pepper gardens (<4 years) with *Vetiveria zizanoids* or *Alpinia calcarata* is recommended. Among tuber crops, greater yam (*Dioscorea alata*) is recommended to get maximum income. Inter cropping of elephant foot yam (*Amorphophallus campanulatus*) or Hybrid Napier grass or medicinal plants like *Plumbago rosea* are recommended for yielding black pepper gardens for maximizing the profit.

Fertilizer management in black pepper: A fertilizer schedule, including lime application (500 g/ vine) and application of N, P_2O_5, K_2O @ 140: 55: 270 kg/ha (applied in two equal splits) for obtaining optimum yields in black pepper grown in laterite soil was developed. This increased yield by 71% under the mixed cropping with coconut. Mussoorie rock phosphate was found to be a good source of P compared to super phosphate for better soil P availability. Yield increase of 47% and higher agronomic efficiency was recorded when rock phosphate was used as P source.

Increasing use efficiency of fertilizers: Application of urea coated with nimin (neem seed extract@ 1%) to black pepper (100 kg/ha) is recommended, which increases N availability in soil by 38% and black pepper yield by 51%. For economic yield and quality, 50% of recommended dose of K as SOP for soils of high K status and 100% recommended K as SOP + 2% foliar spray for soil of low K status has been recommended.

Integrated Nutrient Management: Application of coir pith compost (1.25 t/ ha) integrating with half the recommended fertilizer dose and *Azospirillum* sp. (20g/ vine and Mg (200g/ vine) is recommended for higher yield and fertility build-up in black pepper gardens. The INM increases the yield by 20% compared to application of NPK alone.

A low-input technology for black pepper: Application of half the recommended dose of fertilizers + Zn (6.2 kg/ha) or foliar application (0.25%) of Zn twice as inputs is a risk-free technology ensuring better returns for small and marginal pepper growers in Kerala. Alternately, application of FYM+½ dose of P + Azospirillum (or) FYM + half dose of N + Phospho bacteria is also recommended.

Organic production technology for black pepper: An organic package for production of black pepper by applying FYM (10 kg), vermin-compost (2 kg), ash (500 g) and rock phosphate combinations and Azospirillum and phosphobacteria (20 g each) and *Trichoderma* sp. *Pseudomonas* sp. as biocontrol agents has been developed. Yield was on par with that of integrated management with higher piperine content and soil health improvement.

Crop production technologies for cardomom, ginger and turmeric

Fertilizer schedules for cardamom: Fertilizer schedules with neem cake or vermicompost (2.5 t/ha) and an NPK dose of 120: 120: 240 kg/ha for closer planting (2 x 1m) and 75: 75: 150 kg/ha for normal spacing (2 x 2 m) giving higher yields have been developed.

Mixed cropping of cardamom with coffee and black pepper: A mixed cropping system for cardamom with coffee, arecanut, coconut and black pepper for obtaining high productivity from unit area has been developed and is being popularized. Mixed cropping of cardamom recorded 4.1 times higher net returns and created 1.6 times additional labour opportunities over mono cropping.

Irrigation schedule for cardamom: Irrigating cardamom with drip (8 l/ clump), or sprinkler irrigation (for 6 h once in 12 days) during summer months is recommended, which gives higher capsule setting (20%) and yield (13%).

Micronutrient for cardamom, ginger and turmeric: In a micronutrients-deficient soil, foliar application of cardamom-specific micronutrient mixture (0.5%) twice a year is recommended, which gives an yield increase of 10%. Besides, ginger and turmeric-specific micronutrient mixtures suited for both acid and alkaline soils are also developed, which gives a yield increase of 15-30 %.

Integrated nutrient management in ginger and turmeric: Application of neem cake @ 2 t/ha or coir compost @ 2.5 t/ha during planting along with recommended NPK fertilizers increased the yield in ginger and turmeric up to 66%.

PGPRs for black pepper and ginger: A bio-formulation containing PGPR consortium (*Micrococcus luteus* (BRB3), and *Micrococcus* sp. (BRB 23) and *Enterobacteraerogenes* (BRB13)) for black pepper was developed in sterilized talc powder containing minimum population of 108 CFU/g. Application of this consortium resulted in growth (root biomass) promotion, 25% reduction in requirement of N fertilizer, and 70% reduction in disease incidence. This product named IISR Biomix- BP, has been licensed for commercial production.

Another talc-based formulation of rhizobacteria, GRB 35 *Bacillus amyloliquifaciens*, was developed protecting ginger against soft rot disease and enhancing nutrient mobilization in soil.

Technologies for disease/pest control

Disease management in black pepper nursery: Use of solarized potting mixture fortified with biocontrol agents (VAM and *Trichoderma* sp.), drenching with copper oxychloride (0.2%) (or) potassium phosphonate (0.3%) or metalaxyl-mancozeb (0.125%) and foliar spraying of Bordeaux mixture (1%) is recommended for management of Phytophthora infections in black pepper nursery, with a disease control efficiency of more than 90%.

Nematode control in black pepper nursery: Use of solarised potting mixture fortified with biocontrol agents (*Trichoderma* sp. and *Pochonia* sp.), drenching carbosulfan @ 50 ml/poly bag (containing 1.5 kg potting mixture) is recommended for management of plant parasitic nematodes in black pepper nursery. Disease control efficiency is 100% with the cost of treatment just four paise per plant.

Disease management in cardamom nursery: Solarization of cardamom nursery beds before sowing, soil fumigation or application of phorate and 0.2% copper oxychloride, two weeks after germination and again after three months reduced root-knot nematode and damping off disease in cardamom nurseries. Drenching tebuconazole 0.05% was effective against rhizome and root rot pathogens in the nursery.

***Phytophthora* foot rot disease management in black pepper gardens:** Integrated disease management schedules for Phytophthora foot rot involving phytosanitation, adequate drainage, foliar spraying Bordeaux mixture (1%) and drenching copper oxychloride (0.2%) (or) potassium phosphonate (0.3%) or metalaxylmancozeb (0.125%) @ 5-10 litres/vine and application of Trichoderma harzianum @ 50 g/vine were formulated. If biocontrol agent is applied, drenching with copper oxychloride can be avoided. This technology has been adopted in all black pepper growing tracts and has kept the disease incidence to less than 5%.

Slow wilt disease management in black pepper gardens: Integrated disease management schedules for slow wilt disease management involving phytosanitation, application of phorate 10 G @ 15 g (or carbofuran 3 G @ 50 g) at the time of planting and during May/ June and September/ October along with bioagents *Pochonia chlamydosporia* and *Trichoderma harzianum* @ 50 g/ vine twice a year were formulated. This technology has been adopted in black pepper growing tracts which kept the disease incidence to less than 15%.

Management of pollu beetle in black pepper: Regulation of shade, spraying quinalphos (0.05%) during June-July and September-October or quinalphos (0.05%) during July and Neemgold (0.6%) (neem-based insecticide) during August, September and October is recommended. Technology was adopted in all black pepper growing tracts and kept the pest incidence <2% with no residues of pesticides in the product.

Management of katte disease in cardamom: An integrated disease management strategy involving rouging of affected plants, vector management through botanicals (neem-based products) and an entomopathogen (*Beauveria bassiana*) and replanting with disease-free material was developed for management of katte disease. Adoption of katte management strategy prevented disease spread effectively and increased the economic life of the plantation by 3-4 years.

Rhizome rot management in cardamom: An integrated disease management strategy involving provision of drainage, phytosanitation, spraying Bordeaux mixture 1% and drenching with copper oxychloride 0.2% (or) spraying and drenching potassium phosphonate 0.3% or metalaxyl-mancozeb 0.125% is recommended. Application of *Trichoderma* sp. @ 1 kg during May/June and September/October may also be undertaken. If biocontrol agent is applied, drenching with copper oxychloride can be avoided.

Management of nematodes in cardamom: Application of neem cake twice a year @ 500-1000 g and spot application of carbofuran/ phorate (15-50 g) during May/ June and September/ October and application of *Trichoderma* sp. (1 kg) during May/ June and September/ October is recommended. Significant reduction in nematode population up to 80% was achieved with this practice.

Integrated management of rhizome rot in ginger and turmeric: Seed treatment with metalaxyl-macozeb 0.125 %, soil solarization, phytosanitation, provision of adequate drainage and soil application of metalaxyl-mancozeb 0.125% along with neem cake (1 kg/ bed) enriched with *Trichoderma harzianum* reduced the disease incidence.

Management of shoot borers of ginger and turmeric: An integrated strategy involving pruning and destroying freshly infested pseudostems during July-August (at fortnightly intervals) and spraying malathion 0.1% during September-October (at monthly intervals) was developed. This integrated practice ensuring sparing/judicious use of pesticides recorded low shoot borer incidence (<5 %) and a product without pesticide residue.

Technologies for harvest and post harvest operations

Harvesting fully matured un-split fruits of nutmeg and dipping them in 500 ppm ethrel for 10 min resulted in 100% splitting in 20 h. Uniform harvesting/ minimum number of harvesting operations, ensure cost-savings, reducing the drudgery in harvesting and chances for aflatoxin contamination.

Drying black pepper on polyethylene sheets (LDPE/ HDPE) has been found to be ideal for obtaining a clean product, in lesser time for drying (17 hours). The modified atmosphere packaging (90% N + 10% CO_2) in three layered polyester cover was found to be ideal for long term storage of black pepper without nay aflatoxin contamination and insect damage. In this method, dried pepper can be stored for 480 days without reduction in oil, oleoresin and piperine contents. Besides a process for production of high quality and foul smell-free white pepper using bacterial fermentation technology was developed. The advantages are good colour and recovery, ensuring premium prices.

Impact of R&D in spice sector is evident

The synergy of co-ordinated activities of R&D institutions like the ICAR- IISR/ AICRPS under the ICAR system, Spices Board and DASD is manifest itself in the substantial increase in production to 6.108 million tonnes from an area of 3.317 million ha during 2014-15. In terms of export, a total of 8.42 lakh tonnes of spices and spice products valued ₹ 16238.2 crore (US$ 2482 million) have been exported from the country during 2015-16, registering an increase of 46% in quantity and 66% in value terms over the last five years with value-added products forming an integral part of our export basket.

Despite this promising scope, the yield levels of some of the spice crops like cardamom, black pepper and fennel continue to be well below the global average productivity level. The small size of the holdings presents both challenges and opportunities for sustainable growth. The spices sector has shown considerable interest to adopt modernization, visible across the plantations showing renewed interest in adopting advanced technologies in production and post-harvest practices, auguring well for the bright future in this sector.

A futuristic vision of spice scenario

Many countries are competing with India in the spice trade with the opening up of international markets. With the liberalization of trade regimes in India in the wake of WTO/regional FTAs, import of spices to India is also on the rise. To make matters difficult, productivity level in India is believed to be low compared to other competing countries, making it inherently weak in such a competitive trade environment. An illustrative case is that of pepper productivity in India, the 'legendary home' of pepper, with just 283 kg/ ha, one of the lowest in the world. In India, even the gap between national average and the realizable yield is very wide. In pepper, it is around 2445 kg/ha and in cardamom 1625 kg/ha (national average is just 120 kg/ha). The bottom-line is that bridging this enormous gap in productivity is in itself sufficient to increase country's production many-fold.

Increasing the productivity per unit area through spice based farming systems, development of varieties with high degree of resistance to biotic and abiotic stresses, development of agro- technologies towards low input management, precision farming, developing eco-friendly IPM strategies, and popularization of proven technologies though extension network are the major areas of future attention. These technological advancements, hopefully, will bring out a surge in productivity of spices sufficient enough to meet the increasing domestic consumption and export demand. Considerable efforts will also have to go in to improving the present post-harvest processing and storage systems and in educating the farmers and traders in hygienic handling/processing. Besides, achieving the desired increase in share of value-added products in the export basket of spices necessitates strengthening of processing facilities, both on farm and of the farm.

CASHEW: THE SOUTH AMERICAN 'KING OF NUTS' THAT MADE INDIA ITS THRONE

The cashew (*Anacardium occidentale* L., family Anacardiaceae) is 'the precious gift of nature to the mankind', as cashew kernel is a 'unique nutritional capsule' packed with proteins (with several essential amino acids), fat, carbohydrate, minerals and vitamins, and literally a powerhouse of energy. It is undoubtedly the most delicious and nutritious snack food in the world. If there is one innovation which changed the destiny of this crop forever, it is the technology of vacuum packing of kernels which made it possible to transport long distances over continents and to store it for a fairly long periods. With that, the wasteland crop transformed itself to the million-dollar crop.

Cashew is native to northeastern Brazil and the name is derived from the Portuguese *caju*, which itself is derived from the native Tupian word *acajú in* South America, literally meaning "nut that produces itself". The nut is the real fruit and what appears to be the fruit (pseudocarp or false fruit), the cashew apple, is a hypocarpium that develops from the pedicel and the receptacle of the cashew flower. The generic name *Anacardium* (originally from the Greek), refers to the unusual location of the seed outside the core or heart of the fruit (ana- means 'again' or 'backward' and -cardium means 'heart').

Though, cashew is presently cultivated in about 32 countries around the world including Latin America, Tropical Asia, Africa and Australia, India is the first country to exploit cashew as a commercial horticultural crop. Cashew was introduced in India by the Portuguese in the beginning of 16th century. Initially, it was adopted as a plant for afforestation of coastal degraded lands but realizing the importance, it has been commercialized as one of the important forex earning crops by exporting cashew kernel after processing. In India, cashew is grown mainly in Kerala, Karnataka, Goa, and Maharashtra along the West Coast and Tamil Nadu, Andhra Pradesh, Odisha and West Bengal along the East Coast and also spreading in non-traditional areas like Bastar region of Chhattisgarh, Jharkhand, Gujarat and North- Eastern Hill Region. Cashew is grown in an area of 10.08 lakh ha with an annual raw nut production of 7.37 lakh tonnes in 2013-14.

In the global scenario, India not only occupies largest area (20.30%) under cashew cultivation but also the largest processor, exporter, importer and consumer of cashew; but, contribution of India to global raw cashew nut production of 16.10% is not commensurating with the area under the crop. Vietnam is the largest producer of raw cashew nut (30.30%) followed by Nigeria (19.40%), India (16.10%), Ivory Coast (10.80%), Brazil (5.50%), Philippines (3.20%), Guinea-Bissau (3.10%), Indonesia (2.90%), Benin (1.70%) and Mozambique (1.70%). Moreover, India is lagging behind in productivity of raw cashew nut (782 kg/ha) compared to country like Vietnam (> 3000 kg/ha). The main factors associated with low productivity of cashew in India are the large area under cashew plantations of seedling origin, most of the plantations being on degraded sites and under rainfed conditions, poor adoption of latest cashew production technologies, severe damage caused by tea mosquito bug (TMB) and cashew stem and root borer (CSRB) and coincidence of adverse weather conditions with flowering and fruiting.

India is the first country which commercialized cashew as a horticultural crop. India exports 1.151 lakh tonnes of cashew kernels per annum to over 65 countries and is a prominent trader for over a century. The major countries that import Indian cashew are United States of America (USA), United Arab Emirates (UAE), Netherlands, Saudi Arabia, Japan, Spain, France, United Kingdom, Germany, Korean Republic, Belgium, Singapore, Kuwait and Algeria. About Rs. 5062.76 crores are earned as foreign exchange through export of cashew kernel and additional Rs. 38.61 crores by export of Cashew Nut Shell Liquid (CNSL).

However, the most striking fact is that there is a steady upward trend in domestic consumption of cashew kernels, surpassing the kernel export during the present decade since 2005-06 (even to the extent of 150 % more than the export in 2012-13), an indisputable testimony to its affordability to a large segment of the consumers on account of the increasing purchasing power of the Indian urban middle class and its changing food habits. Cashew kernels being a rich source of protein, carbohydrate and fat with right proportion of saturated, mono unsaturated and poly unsaturated fatty acids, besides several vitamins like vitamin E which improves immunity, can complement the nutritional security for a sizable growing population.

The major challenges in cashew sector are breaking the yield barrier of low productivity enabling the native processing industry to meet the ever increasing demand for cashew kernel both at national and international level, and improving the livelihood options of cashew farmers, through development of site-specific technologies for better input use efficiency, development of eco-friendly management strategy for devastating pests like TMB and CSRB, up-scaling of cashew apple based products and development of cashew by-product based industries. Since India has the benefit of well developed processing industries with about 15-20 lakh tonnes of raw nut processing capacity and the quality of Indian cashew kernels have global repute and increasing domestic demand of cashew kernel, there is an urgent need to enhance the present level of productivity and a reasonably good scope for area expansion on degraded lands and in non-traditional areas.

A mouthful bite of its history

Cashew research in India was first initiated in 1951 by the Indian Council of Agricultural Research (ICAR) through ad-hoc research schemes at Kottarakkara (Kerala) in 1952, Ullal (Karnataka) in 1953, Bapatla (Andhra Pradesh) in 1955, Deragaon (Assam) in 1956 and Vengurle (Maharashtra) in 1957. The programmes in these ad-hoc schemes included introduction and evaluation of cashew germplasm, propagation trials, production and evaluation of hybrids.

With the establishment of the Central Plantation Crops Research Institute (CPCRI) at Kasaragod (Kerala) in 1970 and starting of the All India Coordinated Spices and Cashewnut Improvement Project (AICS & CIP) in 1971 with its headquarters located at CPCRI, Kasaragod, cashew research was further strengthened in the country. The implementation of the World Bank aided Multi

State Cashew Project (MSCP) with a research component for cashew during 1982 to 1986 in Kerala, Karnataka, Andhra Pradesh and Odisha States gave cashew research the much needed impetus. Pioneering studies on vegetative propagation methods in cashew were undertaken under MSCP.

Based on the recommendation of the Quinquennial Review Team (QRT) of CPCRI constituted by ICAR in 1982, the Working Group on Agricultural Research and Education constituted by the Planning Commission for VII Plan Proposals and the Task Force on Horticulture constituted by ICAR, the National Research Centre for Cashew (NRCC) was established at Puttur on 18th June 1986. The NRCC was conceived to undertake mission oriented research projects with the objectives of evolving high yielding varieties of cashew with resistance/tolerance to pests such as tea mosquito, standardization of agro techniques for achieving higher production and sustainable productivity and transfer of technology to end users. The NRC for Cashew was upgraded as Directorate of Cashew Research (DCR) as approved in the EFC of XI Plan, on 30.01.2009. The Directorate organized the Silver Jubilee Celebrations of its establishment during December 2011.

The present research establishment: ICAR-DCR and AICRP (Cashew)

The headquarters of ICAR-Directorate of Cashew Research (formerly National Research Centre for Cashew) is located 5 Km away from Puttur town, off the Mangalore-Madikeri-Mysore Road (12.45o N latitude and 75.42oE longitude) and is about 90 m above MSL. The main campus at Kemminje, Puttur has an area of 68 ha of land having field experiments and Laboratory-cum-Administrative building. Besides the main campus at Puttur, an Experimental Station at Shantigodu, with an area of 80 ha also forms part of this Directorate. This Experimental Station was started as Cashew Seed Farm under Central Plantation Crop Research Institute in the year 1972.

The Vision of ICAR-DCR is accomplishing self-sufficiency in raw cashewnut production and thereby enabling the nation in maintaining its premier position as the largest producer, processor and exporter at global level. Over the years, DCR underwent time-bound scientific reviews by several Quinquennial Review Teams which helped to prioritize and guide the research activities of this Directorate.

The present mandate of ICAR-DCR, Puttur is:

- Basic, strategic and applied research on genetic resource management, enhanced productivity and utilization of cashew.
- Transfer of technology and capacity building of stakeholders for enhanced productivity of cashew
- Coordinate research and validation of technologies through AICRP on Cashew.

Subsequent to the bifurcation of All India Coordinated Spices and Cashewnut Improvement Project (AICS & CIP), the headquarters of All India Coordinated Research Project on Cashew (AICRP on Cashew) was shifted to NRC for Cashew, Puttur. At present, this Coordinated Research Project is operating in

Experimental Station at Shantigodu

thirteen centres and a sub centre located in major cashew growing states of the country.

The mandate of the AICRP on Cashew is to give additional thrust to increase production and productivity of cashew through multi-location research by:

- Evolving high yielding varieties with good kernel quality and tolerance to biotic and abiotic stresses.
- Standardizing agro-techniques for the crop under different agro-climatic conditions, and
- Evolving cost effective and efficient pest and disease management practices.

Research is organized under five major research disciplines of Crop Improvement, Crop Production, Crop Protection, Post Harvest Technology and Transfer of Technology. The major laboratories are Horticulture, Plant Physiology, Biochemistry, Plant Breeding, Biotechnology, Soil Science, Agricultural Entomology, Plant Pathology, Post Harvest Technology and Audio Visual Laboratory. These laboratories are well equipped with modern equipments for carrying out various research activities.

Infrastructural facilities

The Directorate also has a well furnished Library which subscribes to various national and international journals. Other infrastructure facilities include, two Conference Halls, a Committee Room, Museum, Insectary, Green house structures, well furnished Guest House, etc. Apart from these, the Directorate has a state-of-the-art facility as Smart Class Room to conduct HRD programmes on cashew technologies to scientific community/end users. Besides, separate Project Coordinator Cell, AKMU, PME Cell, ITMU and Official Language Cell are also functioning in this Directorate. The Directorate has also been awarded ISO 9001:2008 based on the standard evaluation procedure and protocol.

Pioneering research in cashew

A landmark in cashew research and development was the establishment of the Cashew Seed Farm at Shantigodu, near Puttur (South Kanaradistrict, Karnataka State) over 20 ha of land made available by the Karnataka Government for the isolation and multiplication of genetically superior planting materials.The Seed Farmwas formally inaugurated on 10 November, 1973, by Shri K.H. Patil, then Minister for Agriculture and Forests, at a meeting presided over by Shri K.Shankara Alva, Minister for Co-operation, Government of Karnataka. subsequently, another 60 ha wasalso transferred to the Institute by June, 1974.

Another positive development for the cashew sector was the sanction of the Multi-State Cashew Project (a World Bank aided project). The funds available under the MSCP were utilized to develop full-fledged inter-disciplinary research programmes in cashew, covering various aspects of vegetative propagation, plant protection measures and crop management including product development.A positive outcome of thisprojectwas the development of the

ICAR - DCR, Puttur

epicotyl grafting technique for large scale multiplication of elite cashew lines, which revolutionized the cashew cultivation since then. Infrastructural facilities for cashew research at Regional Station Vittal and Seed Farm at Shantigodu were also augmented with funds the MSCP.

Collection, conservation cataloguing and evaluation ofcashew germplasm

A germplasm block with 161 cashew collections (both indigenous and exotic ones) were planted in 1972 at Regional Station, Vittal. Subsequently, a comparative yield trial of cashew consisting of 16 high yielders from the four cashew research centres (Vengurla, Vridhachalam, Bapatla and Anakkayam) was laid out. The high yielding varieties from these trials, M 44/3, M 10/4 and BLA 139, wererecommended for large scale multiplication.

By 1984, a total of 273 accessions of cashew germplasm were assembled at Vittal and Cashew Seed Farm Shantigodu. Subsequently, a germplasm survey carried out in Goa and in four districts of northern Kerala which helped to identify types with specific characters and 40 collections from Goa, 22 from Kerala and 12 accessions from Cashew Research Station, Ullal were collected during 1984. These collections were planted in a replicated trial (Goa & Malabar Collections) at Regional Station, Vittal. In the later years, promising ones from all the germplasm blocks at Vittal were clonally propagated and planted in the clonal germplasm conservation and evaluation blocks at DCR, Puttur.

Nutritional studies in cashew

Studies on immature fruit drop in the early 1970s showed that nutritional imbalance and other physiological factors alone accounted for 60.4% of fruit drop, while insect attack accounted for 20% of fruit drop (at the mustard, peanut, and later stages) andnearly 15% of fruit drop is due to defective fertilization.

As early as 1972, an NPKfertilizer experiment was laid out on adult bearing trees at the Kerala Government Cashew Plantations, Periya in Kasaragod district,with for assessing the manurial requirement of cashew trees. A study on the nutrient removal indicated that a healthy cashew tree yielding about 24 kg nuts and 155 kg apples annually removes about 2 kg N, 0.6 kg P_2O_5 and 1 kg K_2O.

Effect of graded doses of NPK fertilizers on the productivity of cashew layers and seedlings was studied in an experiment was laid out in 1970s with three levels each of N, P and K using sevenvarieties of cashew layers and seedlings. Fertilizer application had significantly influenced plant height both in air layers and seedlings. In the seedling progeny, application of N at 450 g/plant recorded significantly higher plant height compared to 150 g N. In layers, plant height was increased up to 300 g. Canopy radius was maximum in plants receiving the highest level of N P & K. Air layers gave higher yield compared to seedling progenies. In seedling progenies, trees receiving the highest doses of N, P or K gave significantly higher yield than those receiving middle and lowest doses.

Subsequently, another experiment was started in 1983 with eight varieties of cashew (WBDO-V, M-6/1, M10/4, M44/3, T-1, EPM 9/4, Kodur and BLA 139-1) and three levels of N (250, 500 and 750 g/plant) to study the response of high yielding varieties of cashew to different levels of nitrogen.Preliminary observations on morphological characters (height, girth, vertical and lateral spread and flowering behaviour) indicated a linear response with increase in nitrogen levels.

Studies on high density planting

The trial on high density planting of cashew laid out at Cashew Seed Farm, Shantigodu during July 1982 has given promising leads. The results indicated a direct correlation of surface area of different tree densitieswith yield per unit area, since cashew bears fruits only on the outer canopy of the tree.

Studies on canopy architecture

A field trial to study the effect of time and severity of pruning in cashew had been in progress since 1984 at the Research Farm in Shantigodu. The preliminary results indicated that, in general, the leader shoot pruning was better than the lateral shoot pruning and a pruning regime for maintaining optimum canopy was standardized in later years.

Pest and disease management

Studies on the biology and bionomics of stem borer, tea mosquito, and leaf miner and chemical control trials against these insect pests were also initiated. Inflorescence blight was another serious malady responsible for severe losses in cashew.It was confirmed that infestation by the tea mosquito (*Helopeltis antonii*)was primarily responsible for inflorescence blight and the associated fungi were only secondary saprophytic colonisers. Preliminary field trials on the control of inflorescence blight showed promising results.

Research Accomplishments of ICAR-DCR

Crop Improvement

Germplasm Resources: The initial seedling germplasm collections (assembled at CPCRI) were transferred to ICAR- DCR, Puttur on its inception and since then, ICAR-DCR has made considerable efforts for surveying diverse germplasm from India. The National Cashew Field Gene Bank (NCFGB) has presently 539 collections including exotic accessions and three wild species (*Anacardium microcarpum, A. othonianum* and *A. pumilum*) and many other diverse types such as Cashew Nut Shell Liquid (CNSL) free type, purple leaf types and dwarf types. This Directorate has also made valuable contributions in the field of breeding behavior. (reproductive biology, pollination mechanism, pollen germination) and standardized the hybridization technique. The three cashew varieties with consistent performance and desirable yield attributes were released as NRCC Selection-1, NRCC Selection-2 and Bhaskara *(named in tribute to Dr. E.V.V. Bhaskara Rao, the first regular director of the institute who steadfastedly built up the institution right from the beginning)*.

Hybridization initiatives: Hybridization with promising parents was carried out and the progenies are being evaluated. H-43, H-66, H-68 (all from NRCC Sel.2 × Bhutnath-II), H-125 and H-126 (both from NRCC Sel.2 × Bhedasi) had consistent annual and cumulative yield. Efforts are also in progress to develop dwarf and compact hybrids deploying both direct cross and back cross breeding approaches. Hybrids were also produced from cross combinations involving wild species like *A. microcarpum* and *A. orthonianum* with popular cultivars for imparting resistance to pests of cashew. The most exciting new development is the jumbo nut variety, H-126, with a kernel grade of W180.

Softwood grafting revolutionized the planting material production

A vegetative propagation technique of softwood grafting was standardized during the early 1990s facilitating large-scale production of quality planting material for area expansion. This method is highly successful and widely adopted with about 3.0 lakh grafts of recommended varieties produced

annually and distributed to farmers and other developmental agencies. Apart from nurseries at ICAR-DCR and AICRP-Cashew centres, several accredited nurseries in the private sector are also supplying region-specific elite planting materials.

Crop Management

High Density Planting system

High Density Planting (HDP) is one of the best means of enhancing productivity. Spacing of 4m x 4m (625 plants/ha) instead of the conventional 8m x 8m (156 plants/ha) has proved to be successful in increasing the nut yield by 2.5 folds in the initial ten years.

Optimizing input use efficiency

Fertilizer and irrigation requirement in cashew has been investigated in detail at this Directorate. Foliar spray of major nutrients (3% urea + 0.5% H3PO4+ 1% K_2SO_4) as well as secondary and micronutrients (0.5% $ZnSO_4$+ 0.1% Solubor + 0.5% $MgSO_4$) in addition to the recommended dose of fertilizer (500:125:125 g NPK/tree/year) had positive significant effects on yield attributes leading to 16-30 per cent higher yield. Drip irrigation at 60-80 L of water/tree (once in four days after flowering till fruit set and development) with 750:187.5:187.5g NPK /tree/annum doubled the yield of cashew under West Coast of Karnataka.

Good scope for intercropping in cashew in the initial years

Cultivation of intercrops (Amorphophallus, pineapple, turmeric, brinjal and chillies) in cashew orchards is cost-effective. Pineapple as an intercrop in cashew orchard helped in enhancing the yield of cashew in addition to the pineapple

yield (21 t/ha) for the first five years. The trenches for planting pineapple acted as a soil and water conservation structure. Glyricidia when cultivated as green manure crop during initial years produced 6.75 t/ha/annum of dry matter which could contribute186 kg N, 40.8 kg P and 67.8 kg K/ha.

Soil and water conservation measures lead to higher production

Majority of the cashew plantations are in degraded lands under rainfed conditions. Hence, soil and water conservation practices can aid in enhancing cashew productivity. Crescent bund and staggered trenches with coconut husk burial checked annual run-off by 14 per cent and conserved the soil moisture, thereby increasing cashewnut yield by 30-40 per cent. On sloppy areas, terrace with crescent bund for individual cashew tree was the best soil and water conservation measure.

Soil fertility status of Konkan and Bhubaneswar regions delineated

Soil fertility has a direct influence on productivity and nut quality in cashew and a soil fertility index of major cashew growing tracts will lead to development of location/region-specific management recommendations. Soil fertility index of Konkan region indicated that soils of Dakshina Kannada district are rich in organic carbon, low available N and medium P, while soils of Vengurla region are rich in organic carbon and medium in available N and P. However, soils of Bhubaneswar fell in the ‘low’ category for all the three nutrients (organic carbon, available N and P). Micronutrient status of Dakshina Kannada district indicated sufficiency in Fe and Mn, and deficiency in Cu, Zn and B.

Crop Protection

Of the insect pests infesting cashew, the tea mosquito bug (TMB) and the cashew stem and root borer (CSRB) cause significant damage and reduction in nut yields, apart from the other minor (sporadic) insect pests (leaf miner, shoot tip caterpillar, leaf and blossom webber, apple and nut borers, leaf thrips, inflorescence thrips), which are of regional importance.

Managing the tea mosquito bug, *Helopeltis antonii* Signoret

During the early 1990s, investigations focused on management strategies for tea mosquito bug (TMB), which is a serious foliage and fruit pest of cashew. Both adult and nymphal stages induce damage by sucking sap from tender leaves, shoots, panicles, immature apples and nuts. Other species like *H. bradyi* Waterhouse, *H. theivora* and *Pachypeltis maesarum* Kirkaldy also occur concurrently with *Helopeltis antonii* and cause similar damage.

Consequent on the statutory withdrawal of conventional insecticides (monocrotophos, endosulphan and carbaryl), evaluation of the two synthetic pyrethroids - fenpropathrin (0.02%) and λ-cyhalothrin (0.003%) - gave on par efficacy and benefit: cost ratio with the recommended spray schedule. Most importantly, there was no traceable level of residues in the kernels obtained from insecticide-treated plots. The kernels from nut samples collected from the farmers’ fields in the major cashew growing areas of Tamil Nadu, Odisha, Maharashtra and Karnataka were also free from any traces of insecticide residues.

Evaluation of released varieties and germplasm accessions for their tolerance/ resistance to TMB, though laboratory screening/field caging, has not given promising results, a germplasm collection - Goa 11/6 - was identified as TMB ‘escape’ type under natural epiphytotic conditions, possibly due to its mid-season and re-flowering habit. This type was subsequently released as a new variety “Bhaskara” in 2006.

Towards developing a biological control regime, field surveys could locate certain egg parasitoids like *Erythmelus helopeltidis, Telenomus* sp., *Chaetostricha* sp. and *Gonatocerus* sp. nr. bialbifuniculatus from West Coast regions and *Ufens* sp. from the East Coast as regulating the pest populations. Unfortunately, as these parasitoids have very specific biotic requirements, these are not amenable for mass multiplication. Presence of female sex pheromone activity in virgin females of TMB has been confirmed and whole body extracts (WBE) could also elicit response from male TMB under field trials. Further efforts at exploiting this new possibility is being pursued vigorously.

Integrated management of cashew stem and root borers (CSRB)

A mixed field population of the two species, *Plocaederus ferrugineus* (62.5%) and *P. obesus* (31.0%), along with *Batocera rufomaculata* as a secondary pest, was confirmed through extensive field surveys. Post extraction prophylaxis (PEP) (involving removal of CSRB grubs followed by swabbing and drenching) with chlorpyriphos (0.2%) gave high recovery (82.52%). However, efficacy of curative control measures are highly dependent on the stage of infestation.

It was confirmed through extensive field trials that trees having less than 25 per cent bark (circumference) damage could recover better (96.0%). By adopting ‘phytosanitation’ (i.e., removal of dead infested trees and removal of pest stages from other trees as well as uprooting of trees beyond recovery), fresh incidence of CSRB and mean number of CSRB grubs per infested tree was reduced significantly.

Towards developing an efficient biological control, three indigenous entomopathogenic fungi (*Beauveria bassiana, B. brongniartii* and *M. anisopliae*) were evaluated for their virulence on CSRB grubs and *B. basianna* was found to be most virulent with LD50 of 1.41 x 106 spores/ ml. Among the three species of coleopteran infecting strains of EPN tested (*Steinernema abbasi, S. bicornutum* and *Heterorhabditis indica*), it is observed that all the three EPN species caused 100 per cent mortality of laboratory reared CSRB larvae in a short spell of 5 days, offering great promise in the near future.

Towards minimizing insecticide usage in management of CSRB, the novel approach of semio-chemicals is being investigated. Preliminary bioassay using wind tunnel glass olfactometer indicated that fresh frass and bark of infested tree elicited maximum response from both male and female adults of CSRB beetles. Under free choice conditions, highest egg laying was observed on bark of infested tree having frass. The response-inducing volatile concentrates and extracts of frass (identified by EAG) were synthesized and are being evaluated using bucket traps and cross- vane traps installed in CSRB infested plots which, hopefully, will give positive results.

Post-harvest technologies

Cashew nut processing equipments

A comprehensive database on cashewnut processing industries in India was prepared, outlining the operational conditions and problems faced by the industry, as a prelude to developing appropriate technology interventions for addressing the problems.

For overcoming the problem of drying moistened nuts due to coincidence of harvest and monsoon rains in North East hilly regions, a dual-mode dryer was developed (dryer which can be operated by electric power or bio fuel or both). In order to promote differential pricing for graded raw cashewnuts, a motorized concentric drum type grader, was developed to segregate into five different sizes, conforming to the prevailing standard kernel grades in the industry.

Opposite: Sucking pests of cashew

A patent has been awarded for 'Radial arm type cashew kernel extracting machine' (Indian Patent No.272371) and another patent entitled 'Rotary drum roasting machine for raw cashewnuts' (3843/CHE/2013) is under examination. Densification of pulverized cashew shell cake and saw dust mixture to produce stable briquettes and updraft gasifier were standardized. A pilot plant for cashew apple processing has been developed and relevant technologies are being disseminated through training programmes to the end-users.

Value-added products

Organoleptically acceptable cashew spread could be prepared from cashew kernel baby bits and its shelf life under low temperature (<10°C) is for a period of six months, without any quality deterioration. Lowest grade cashew kernels coated with sugar, honey, salt with different combination of flavour and colour have also been developed.

The cashew apple pomace powder could be stored up to four months at ambient temperature without any loss of antioxidant activity. This could be blended with cereals (wheat, rice and ragi) and pulses (green gram) flour up to 10 % and could be stored for 12 months without deterioration. An RTS beverage, prepared by blending cashew apple juice with lime juice, was found to have maximum organoleptic acceptability.

Impact of research technologies

ICAR-Directorate of Cashew Research has been instrumental in bringing about a critical change in use of planting material from seedlings to grafts, which has brought about remarkable impact in ensuring uniformity of crop performance. Further, three cashew varieties (NRCC Sel-1, NRCC Sel. -2 and Bhaskara) have been released and Bhaskara has gained wide popularity in Dakshina Kannada District and neighboring districts of Kasaragodu and Udupi. High density planting is yet another technology which has gained acceptability among the farmers. Quite a few farmers have adopted the intercropping system and supplemented their income during the initial cropping period. Wherever feasible, drip irrigation has been attempted by enterprising farmers and their yield increase has corroborated the findings of trials conducted at this Directorate. Till recently, application of fertilizers was very uncommon among the farmers, however, majority of the farmers have now started recommended fertilizer usage and realized better yields. Plant protection has long been an ignored aspect; however, due to the numerous plant protection campaigns, awareness and adoption of plant protection activities to minimize losses due to TMB and CSRB has shown an increasing trend. Value addition of cashew apple is yet another area in which the research institute has made substantial progress by way of conducting trainings for farm women/SHGs for promoting value-added products like cashew apple juice, jam, jelly RTS and cashew pickles.

Attaining self-sufficiency in raw cashewnut production

India requires about 16-18 lakh tonnes of raw cashewnuts per annum to meet the domestic requirement of around 5000 cashew processing units. India's raw nut production is not sufficient to sustain the processing capacity established in the country. For meeting this deficit, India imports 50-60 per cent of the required raw cashewnuts every year, mainly from African countries. It has been estimated that the requirement of raw cashewnuts will be 25.0 lakh tonnes by 2030 and 45.0 lakh tonnes by 2050. However, the future availability of raw cashewnuts is at stake as these countries have built up processing industries. Hence, it has become inevitable for us to increase the raw cashewnut production in India to maintain this supremacy in processing and exports.

This target can be achieved by a dual strategy of enhancing the present below par productivity of cashew to 2.5 - 3.0 t/ha and area expansion in potential locations. Undoubtedly, the single most important step in this direction is replacing the present low yielding cashew plants of senile and non-descript origin with cashew grafts of high yielding varieties along with adoption of improved production technologies.

OIL PALM: BRIDGING THE EDIBLE OIL DEFICIT

Oil palm (*Elaeis guineensis* Jacq.) is a native of West Africa and is grown extensively in South-East Asian countries (Malaysia, Indonesia and Papua New Guinea), African countries (Nigeria, Cote de'Ivoire, Ghana, Liberia, Sierra Leone, Cameroon, Republic of Congo and Zaire) and South American countries (Costa Rica, Panama, Columbia, British Guyana, Peru, Ecuador, Venezuela and Brazil). Malaysia, Indonesia and Nigeria are the leading producers of oil palm in the world.

Tenera is the ruling hybrid grown all over the world. It is a cross between thick shelled Dura (female parent) and shell less Pisifera (male parent). Tenera has thin shell, medium to high mesocarp and oil content. Palm oil is derived from the mesocarp of the oil palm fruit and palm kernel oil is extracted from palm kernels. Processing of oil palm involves multi unit operation. Major steps in the extraction of palm oil are harvesting of bunches, sterilization, stripping, digestion, pressing, clarification and purification. Methods such as refining, bleaching and deodorization (RBD) for palm oil and further fractionation of palm oil is followed to produce a liquid fraction called palm olein. Oil palm is the richest source of vegetable oil and has potential to yield 4-6 tonnes of oil / ha / year, which is 5 to 8 times the yield of cultivated annual oilseeds. Palm oil is a wholesome source of energy and is stable against oxidation due to low content of poly unsaturated fatty acids and also non foaming, have good frying qualities suitable for cooking. It can play a vital role in sustainable vegetable oil production and vegetable oil economy of the country.

Why oil palm?

Oil palm is known to be the highest edible oil yielding perennial crop that produces two distinct oils which have both culinary and industrial uses: palm oil from the fleshy mesocarp (45-55 %) of the fruit and the palm kernel oil from the kernel of stony seed. Oil palm has a greater advantage in terms of productivity that is much higher than that of any other oil yielding crops. Oil palm , on an average, produces 5.00 tonnes of crude palm oil and 0.50 tonnes of palm kernel oil per ha annually from 4^{th} to 30^{th} year of its productive life span, making it virtually the 'edible oil wells'.

Oil palm is the crop of the present and future vegetable oil economy of the world and for India too. The remarkable growth in per capita consumption of vegetable oil in India over the past three decades was driven by the tremendous income growth. Palm oil has good consumer acceptance as a cooking medium because of its price advantage. It is also a good raw material for manufacturing oleochemicals used in preparing cosmetics, pharmaceuticals and nutraceuticals. To meet the ever widening deficit in vegetable oils on account of the increasing per capita consumption and the projected population growth, there is an urgent need to increase the production of vegetable oils in the country.

Initial introductions

Oil palm was introduced in India during the 19^{th} century (probably during 1848 or 1890) in the National Botanical Gardens, Calcutta. During 1947-54, the African oil palm (dura) plants were introduced and planted in Pune for ornamental purpose by the Maharashtra Association for Cultivation of Sciences (MACS). The Government of Kerala introduced oil palm and set up an oil palm research station at Thodupuzha during 1960. The growth of plants at this station

was satisfactory, which prompted the Plantation Corporation of Kerala Limited to start oil palm plantations on a commercial scale during 1971.

Exploratory plantings and its further spread across India

Oil palm was introduced in Andhra Pradesh nearly 40 years ago at Agricultural Research Station, Kovvur and Ambajipet in East Godavari District. Dura palms were planted at Curzon Park, Mysore and Chetahalli, Kodagu District, nearly 38 years ago. The Department of Horticulture, Govt. of Karnataka has planted oil palm seedlings at most of their horticulture farms located in different agro-climatic regions in Karnataka State for demonstration purpose. In Kanyakumari district of Tamil Nadu, 24 dura palms were planted in 1969 at Pechiparai. Fifteen palms were planted during 1972 at the Coconut Research Station, Veppankulam, Thanjavur district. Dura palms were introduced in Maharashtra near Pune during 1947-54, for ornamental purpose. Few palms were planted at Neeral and Ganeshkhand, Pune. Few dura palms are growing satisfactorily in Dapoli. CPCRI has supplied 100 palms and planted at Agricultural School, Manjri, Pune during 1982.

At the Coconut Research Station at Sakhigopal, Orissa, four dura x dura and three plants of dura x pisifera were brought from Kerala and planted during 1965. Few palms were available at Coconut Seed Garden, Isaneshwar and tourist guest house at Konark. In West Bengal, tenera oil palm seedlings were planted during 1979 at Indian Statistical Institute, Calcutta. Tenera seedlings were brought from CPCRI Research Centre, Palode during 1986 at planted at Agricultural Farm, Manmatha Nagar in 24-Parganas district. Few palms are more than 50 and 100 years old. In Tripura, 24 tenera palms planted during 1975 at bio-complex of Sipahijala along lake side. Tenera seedlings were planted during 1983 at Horticultural Station, Nagicheera. In Assam, oil palm was introduced in Jorhat, nearly 38 years ago. During 1986, ten tenera hybrid seedlings were planted at Central Plantation Crops Research Institute, Research Centre, Kahikuchi, Assam. Large scale oil palm planting was taken up in Karnataka in Dakshina Kannda during 1969.

All these early introductions of oil palm in the country were made on experimental basis without adequate working knowledge about the crop. Despite several limitations, stray plants have given useful indication of the possibility of growing oil palm successfully in these areas. For example, the better performance of palms located near water source or under irrigation confirmed the need for assured water supply for oil palm cultivation.

Commercial plantations comes up in Kerala and Andamans

Oil palm cultivation was taken up on a commercial scale in Andaman and Nicobar Islands (2,400 ha) by the Andaman and Nicobar Islands Forest and Plantation Development Corporation (ANIFPDC) and in Kerala by the Plantation Corporation of Kerala Limited (PCKL)(1,052 ha) and Oil Palm India Limited (OPIL) (3,705 ha) under rainfed conditions during 1970s and 1980s. The pollinating weevil, *Elaeidobius kamerunicus*, was introduced for pollination, better fruit set and yield.

Oil palm gardens under irrigation comes up in Andhra Pradesh for the first time in India

During the 1980s, a shift was made in the development of oil palm in the country. The concept of irrigated oil palm was developed after identification of about 0.81 million ha in 11 states as potential area for this crop. For the first time in India, commercial planting under irrigated condition was taken up during 1987 in Pedavegi Mandal, West Godavari District under District Rural Development Agency (DRDA) programme.

Area expansion drive

Satisfactory growth and establishment of oil palm plants in different parts of the country, from the down south to north east and from the western and eastern India, demonstrated the vast potential to grow oil palm in India. Systematic planting programmes were taken up from 1988-89 onwards. Three large demonstrations were laid out in the states of Andhra Pradesh, Karnataka and Maharashtra under the aegis of Department of Biotechnology to assess the potentialities of the crop.

Chadha Committee reports (1988 and 2006) recommended an area of 10.36 lakh ha as potential for oil palm cultivation in India. Based on these recommendations, a massive Oil Palm Development Programme (OPDP) was formulated by Technology Mission on Oilseeds and Pulses (TMO&P) under the Ministry of Agriculture, Government of India to promote oil palm on a commercial scale under irrigated conditions in several potential states. The area expansion took place in 16 states - Andhra Pradesh (1,50,530 ha), Arunachal Pradesh (330 ha), Assam (570 ha), Chhattisgarh (2162 ha), Goa (938 ha), Gujarat (5,301 ha), Karnataka (41,431 ha), Kerala (5,769 ha), Maharashtra (1,474 ha), Mizoram (25,471 ha), Nagaland (140 ha), Odisha (18,444 ha), Telangana (16,239 ha), Tamil Nadu (29,806 ha), Tripura (530 ha) and Andaman Nicobar Islands (1,593 ha). As a result of this expansion drive, area under oil palm steadily increased from 8585 ha in 1991-92 to around 3.00 lakh ha in 2015-16. Similarly the fresh fruit bunch (FFB) production increased from 21,233 tonnes in 1992-93 to 11,50,000 tonnes during 2014-15.

Oil palm research in India

Oil palm research in India started with the establishment of a Research Station at Thodupuzha by the Department of Agriculture, Kerala during 1960. Indian Council of Agricultural Research (ICAR) started oil palm research at Central Plantation Crops Research Institute Research Centre at Palode during 1975. Oil Palm was included as one of the crops in the All India Coordinated Research Project on Palms during VII Five Year Plan period.

However, cultivation of oil palm under irrigated conditions is practically a new development and the ICAR established the National Research Centre for Oil

Palm (NRCOP) at Pedavegi in West Godavari district of Andhra Pradesh on February 19, 1995. NRCOP serves as a centre for conducting and coordinating research on all aspects of oil palm conservation, improvement, production, protection, post-harvest technology and transfer of technology. The research centre of CPCRI at Palode was merged with NRCOP during April, 1999. Later, NRCOP was upgraded to Directorate of Oil Palm Research on 19 February, 2009. This directorate was further upgraded to the ICAR-Indian Institute of Oil Palm Research (ICAR-IIOPR) during September, 2014.

Research work at the Palode Centre

Realizing the prospects of oil palm industry in India, Central Plantation Crops Research Institute took up research on the crop from as early as 1968 at its Palode Research Centre. Initial efforts were confined to identification of *dura* mother palms and *pisifera* pollen parents from the exotic population available at Oil Palm Station, Thodupuzha. *Tenera* hybrids using these parents were planted in 1976 at Palode. The Palode Centre led the research on this crop from the forefront for the next two decades and came out with significant achievements.

- Assemblage of a germplasm holding at Palode consisting of 80 accessions from 11 countries Nigeria, Cote'dIvorie, Republic of Zaire, Indonesia, Malaysia, Cameroon, Costa Rica, Guinea Bissau, Zambia, Tanzania, besides India during 1979-96
- Identification of high yielding *tenera* hybrids capable of yielding 4.6 t oil / ha even under rainfed conditions
- Indigenous production of hybrids to the tune of three lakhs per year
- Developing agro-techniques for maximum yield realization
- Introducing pollinating weevil *(Elaedobius kamerunicus)* to increase yield of Fresh Fruit Bunches (FFB) through improved fruit set
- Evolving plant protection measures including very cheap methods to control avian pests
- Design and development of a small scale extraction unit of one tonne/ ha capacity in collaboration with the CSIR Research Laboratory at Thiruvananthapuram

Research Centre at Palode

- Establishing the edible oil quality attributes of palm oil and popularizing its use for edible purpose
- Development of a tissue culture protocol for clonal propagation of elite oil palm lines.

With the establishment of the National Research Centre for Oil Palm at Pedavegi, the research work initiated at the Palode Research Centre in the 70s were further intensified.

Significant Research Achievements of IIOPR

Genetic Resources Management: Oil palm germplasm has been collected from different oil palm growing countries, with wide variability for different characteristics. Presently, IIOPR has an assemblage of 128 accessions. High yielding cross combinations have been identified and mother palms for production of new hybrids planted in seed gardens. Intensive evaluation of African germplasm resulted in the identification of a few remarkably high yielding accessions that could play a major role in oil palm crop improvement programme in India. Twenty best performing tenera hybrids have been identified

Milestones in oil palm research and development

1886	: Oil palm introduced in India at the National Botanical Gardens, Calcutta
1947-1959	: The Maharashtra Association for Cultivation of Sciences (MACS) introduced African dura palms for ornamental purpose and later plants along the canal bunds, home gardens and to some extent in forest lands in Pune.
1960	: Government of Kerala establishes an Oil Palm Research Station at Thodupuzha; collections at this centre formed the basic source for research and seed production in India.
1975	: Oil palm research (under ICAR) initiated at CPCRI Research Station, Palode.
1971-1984	: Large scale planting of oil palm launched in Kerala by PCKL (subsequently taken over by OPIL) covering an area of 3705 ha with the imported seeds from Malaysia, Nigeria, Papua New Guinea (PNG) and Ivory Coast.
1976-1985	: The Andaman Forest and Plantation Development Corporation planted 1563 ha in Andaman and Nicobar Islands with the planting material from Nigeria, Malaysia, Ivory Coast, PNG and Zaire.
1986-87 onwards	: A massive area expansion drive in India
1995	: ICAR establishes the National Research Centre for Oil Palm (NRCOP) at Pedavegi (West Godavari district) of Andhra Pradesh
1999	: Oil palm research totally delinked from CPCRI with the merger of the CPCRI Research Centre at Palode with NRCOP
2009	: NRCOP upgraded to Directorate of Oil Palm Research (DOPR).
2014	: DOPR further upgraded to ICAR-Indian Institute of Oil Palm Research.

for use in crop improvement programmes at Palode. Screening of 240 African dura palms for drought tolerance based on physiological and biochemical characters have been completed. With a view to develop dwarf and compact palms and to facilitate planting more palms per unit area and easy harvesting, inter-specific hybrids have been developed and being evaluated. Evaluation of inter-specific hybrids at Palode has resulted in identification of three promising dwarf palms that can be used for further improvement.

Production and Processing System Management: Results from irrigation experiments have indicated that when irrigation was restricted to replace evaporation losses by 100 per cent either with drip or micro jet system, crop growth and yields were superior to that of basin irrigation. The highest FFB yield (24.15 t/ha) and bunches (8.37/palm) was obtained with application of 1200:600:2700g NPK/palm/year. Oil palm based cropping systems with heliconia, red ginger, bush pepper, guinea grass and cocoa have been standardized in adult oil palm plantations. The technique of vermicomposting has been perfected for oil palm plantation wastes, wherein almost 90% of N, 50% of P and 75% of K requirement of palms could be met through composting process. A height adjustable hydraulically elevated platform and back pack/ trolley mounted motorized sickles have been developed for easy harvesting. Technologies for mushroom cultivation from oil palm factory wastes and animal/fish feed formulations based on palm oil mill effluents have also been standardized.

Plant Health Management: Management measures for rhinoceros beetle, the most frequently observed pest in oil palm plantations in India, have been standardized. Infestation of rhinoceros beetle was brought down from 8.25 per cent to 1.8 per cent by release of baculovirus-infected beetles. Integrated disease management package for the management of basal stem rot has been found to be successful. Oil palm is an entomophilous crop and the pollinating weevil (Elaeidobius kamerunicus) introduced from Malaysia has established well in all agro-climatic zones in India.

Oil palm seed production centres

India has reached a stage where it can produce Tenera hybrid seeds to meet the demand for planting materials in the country to the full extent. At present, in India, six seed gardens are established where Tenera hybrid seeds are being produced and supplied to the agencies for raising the oil palm nurseries. During 1982, a seed production programme was initiated at Thodupuzha with basic breeding materials introduced from Malaysia and Nigeria. From this material, eleven promising dura palms were selected and crossed with pollen of four Pisifera palms imported from Nigeria. The Tenera hybrids thus produced were further improved through intensive selection based on combining abilities in the progeny trials. Selfing/ inter se crossing among selected genotypes was done and this gave rise to advanced Dura and Tenera populations subsequently planted in five seed gardens established in the country.

Oil extraction unit established at Palode

The best performing Dura and Pisifera palms have been selected for augmenting the oil palm hybrid seed production from these seed gardens. From these six seed gardens in production at present, there is production potential of 4.2 million Tenera sprouts annually.

Oil palm at a glance

Oil palm	: Highest vegetable oil yielder/ unit area (4-6 t/ha/annum)
Family	: Arecaceae
Species	: Elaeis guineensis Jacq. (African Oil Palm) Elaeis oleifera (American Oil Palm)
Source of oil	: Palm oil : Mesocarp
Kernel oil	: Kernel
Economic cropping period	: 25-30 years
Climatic requirements	: Above 2000 mm evenly distributed rain/ irrigation. Max. temp. 29-33°C, Min. temp. 22-24°C, 5 hrs sunshine and above.
No. of palms/ha	: 143 (9 x 9 x 9 m triangular)
Nursery period	: 12 - 18 months
Pollination	: Insect (Elaeidobius kamerunicus)
Tree height	: 15 - 18 m
Leaf production/year	: 24-30
Leaf length	: 6 - 8 m
First harvest	: 36 months after planting
Yield of FFB/ha/year	: 15 - 30 t
No. of bunches/palm/year	: 5 - 12
No. of fruits/bunch	: Above 2000
Av. bunch weight	: 25 kg.
Weight of fruit	: 30 gm.
Fruit to bunch	: 42 - 65%
Mesocarp to fruit	: 60 - 83%
Oil to mesocarp	: 77 - 81%
Kernel to fruit	: 7 - 12%
Oil to kernel	: 49 - 52%
Shell to fruit	: 3 - 11%
Palm oil yield/palm	: Bunch weight/palm x fruit/number of bunches x mesocarp/fruits weight x oil % / mesocarp

Opposite: Intercropping cocoa under oil palm

Palm oil mills in India

For processing the FFB, State Governments and entrepreneurs have set up factories in different states. Based on the extent of planting in the respective zones, required number of mills have been set up in various states.

Oil palm is now a small holder's crop in India

Except for a handful of oil palm estates in the public and private sector, majority of the oil palm growers are marginal (31.59%) and small farmers (27.91%). In India wide introduction of oil palm (62.60%) took place during 1993-1997. An analysis of technology adoption patterns show that most of these farmers (74.61%) are following basin method of irrigation with four to seven days interval (29.84%). More than eighty per cent of the farmers are applying farmyard manure. Majority of the farmers (34.69%) are applying fertilizers in 2 split doses. Most of the farmers are applying lower doses of Nitrogen (54.07%), Phosphorus (42.64%) and Potassium (34.69%) and majority of the farmers were not applying any micronutrient fertilizers.

Success stories in oil palm cultivation

Progressive farmers succeeded in achieving highest oil palm yields under irrigated conditions by adopting recommended and innovative practices at required intervals.A progressive farmer from Andhra Pradesh harvested 40 tonnes/ha/year (mean of 3 years) from his oil palm plantation at the tenth year after planting. He adopted micro irrigation, applied vermi compost and FYM at regular intervals, applied recommended doses of fertilizers, applied increased doses of major nutrients as per requirement/advice in four splits and micro nutrients in two splits.

A progressive woman farmer from Karnataka harvested 53 tonnes/ha/year (mean of three years) from her 16 year old plantation. She adopted in situ decomposition of poultry manure and application in two splits, applied increased doses of major nutrients in six splits, micro nutrients in two splits, controlled basin/block irrigation is being provided at weekly intervals. Moisture is conserved through oil palm frond mulching. Trenches were made across the palm rows to drain away the excess water. Tank silt was applied in once in a year in the palm basins to conserve moisture.

Another progressive oil palm grower from Karnataka took up the crop during 2008 and harvested 28 tonnes/ha/year from his three year-old oil palm plantation. He adopted recommended doses of fertilizers, vermi compost, basin irrigation at 3-4 days interval, mulching the basins with cut oil palm fronds, dried trash of sorghum, maize, ground nut, sugar cane and soybean.

Bright prospects for oil palm in India

Oil palm is a high yielding crop, with more than 5.0 tonnes of oil per hectare per year. There are ample opportunities for the development of oil palm in India, which has diversified agro-climatic conditions and vast stretches of land with untapped underground water potential. The oil palm crop, though recently introduced in India, comes up well in many regions and a potential area of 1.93 million ha. in 19 states which could be brought under oil palm cultivation. Oil palm crop offers great opportunities to all the stakeholders involved in this sector. To meet the increasing per capita consumption of vegetable oils as well as population growth, there is an urgent need to increase the production of vegetable oils in the country. Thus, the farmers as well as the processing units in India are not likely to face any constraint with reference to the marketing of the produce or remunerative prices. Government of India supports the Oil Palm Development Programme with high budget allocations to improve the production of vegetable oils for import substitution. The sector also offers vast employment potential in rural areas for oil palm cultivation and in processing industries that include product diversification and value addition enterprises.

The country is currently producing 0.785 lakh tonnes of palm oil only. Among the major tree crops, oil palm exhibits a high potential as a long-term source of edible oil, which is expected to contribute significantly towards meeting the growing edible oil demand in the country. By 2050, with an area of 2.0 million ha covered under oil palm, the country must be able to produce about 14.04 million tonnes of oil from oil palm, as against the 31.03 million tonnes of vegetable oil required for feeding 1620 million populations at a per capita requirement of 19.16 kg. Oil palm sector would be contributing 45% of the vegetable oil requirements of the country and import of vegetable oil would be almost negligible in such a scenario. But for this to happen, there is an urgent need for proper policy back-up for sustaining the long-term commitment of the farmers, researchers and policy managers towards oil palm sector.

ALL INDIA CO-ORDINATED RESEARCH PROJECT ON PALMS: THE NATIONAL NETWORK FOR LOCATION-SPECIFIC RESEARCH

Historical background

Plantation crops constitute an important segment of horticulture in Indian agriculture. Palms such as coconut (*Cocos nucifera* L.), oil palm (*Elaeis guineensis* Jacq.), and palmyrah (*Borassus flabellifer* L.) do contribute significantly to the rural economy of India. More than 20 million people in rural areas are engaged in the production, processing and marketing the products of these three crops. The long-term nature of research on these crops, the prospects of higher returns from research investment and the likely distribution of research benefits to the small holders and economically disadvantaged sections of the society, make it imperative to strengthen the research programme on these crops. Although there is scope of coconut production potential of 27,300 nuts/ha/year, the average coconut productivity in India is at a level of 10,345 nuts/ha/year. This indicates the scope for increasing the productivity by bridging the yield gap, through supply of quality planting materials and adoption of better management practices. Though the coconut growing regions have substantially increased their total nut production during the past, still there is an urgent need

Milestones

1970	:	All India Coordinated Coconut and Arecanut Improvement Project was sanctioned by the ICAR
1972	:	The Project started functioning with 12 centres located in eight states were under the project
1975	:	Five more centres were added
1977	:	Konark Centre (OUAT) was added
1980	:	Experiments in Konark were shifted to Patha Farm
1980	:	Mondouri (BCKV) Centre in West Bengal was added
1982	:	Kahikuchi Centre (AAU) in Assam was sanctioned
1985	:	Kahikuchi centre started functioning
1986	:	Renamed as All India Coordinated Research Project on Palms
1987	:	Jalalgarh Centre in Bihar was recommended for closure
1988	:	Razole centre was merged with Ambajipeta centre
1989	:	Four oil palm centres at Vijayarai (Andhra Pradesh), Mulde (Maharashtra), Gangavathi (Karnataka) and Aduthurai (Tamil Nadu) were added
1990	:	Pilicode, Mahuva and Dapoli centres were closed and coconut programmes at Coimbatore were shifted to Aliyarnagar
1990	:	Arecanut centre at Coimbatore was closed
1992	:	Research work on arecanut was phased out
1995	:	Andaman Centre was closed
1995	:	Two centres for Palmyrah research - Pandirimamidi in Andhra Pradesh and Killikulam in Tamil Nadu - were sanctioned
2000	:	Programmes of Konark centre were shifted to Bhubaneshwar due to the Super cyclone
2009	:	Two centres for coconut research (Sabour in Bihar and Navsari in Gujarat) and two oil palm centres (Madhopur in Bihar and Pasighat in Arunchal Pradesh) were added
2010	:	One more centre for coconut research - Pilicode (Kerala) - was started as voluntary centre
2012	:	Programmes of Aduthurai centre (TN) for oil palm research shifted to the Agricultural Res. Station, Pattukkottai in Tamil Nadu.
2014	:	Research on arecanut included in the 12th plan. Four centres started – Goa (Goa), Port Blair (Andamans and Nicobar), Shivamogga (Karnataka) and Wakavali (Maharashtra)
2014	:	One centre for oil Palm was started at IIOPR, Pedavagi as voluntary centre
2015	:	One centre for oil Palm was started at Bavikere (Karnataka) as voluntary centre

to develop location-specific agro-techniques for sustaining and improving the productivity levels.

Oil palm is one of the highest oil yielding crops under equatorial bioclimatic conditions that could help the country to minimize the edible oil imports with the cultivation of location-specific oil palm hybrids along with the required management practices. Under intensive management conditions providing recommended dose of fertilizer and weekly flood irrigation on good sandy loam soils, farmers may be able to realize an annual yield of around 20 tonnes of fresh fruit bunch (FFB), yielding about 4 tonnes of oil/ha.

Palmyrah palm adorns the dry landscape of the semi arid regions of Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Bihar, Karnataka and Maharashtra. India has nearly 102 million palms and half of them are in Tamil Nadu. Palmyrah palm ranks first (among the available palm species) in yielding sugar as well as other edible and non-edible products. Many value-added products can be prepared from the fruit and other parts of the palm. Palmyrah palm can be grown in soils with sub-optimal levels of physico-chemical characteristics. There is a fairly good potential for the growth and development of the palm Products based industries in India.

Mandate

- To identify, conserve and utilize elite genetic resources for useful traits in palms from different agro-climatic regions and to evaluate performance of varieties/hybrids under different locations and to facilitate release of varieties/hybrids.
- To improve input use efficiency and develop location-specific palm based integrated farming systems to enhance the productivity per unit area, and organic cultivation packages for palms and palm based farming system.
- To evaluate bio-intensive pest and disease management strategies, modelling and forecasting of disease incidence and documentation of pest dynamics in changing scenario of palm ecosystem.
- Development of post-harvest technologies in palmyrah and to demonstrate and transfer technologies to the farmers.

Profile of the AICRP Centres

State	Center/Location	Area of Research	Hort. University/ Institutions
Andhra Pradesh	Horticultural Research Station, Ambajipeta	Coconut: Crop Improvement, Production & Protection	Dr.Y.S.R Horticultural University, Andhra Pradesh
	Agricultural Research Station, Vijayarai	Oil Palm: Crop Improvement & Production	
	Horticultural Research Station, Pandirimamidi	Palmyrah: Crop Improvement, Production & Post Harvest Technology	
	Indian Institute of Oil Palm Research, Pedavegi	Oil Palm: Crop Improvement & Production	ICAR
Andamans and Nicobar	Central Island Agricultural Research Institute, Port Blair	Coconut and Arecanut: Crop Improvement & Production	ICAR
Arunachal Pradesh	College of Horticulture & Forestry, Pasighat	Oil Palm: Crop Improvement & Production	Central Agricultural University, Imphal
Assam	Horticultural Research Station, Kahikuchi	Coconut: Crop Improvement & Production	AAU, Assam
Bihar	Bihar Agricultural College, Sabour	Coconut: Crop Improvement & Production	Bihar Agricultural University, Sabour, Bihar
	Regional Research Station, Madhopur	Oil Palm: Crop Improvement & Production	Rajendra Agricultural University, Samastipur, Bihar
Chhattisgarh	Saheed Gundadhoor College of Agriculture & Research Station, Jagdalpur	Coconut: Crop Improvement Sulphi palm: Crop improvement and disease management	Indira Gandhi Krishi Vishwavidyalaya, Raipur
Gujarat	ASPEE College of Horticulture& Forestry, Navsari	Coconut: Crop Improvement & Production	Navsari Agricultural University
Goa	Central Coastal Agricultural Research Institute, Goa	Coconut and Arecanut: Crop Improvement & Production.	ICAR
Karnataka	Horticultural Research Station, Arsikere	Coconut: Crop Improvement, Production & Protection	UHS, Bagalkot, Karnataka
	Agricultural Research Station, Gangavathi	Oil Palm: Crop Improvement & Production	
	Arecanut Research Centre, College of Agriculture, Navile	Arecanut : Crop improvement, Production and Protection	UAHS, Shivamogga

	Agricultural and Horticultural Research Station, Bavikere	Oil Palm: Crop Improvement & Production	
Kerala	Central Plantation Crops Research Institute, Kasaragod	Coconut: Crop Production	ICAR
	Regional Agricultural Research Station, Pilicode	Coconut: Crop Improvement	KAU, Thrissur, Kerala
Maharashtra	Regional Coconut Research Station, Bhatye	Coconut: Crop Improvement, Production & Protection	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli Ratnagiri
	College of Horticulture, Mulde	Oil Palm: Crop Improvement & Production	
	Central Experimental Station, Wakavali	Areanut : Crop improvement & Production	
Odisha	Department of Horticulture, (OUAT),	Coconut:Crop Improvement & Production	OUAT, Bhubaneswar
Tamil Nadu	Coconut Research Station, Aliyarnagar	Coconut:Crop Improvement, Production & Protection	TNAU, Coimbatore
	Coconut Research Station, Veppankulam	Coconut:Crop Improvement, Production & Protection	
	Agricultural Research Station, Pattukkottai	Oil Palm: Crop Improvement & Production	
	Agricultural College & Research Institute, Killikulam	Palmyrah: Crop Improvement & Post Harvest Technology	
West Bengal	Directorate of Research, Kalyani	Coconut: Crop Improvement & Production	BCKV, West Bengal

Anantha Ganga

Coconut varieties/hybrids released from AICRP Centres

Variety	Year of Release	Breeding Method	Parents	Important traits	Developed by
Pratap	1987	Selection	Banawali	Tall palm with semi-circular canopy with round, green nuts; commences flowering 7-8 years after planting; 140-145 nuts/palm/year; copra yield of 145 g/nut (3.5. t/ha) and oil content of 68 %	Dr.BSKKV, Maharashtra
Kamrupa	2001	Selection	Assam Green Tall	Gives an average yield of 101 nuts/palm/year; copra yield of 2.86 tonnes/ha and tender nut water of 253ml with 5.16g/100 ml of total sugar and 2294 ppm of potassium	AAU, Assam
ALR (CN) 1	2002	Selection	Arasampatti local	Small to medium sized; oblong in shape and green in colour; average nut yield of 126 nuts/palm/ year; copra content of 131 g/nut; copra yield of 16.5 kg/palm/year; oil content of 66.5 %	TNAU, Tamil Nadu
Kalyani Coconut -1	2007	Selection	Jamaican Tall	Gives an average yield 80 nuts/palm/year; copra content of 154 g/nut (copra yield of 12.3 kg/palm/year). 350 ml of tender nut water of good with 4.9% of total sugar content and high potassium (2347 ppm) content.	BCKV, West Bengal
Gauthami Ganga	2007	Selection	Gangabondam	Dwarf palm with semi circular canopy; oblong shaped green coloured fruits. Average nut yield of 80-90 nuts/palm/year with copra content of 156.7g/nut and an oil content of 68%.	ANGRAU, Andhra Pradesh
Konkan Bhatye Coconut Hybrid -1	2007	Hybrid	GBGD x ECT	Tall palm with semi- circular crown with green coloured, oval shaped fruits; precocious (bearing at 66 months); yields 122 nuts/palm/year with copra yield of 22.08 kg/palm/year; resistant to stem bleeding diseases and moderately resistant to leaf blight and bud rot.	Dr.BSKKV, Maharashtra
Kera Bastar	2007	Selection	Fiji Tall	Nut yield in the range of 110-117 nuts/palm/year; copra yield of 2.5 to 3.1 tonnes/ha; widely adapted to different agro- climatic zones; 332 ml of tender nut water with 6.2g/100 ml of total sugar.	IGAU, Chhatisgarh
Kalpatharu	2009	Selection	Tiptur Tall	Suitable for ball copra production; average yield of 20300 nuts/ ha, copra yield of 35 q/ha and oil yield of 25 q/h; recommended for rain fed and irrigated regions of Karnataka, Tamil Nadu and Kerala.	UHS, Karnataka
Vasista Ganga	2014	Hybrid	GBGD x PHOT	Precocious; higher nut yield (125 nuts/palm/year), copra output (21.9 kg/palm/year) and oil content (69%) and oil yield 15.1 kg/palm/year) with good tender nut water content (395 ml) and TSS (6.20 Brix).	Dr. YSRHU, Andhra Pradesh
Anantha Ganga	2014	Hybrid	GBGD x LCOT	High yielding, precocious; having heavy bunches with average nut yield (128 nuts/ palm/year), copra output 21.7 kg/palm/year, oil content 72 % and oil yield 15.5 g/palm/year).	Dr. YSRHU, Andhra Pradesh
Kalpa Ganga	2014	Hybrid	GBGD x FJT	Nut yield of 120 nuts/ palm/year; copra out turn of 3386 kg/ha; short stature and suitable for ball copra production.	UHS, Karnataka
VHC-4	2015	Hybrid	LCT × CCNT	Mean nut yield of 161 nuts/palm/year; copra content of 149.8 g/ nut and oil content of 70%	TNAU,Coimbatore

EPILOGUE

In the foregoing pages, together we had embarked on a journey, traversing great distances in time and space, revisiting places and events, reliving excitements of new discoveries and disappointments of unexpected failures, meeting hundreds of men and women named and unnamed, for over a century since 1916. An eventful journey in rediscovering our legacy of the past, a realistic assessment of the present and its achievements to be proud of, and limitless opportunities and responsibilities that the future beckons... this chronicle is all of that and much more.

Plantation crops in India has a rich diversity and varied history with each crop having its own distinct historical and economic context of development; some of these crops native to India and some others gifts from the new world tropics, introduced and naturalized in India. Evidently it is not a single storyline in linear progression, rather a few parallel storylines, temporal and spatial, merging in one canvas - Central Plantation Crops Research Institute - the citadel of research in plantation crops. There is one thread that binds them all- CPCRI - where research in all these crops were either initiated or conducted, one time or the other, in course of history. Today, CPCRI is a proud mother basking in glory of not just its own, but of the growth and achievements of the siblings as well, the present-day specialist crop research institutes. And that sums up the very genesis and relevance of this book.

As one reflect on the 100 years of history of the ICAR-CPCRI, the emerging picture is that of an institution that has come a long way since its modest beginning in 1916, with its incredible list of accomplishments to be proud of, vision to grow further as an organization of truly international standards, and unwavering commitment to serve the farming community it is beholden to.

And dear reader, we have taken you along in this 100 years journey in pursuit of excellence and it's time now to leave you to ponder over it, with a promise to meet you again at the next milestone in its journey. Like Ulysses in his never ending pursuit of knowledge, however distant and challenging it might be, and to go beyond the known limit or boundary of it...

To follow knowledge like a sinking star,

*To strive, to seek, to find, and not to yield**

*Alfred, Lord Tennyson (in Ulysses)

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