TECHNOLOGICAL ADVANCEMENT AND FUTURE STRATEGIES FOR ENHANCING PRODUCTION AND PRODUCTIVITY IN COCONUT, ARECANUT AND COCOA

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1. INTRODUCTION

Coconut, arecanut and cocoa are the major small land holder's plantation crops cultivated in India in an area of 2.35 m ha predominantly in the humid tropics and tropical belts of the country extending throughout the peninsular India comprising of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa, Orissa, West Bengal, parts of Maharashtra, the north eastern region and in Union Territories, Andaman and Nicobar and Lakshadweep islands. These crops provide livelihood security to millions of people in rural sector involved in production, processing and trade of the commodities.

The research programmes on coconut, arecanut and cocoa crops are being undertaken at Central Plantation Crops Research Institute (CPCRI) ever since its establishment in 1970 as one of the Agricultural Research Institutes in the National Agricultural Research System under Indian Council of Agricultural Research (ICAR) by merging various research stations on plantation crops in the country. The institute also serves as headquarters of the All India Co-ordinated Research Project on Palms to co-ordinate research within the country on palm species viz.,coconut, palmyrah and oilpalm. The institute has developed and disseminated production and protection technologies to enhance the productivity of its mandate crops under different agro-climatic conditions. Of late, thrust is also given to product diversification and value addition with a view to enhance the net returns from the coconut holdings. The technologies developed by the Institute in different spheres of crop improvement and production activities and future strategies to enhance the production and productivity of its mandate crops are summarized below:

2. RESEARCH ACHIEVEMENTS

2.1 Coconut (*Cocos nucifera* L.)

Coconut is a versatile crop grown throughout the tropical world, for decoration as well as for its many culinary and non-culinary uses; virtually every part of the coconut palm has some human uses. It is grown in 92 countries and India, Indonesia, Philippines and Sri Lanka are the major growing countries. In India it is grown in 1.95 million ha with a production of 14811 million nuts and productivity of 7608 nuts per hectare (during 2005-06).

The demand for coconut by the end of 11th plan period is expected to be 17054 million nuts due to the enhanced domestic demand as well as the increased diversion to product diversification. In order to increase the coconut production and to narrow down the production gap in the country, the efforts made by CPCRI have been summarized below:

2.1.1 Crop Improvement

2.1.1.1 Genetics and plant breeding

The institute has the largest coconut germplasm of 364 accessions comprising 232 indigenous and 132 exotic collections in the world. The exotic collections are from 22 countries of South Asia, South-East Asia, Caribbean Islands, Indonesian Islands, Pacific Ocean Islands, African countries, Bangladesh and Sri Lanka. The International Coconut Gene Bank for South Asia (ICGSA) is hosted at CPCRI Research Centre, Kidu, Karnataka.

The crop improvement programmes undertaken by the Institute resulted in the release of seven coconut cultivars and three hybrids for commercial cultivation. The high yielding cultivars released are Chandrakalpa, Kera Chandra, Kalpa Pratibha, Kalpa Dhenu and Kalpa Mitra. Three high yielding coconut hybrids, Chandrasankara (Chowghat Orange Dwarf x West Coast Tall), Chandralaksha (Laccadive Ordinary Tall x West Coast Tall) and Kerasankara (West Coast Tall x Chowghat Orange Dwarf) were released for commercial cultivation. These coconut hybrids gave 49 to 77% more copra yield over local talls and are not only early bearers but also give higher yield than either of the parent. The cultivar, Chowghat Green Dwarf (CGD), have been found to have field tolerance of over 90%, and is utilized for production of coconut hybrid, CGD x WCT which showed relative tolerance to root (wilt) disease. Further, Chowghat Orange Dwarf (COD) as the best tender nut variety and Kalpa Raksha (Malayan Green Dwarf) for root (wilt) diseased tract due to its relative resistance to root (wilt) disease were released.

Based on the performance of varieties/hybrids in multilocation trials, the recommended varieties/hybrids from the institute for different coconut growing states are listed below:

Cultivar	Nut yield (palm/ year)	Copra yield (g/nut)	Oil content (%)	Year of release	Area
Chandrakalpa	98	195	70	1985	Kerala
Kerachandra	110	198	66	1995	Kerala, Karnataka
Chowghat Orange Dwarf	63	Tender nut variety		1991	Kerala, Karnataka, Tamil Nadu
Kalpa Pratibha	91	256	67	2007	WestCoast Region, Peninsular India
Kalpa Dhenu	86	242	65.5	2007	West Coast Region & A&N Islands
Kalpa Mitra	80	241	66.5	2007	West Coast Region & W. Bengal
Kalpa Raksha	65	240	65.5	2007	Root (Wilt) affected areas

Contd.....

Hybrid					
Chandra Sankara (COD x WCT)	116	215	68	1985	Kerala, Karnataka, Tamil Nadu
Kera Sankara (WCT x COD)	108	187	68	1991	Kerala, Karnataka
Chandra Laksha (LCT x COD)	109	195	69	1984	Kerala, Karnataka

2.1.1.2 Biotechnology

A protocol for aseptic collection of embryos, their storage and successful culturing to develop plantlets has been perfected in coconut. This has led to field planting of 405 embryo cultured coconut accessions collected from eight countries at the institute germplasm centre. Tissue culture protocol has been standardized for areca nut which will enable mass multiplication of elite genotypes. Plantlet development has been obtained from various explants of coconut viz., plumular tissues, inflorescence in Y3 medium supplemented with polyamine and picloram in both dwarf and tall cultivars. *In vitro* active conservation of coconut zygotic embryos (short-term) was standardized.

Cryopreservation of coconut zygotic embryos after desiccation pre-treatment was standardized and these embryos could be retrieved into plantlets. RAPD/IISR and SSR markers were used to establish the genetic similarity among some indigenous and exotic coconut accessions maintained at CPCRI, Kasaragod. The protocol for AFLP, DAF and micro satellite analysis of coconut DNA for tagging resistance gene for root (wilt) studies was standardized.

2.1.2 Crop Production

2.1.2.1 Integrated nutrient management

Intensive research undertaken in this institute and All India Co-ordinated Research Project (Palms) centres in the country has led to general fertilizer recommendation to coconut palm as 500g N, 320g P2O5 and 1200g K2O/ palm/year to be applied in two split doses during May and September along with 50 kg organic manure under optimum management conditions. Application of magnesium @500g MgO per palm was found to be advantageous in areas (root (wilt) affected garden) where palms show yellowing of leaves.

A technique for utilization of leguminous cover crops such as *Pueraria phaseoloides*, *Mimosa invisa*, *Calopogonium mucunoides* and cowpea as green manures to supply biologically fixed nitrogen to coconut and to substitute nitrogen fertilizer to the extent of 50 % was standardized.

The technology for vermicomposting of coconut palm wastes by using a local earthworm, *Eudrilus* sp., closely related to the African night crawler, was developed. Multiplication technique for the local *Eudrilus* sp. of earthworm using 1:1 cow dung-decayed leaves mixture was standardized and the earthworm is being distributed to the farmers to popularize vermicomposting. Besides, a technique has been developed to production of vermiwash.

Further, *Marasmiellus troyanus* and a local isolate of *Trichoderma* species were identified as effective microbes for composting of coir pith. Microbial enrichment of compost with N_2-fixing bacteria and phosphate solubilisers was also standardized. Plant growth promoting rhizobacteria *Bacillus coagulans* and *Brevibacillus brevis* were identified for bioaugmentation of coconut seedlings for their growth promotion while raising them in the nursery.

2.1.2.2 Irrigation and fertigation

Research carried out on irrigation water requirement of coconut palm has led to a general recommendation of application of 200 litres of water once in four days during rainless periods. For the WCT palms in red sandy loam soils on the west coast, perfo irrigation with 20 mm water, when cumulative pan evaporation was 20 mm, was found to be the best irrigation schedule. Sprinkler irrigation or perfo irrigation with 20 mm water was found to be the best suited to inter or mixed cropping systems where the entire surface requires wetting. Drip irrigation @ 66 % of the E0 (32 litres of water per palm per day under Kasaragod conditions) from December to May is ideally suited for coconut resulting in 34 per cent saving of water. However, the irrigation water application varies from the region to region depending on the climatic conditions. Further, application of straight fertilizers like urea, muriate of potash and phosphoric acid through drip system (Fertigation) has resulted in the increased fertilizer use efficiency and yield of coconut. Further, adoption of fertigation in coconut helped to reduce in the recommended fertilizer dose by 50 %.

The Institute has developed various bio-engineering measures to sustain crop production in rainfed areas of west coast region. The low cost water harvesting structures developed by the Institute helped in augmenting ground water potential to a great extent. Moisture conservation methods such as mulching with coconut husk, coir dust, green leaves/dried coconut leaves etc., addition of organic manures or green manures, husk burial, inter cultivation, bunding, terracing, etc. were recommended for rainfed coconut cultivation.

2.1.2.3 Coconut based cropping system

Coconut in India is primarily a crop of small and marginal farmers. About 98% of the coconut holdings in the country are less than 2.0 ha in size and more than 90% of them are less than 1.0 ha in extent. The income derived from such small holdings is not sufficient to sustain even the small families. In addition, coconut as a monocrop provides employment only for about 135 mandays/ha under rainfed conditions and consequently the family labour remains unemployed for larger parts of the year. Coconut based cropping/farming systems, involving cultivation of compatible crops in the interspaces of coconut and integration with other enterprises like dairying offer considerable scope for increasing production and productivity per unit area, time and inputs by more efficient utilization of resources like sunlight, soil, water and labour.

Coconut based cropping systems involving cultivation of compatible crops like tubers, flowering, medicinal and aromatic crops, fruits, vegetables, spice crops, in the interspaces of coconut was found more remunerative compared to coconut monocropping. Coconut-based high-density multi-species cropping systems (HDMSCS) involving many crops like tapioca, elephant foot yam, colocasia, banana, pineapple, nutmeg, clove, pepper, etc. was established. Application of 2/3rd of recommended dose fertilizer for coconut is sufficient under the system to attain maximum yield and return. The total energy input (fertiliser, irrigation and manpower) goes into the coconut based cropping system has been worked out, which ranges from 17,02,233 to 17,12,294 MJ/ha. Allelopathic studies in coconut based cropping system with standardisation of extraction procedure for coconut leaf and root leachates from young and adult palms were carried out. Laboratory bioassays to determine the allelopathic concentration of coconut root and leaf leachates through seedling vigour index method were initiated. Leaf and root leachates from adult WCT palm at 1:5 and 1:10 concentrations were found to be allelopathic to cowpea seedlings. *In vitro* studies indicated that the diazotrophs were sensitive to the coconut root and leaf leachates, while, the phosphate solubilizers and PGPRs got stimulated.

Mixed farming in coconut by raising fodder crops in the interspaces with the integration of other enterprises such as dairy, poultry, and pisciculture was quite advantageous in increasing the productivity of the system, improving soil fertility, employment generation and in enhancing the income from the coconut plantations.

Growing *Glyricidia* as green manure crop was found to be ideal for management of littoral sandy soils due to its beneficial effect on soil properties and increased yield of coconut. Incorporation of *Glyricidia* prunings from the interspaces of one hectare of coconut garden can meet a major portion of nitrogen (90%), part of phosphorus (25%) and potassium (15%) requirement of coconut palm. Growing different intercrops in littoral sandy soil with soil moisture conservation measures in the interspaces of coconut did not affect the growth and yield of coconut and in fact found to be beneficial in enhancing the coconut yield.

For management of root (wilt) disease an integrated approach has been developed involving application of organic manures like farm yard manure or green leaf manure or composted coir pith or vermicompost at the rate of 25 kg/palm along with nitrogen, phosphorus and potassium application @ 500:300:1000 g through application of 1.1 kg of urea, 1.5 kg of mussorie rock phosphate and 1.7 kg of muriate of potash on per palm basis. Application of $MgSO_4$ @ 1kg per palm could reduce the yellowing symptom of the palms. Adoption of intercrop/mixed crop with suitable crops and recycling of available of biomass in the system could increase the productivity of the palms and reduce the yellowing symptom of the palms. For boron deficient palms in the root (wilt) disease affected area, Borax application @ 150 g/seedling and @ 300 g/ adult tree was recommended.

2.1.3 Crop Protection

2.1.3.1 Diseases

2.1.3.1.1 Coconut root (wilt) disease

The coconut root (wilt) disease is a non-lethal debilitating malady, caused by Phytoplasma, which reduces the production potential of the palm. The symptoms of the disease are characteristic bending of the leaflets termed "flaccidity", along with foliar yellowing and marginal necrosis.

ELISA technique has been refined for the rapid and early detection of root (wilt) disease of coconut. Since the disease is not lethal but debilitating and no curative control measure is available at present, the approach will be to manage the disease in the already infected gardens. To reduce the loss due to the disease, the strategy recommended would be

- Removal of diseased palms in areas of sparse incidence. In areas of heavy incidence of disease, all the heavily infected and unproductive palms should be eradicated. Within the contiguously disease affected tract, all palms in the pre-bearing age which have taken up the disease should also be eradicated.
- Replanting with progenies of disease resistant/tolerant varieties/hybrids and disease free palms located in the hot spot areas.
- Application of NPK fertilizers, magnesium sulphate and organic manures at recommended dose.
- Growing green manure crops in the basin and appropriate inter and mixed crops.
- Irrigation during summer months.
- Control of leaf rot disease which is usually noticed on root (wilt) affected palms.

2.1.3.1.2 Leaf rot disease of coconut

Leaf rot disease in coconut is caused by many fungal pathogens, chiefly *Colletotrichum gloeosporioides*,

Exerohilum rostratum and *Fusarium solani*. The symptoms are seen as presence of tiny spots of various shapes and shades and of different colours on the soft white leaflets of the unopened spindle, which enlarge and coalesce to cause extensive rotting. Integrated leaf rot disease management strategy involves cutting of the rotten portions of the spindle and pouring either Contaf-5 EC 2 ml or Dithane M-45/Indofil M-45, 3 g dissolved in 300 ml of water in the cavity around the base of the spindle leaf.

2.1.3.1.3 Bud rot of coconut

The disease is caused by *Phytophthora palmivora*. The symptoms of the disease include withering of the spindle, rotting of soft tissues of crown emitting foul odour and ultimately the death of the spindle. As a prophylactic measure, all the healthy palms surrounding the diseased palms should be sprayed with 1% Bordeaux mixture on the spindle and base of 2-3 innermost leaves. For management of the disease, root feeding and stem injection of Akomin (16.8 ml) and Calixin (21 ml) can protect the palms for a period of 8 weeks. In early stages of the disease, application of 10% Bordeaux paste on affected portion can check the disease.

2.1.3.1.4 Stem bleeding of coconut

The disease is caused by Thielaviopsis paradoxa and is characterized by dark brown patches at the base of the trunk of the palm which grow into longitudinal irregular streaks with dark reddish brown liquid exuding from them. Root feeding of 5% Calixin or 5% Bavistin at quarterly intervals is effective in initial stage of the disease. In advanced stage, the affected bark should be chipped off till the healthy tissue is exposed and painted with 5% Calixin (5 ml Calixin in 95 ml water).

2.1.3.1.5 Basal stem rot of coconut

The disease is also called as 'Ganoderma wilt'/'Anabe Roga'/'Thanjavur wilt'. *Ganoderma lucidum* and *G. aplanatum* are causal organisms involved in the disease. In this disease, outer whorl of leaves turn brown and droop and bleeding symptoms appear on the base of stem.

The recommended management practices include phytosanitation measures, digging trenches around affected palms to isolate the diseased palms, application of systemic fungicides like calixin through root feeding (2 g/100 ml), drenching the soil with fungicides (25 litres of calixin 0.1 %) and application of neem cake @ 5 kg/ palm/ year, along with the recommended dose of organic manures.

2.1.3.2 Pests

2.1.3.2.1 Rhinoceros beetle (*Oryctes rhinoceros*)

The IPM package for rhinoceros beetle includes extraction of the adult beetles using a beetle hook during the period of pest abundance (June-Sept.) from crown of all the palms, treatment of all possible breeding sites (farm yard manure dump, fallen coconut logs etc.) of the insect with 0.01% carbaryl (50% WP) on w/w basis. Biological suppression of the pest can be carried out by releasing 10-15 beetles inoculated with Oryctes virus in one hectare of garden and application of 5 x 1011 spores of *Metarhizium anisopliae* fungus/m3 area of the breeding site of the pest, during monsoon period. Prophylactic measure include leaf axil filling of palms with 12.0 g naphthalene balls / palm covered with sand at 45 days interval.

2.1.3.2.2 Red palm weevil (*Rhynchophorus ferrugineus*)

IPM package for red palm weevil includes cleaning of palm crown periodically to avoid decaying of organic debris, proper cutting, splitting and burning of red palm weevil infested palms, treating of any wounds on the palm with coal tar + 1% carbaryl, stem injection with 0.1% dichlorvos or 1% carbaryl. Trapping of floating population of

the weevil can be done by setting up of pheromone traps. Synthesis of Ferrugineol, the aggregation pheromone, is being done at CPCRI. Prophylactic leaf axil filling with 20 g phorate 10G in 200 g of fine sand during May, September and December or with 250 g marotti oil cake + 200 g of fine sand in leaf axils around spindle has been found to be effective.

2.1.3.2.3 Leaf eating caterpillar (*Opisina arenosella*)

This pest feeds on the undersurface of the leaflets within silken galleries resulting in considerable reduction of photosynthetic area. An IPM method for controlling the pest includes cutting and burning of badly infested outer leaves/leaflets, spraying of 0.02% dichlorvos if pest is in active larval stage and release of larval parasitoids *Goniozus nephantidis* @ 20.5%, pre-pupal parasitoids like *Elasmus nephantidis* @ 49.4% and *Brachymeria nosatoi* @ 31.9% respectively at fortnightly intervals depending on the larvae, pre-pupal and pupal population of *Opisina*.

2.1.3.2.4 Eriophyid mite (*Aceria guerreronis*)

The mites suck the sap from the tender nuts resulting in appearance of elongated triangular white patch below the perianth, which in turn becomes pale yellow then brown with the advancement of the mite infestation. Severe infestation results in poor development of the nuts with reduced kernel weight and poor quality fibre and premature nut shedding. Management of this pest is possible by spraying of 0.004% azadirachtin or 2% neem oil, garlic and soap mixture during April-May, Oct.-Nov. and Dec.-Jan., in such a way that all mite infested palms in an area should be covered at the shortest possible interval coupled with integrated nutrient management to improve the health of the palm.

2.1.3.2.5 White grub (*Leucopholis coneophora*)

White grubs damage the roots of palms and also tunnels into the bole and collar region of seedlings. IPM technology includes deep ploughing and digging of soil during pre- and post-monsoon period, collection and destruction of adult beetles during peak emergence period in May-June, setting up of the light traps to attract adult beetles and killing them, insecticidal application with phorate 10G @ 100 g/palm during May-June and September-October.

2.1.3.2.6 Coreid bug (*Paradasynus rostratus*)

The adults and nymphs of this pest suck the sap from buttons and developing nuts resulting in nut fall and malformation of the nuts. It can be managed by spraying the crown bunches and leaf axils with 0.1% carbaryl.

2.1.3.3 Nematode Management

The burrowing nematode (*Radopholus similis*) infested coconut seedlings exhibit symptoms like yellowing, button shedding, reduction in leaf size and yield. Soil application of phenamiphos or phorate @ 25 kg ai/ha during Sept., Dec. and May completely eliminates R. similis in coconut nurseries.

2.1.4. Physiology & Biochemistry

Coconut hybrids such as Keraganga, Chandralaksha, Kerasankara and talls like Chandrakalpa and West Coast Tall were identified as relatively drought tolerant compared to the other varieties and hybrids. Gangabondam Green Dwarf, Malayan Orange Dwarf and Chandrasankara were found to be more susceptible to drought under sandy and sandy loam soil than laterite soil under rainfed condition. Further, drought management practices such as husk burial and coir pith application were found to increase the nut yield under rainfed conditions. Prediction models to predict the nut yield in coconut were developed based on the weather data.

Genotypic variation in fatty acids and other biochemical parameters at different stages in development of coconut were worked out. Coconut cultivars/hybrids were characterized based on fatty acid profiles for edible and

industrial purposes. Shelf life of coconut oil can be enhanced by storing it in brown bottles, plastic cans or clay jars with preservatives like tamarind (2%), common salt (1%) or citric acid (0.05%).

2.1.5 Pre and Post Harvest Technology

- A manually operated coconut-husking machine has been developed with an out turn of 110 nuts/hr.
- A power operated semi automatic coconut dehusking machine has also been developed which can dehusk 500-600 nuts/hour.
- A new processing method for preparing ball copra was developed.
- Preservation of fresh kernel upto 4 days is possible by dipping fresh kernels in 1000 ppm propionic acid for 60 minutes.
- Simple smoke free collapsible copra dryers have been developed in which about 1000 coconuts/batch can be dried in 24 hours. The cost of the dryer is in the range of Rs.7000/ to Rs. 25000 depending on the capacity and the fuel used.
- A solar cum electric dryer with agriculture waste as third source of energy has been developed for copra drying with a capacity of more than 3000 nuts/ batch at a cost of Rs.40000/-.
- A technology for making snow ball tender nut (SBTN) from 8 months old coconuts has been developed. Along with the process, a suitable machine has also been developed for making SBTN. The cost of the machine is Rs 22,500/-.
- A technology for the production of sweet coconut chips has been developed, by the process of osmotic dehydration, with a shelf life of 6 months. A process for production of coconut chips with different flavours, medicated, spicy as well as instant coconut chips by microwave oven has also been developed.
- A tendernut punch and a cutter has been developed at a cost of Rs. 1365/-.
- Process for the production of the fuel briquette with different composition of pith and shell powder of tender coconut husk has been developed.

2.2 Arecanut (*Areca catechu* L.)

In India, the palm is being grown in an area of 0.381 m ha with a production of 0.483 m metric tonnes and productivity of 1268 kg/ha (2005-06). Arecanut research as detailed below helped in increasing the production and productivity and the country achieved self sufficiency.

2.2.1 Crop improvement programme

A total of 153 germplasm accessions of areca comprising 130 indigenous and 23 exotic collections are maintained at CPCRI, RS, Vittal. So far five high yielding varieties of areacnut viz. Mangala, Sumangala, Sreemangala, Mohitnagar and Swarnamangala with 3.00, 3.28, 3.18, 3.67 and 3.78 kg chali/ palm/ year were released for commercial cultivation in the country. Hybridization of natural dwarf identified from Hirehalli with released varieties is giving promising results in combining high yield and dwarf nature. The promising hybrids such as HD x Mohitnagar, HD x Sumangala and Mohitnagar x HD have been developed and recommended for cultivation in the country. Further, evaluation of exotic accessions and selection for economic traits resulted in the development of high yield potential variety VTL-12 (Saigon). Average yield of this palm is 3.88 kg chali/ palm/year.

Viable and repeatable protocol for plantlet regeneration from adult arecanut palm explants (inflorescence tissues; non-destructive method) was standardized for all the released varieties *viz.* Mangala, Sumangala, Sree Mangala, Mohitnagar and South Kannara Local.

A study on feasibility of long term conservation (cryopreservation) of somatic embryos of YLD resistant arecanut revealed that maximum plantlet recovery could be obtained from the pre growth treatment of 2M sucrose for 24 hours followed by 4 hours of laminar air current desiccation.

2.2.2 Production technologies

2.2.2.1 Integrated nutrient management

A package for integrated nutrient management was developed with organic and inorganic fertilizer regimes i.e application of 100: 40: 140 g N: P2O5: K2O, 20 kg FYM/palm/year, growing and incorporation of green manure crops in the garden. Vermicomposting of areca wastes using two species of earthworms *Eudrilus eugeniae* and *Eisenia foetida* was proved to be an efficient method of composting.

Studies at CPCRI, RS, Vittal have revealed that mushroom and vermicompost production using arecanut wastes such as leaves, leaf sheaths and husk are the promising technologies in terms of waste recycling and employment generation. Production of oyster mushrooms (*Pleurotus sajor-caju*), which are edible and rich in protein content, generates Rs. 17,000/ ha/year. The spent substrates can be reused for vermicompost production. On an average, a net income of Rs. 28,000/ ha/year is realized with mushroom and vermicompost production using wastes form one hectare of arecanut plantation.

2.2.2.2 Irrigation/Fertigation

Irrigation with 30 mm water at 30 mm pan evaporation was recommended for arecanut plantation during summer months through flood or perfo method of irrigation. The irrigation schedule for arecanut is 200 litres of water per palm once in 6 days through hose. Irrigation intervals depending on seasons were worked out and 20 litres of water per day per palm was found to be sufficient through drip, hence a saving of 44% water.. Fertigation technique developed has reduced the cost of cultivation by way reducing the recommended dose of fertilizers.

2.2.2.3 Areca based cropping system

The long pre-bearing period, low returns during the initial bearing stage, fluctuations in market prices, unexpected loss due to pests and diseases and natural calamities are some of the problems associated with arecanut cultivation. To overcome these problems, inter/mixed cropping with banana, betelvine, pepper, tapioca, colocasia, dioscoria, pineapple etc. are recommended to realise income during juvenile phase of arecanut.

Mixed and inter cropping systems developed with different combination of crops such as banana, betelvine, pepper, tapioca, colocasia, dioscoria, pineapple, vanilla, clove, nutmeg, lemon, Shatavari (Asparagus racemosus), Vetiver (Vetiver zizanoides), Long pepper (Piper longum). Research efforts at CPCRI,RS, Vittal, CPCRI, RC Hirehalli, Kahikuchi and Mohitnagar revealed that banana; cocoa, pepper, lemon, betelvine, elephant foot yam and tapioca can be grown with arecanut in HDMSCS. At Vittal, cultivation of cocoa, banana and pepper was found profitable with arecanut. At Hirehalli, cocoa, pepper, banana and lemon were found profitable where as at Mohitnagar, a combination of arecanut, banana and pepper increased the net profits.

The system of growing more number of crops of different species mixed with main crop to meet food, fuel and timber needs is called High Density Multi Species Cropping System (HDMSCS). Research efforts at

CPCRI,RS, Vittal, CPCRI, RC Hirehalli, Kahikuchi and Mohitnagar in this direction have revealed that banana; cocoa, pepper, lemon, betelvine, elephant foot yam and tapioca can be grown with arecanut in HDMSCS. At Vittal, cultivation of cocoa, banana and pepper was found profitable with arecanut. At Hirehalli, cocoa, pepper, banana and lemon were found profitable where as at Mohitnagar, a combination of arecanut, banana and pepper increased the net profits. By following HDMSCS, we can increase the net returns by 2 to 2.5 times over arecanut alone.

2.2.3 Management of disease and pests

2.2.3.1 Management of fruit rot of arecanut

Fruit rot (Kole roga) is one of the major diseases of arecanut palm caused by *Phytophthora* spp. (*P. arecae* and *P. meadii*). The disease is seasonal and occurs during South West monsoon. The present control measure is prophylactic spraying of one per cent Bordeaux mixture before the onset of monsoon. Besides the chemical method, mechanical method of control of the disease by protecting the bunches through covering with polythene is found to be very much effective in checking the incidence and spread of the disease.

2.2.3.2 Inflorescence dieback and button shedding

Inflorescence dieback and button shedding are caused by several factors including the fungus, *Colletotrichum gloeosporioides*. The disease can be controlled by spraying Indofil M-45 or Dithane Z- 78 @3g/l on opening of female flowers in most of the inflorescences.

2.2.3.3 Yellow leaf disease of arecanut

Yellow leaf disease caused by Phytoplasma is characterized by interveinal foliar yellowing. The disease is transmitted by the vector, *Proutista moesta*. Yield of the disease affected garden can be sustained by applying balanced fertilizers (NPK @100:40:140 g/ palm/ year) and an additional dose of super phosphate with lime (1 kg/ palm). Application of organic manure @ 12 kg/ palm/ year along with provision of summer irrigation and drainage can improve the condition of the palms. Removing the diseased palms in the mildly affected areas to prevent the spread and adopting need based plant protection measures against other pests and diseases is advised.

2.2.3.4 Scale insects and mealy bugs (minor pests)

Scale insect infestation is seen on leaves, button and rachillae while mealy bugs colonize on all tender parts like the bases of spear leaf, spadix, and inflorescence and inside the perianth of nuts. They can be managed by spraying 0.1% Fenthion/ Malathion on the infested leaves, buttons and rachillae (for scale insects) and 0.05% monocrotophos or 0.1% fenthion (for mealy bugs).

2.2.3.5 Spindle bug of arecanut *(Carvalhoia arecae)*

The symptoms of attack includes linear water soaked lesions on damaged leaves, which turn necrotic and dry and drop off, the infested spindle do not open completely. The pest can be managed by placing Phorate 10G, @ 2g granules in perforated polythene sachets in the innermost leaf axils.

2.2.3.6 Management of white grubs in arecanut

Preliminary field trials on evaluation of newer pesticide molecule showed that application of carbosulfan @ 20 g/palm gave 80% control of white grubs.

2.3 Cocoa (*Theobroma cacao* L.)

In India, cocoa is being grown in an area of 18,000 ha, with a meager production of 10200 MT and productivity of 454 kg/ha of beans against the installed processing industry capacity of 30,000 MT a year. The

present production is sufficient to meet only 15% of the industry demand, necessitating huge import of cocoa beans. The growth in area and production of cocoa in the country is at snail's pace due to lack of enthusiasm among farmers to cultivate the crop, which does not seem to have a ready market. Cocoa is not grown as pure plantations. It is planted as an inter/mixed crop mainly in irrigated coconut and arecanut gardens in Kerala, Karnataka, Andhra Pradesh and Tamil Nadu. Cocoa has the imminent capacity to share the alley spaces of tall growing coconut and arecanut palms and its combining ability with the microclimate conditions available in such perennial gardens helps its cultivation in utilizing such areas. In any groves of tall growing palms where 40-50% sunlight penetration is possible, cocoa stands first to absorb such solar energy, remaining symbiotic to the main crop and generating additional income as well, besides helping the amelioration of the soil conditions making beneficial not only for its own growth but also for the benefit of the main crop under which it takes its shelter. The research achievements, so far, in this institute are described under the following heads.

2.3.1 Crop improvement programme

The cocoa germplasm holding at CPCRI Regional Station, Vittal (DK), Karnataka consist 210 including 13 indigenous genotypes. In cocoa, so far the following variety/hybrids have been developed and released for cultivation in the country.

Varieties/Clone: NC 45/53 (Dry bean yield 781 kg/ha.), NA 242, (Dry bean yield 537.5 kg/ha).

Hybrids: I-56 x II-67 (Dry bean yield 1007 kg/ha), ICS 6 x SCA 6 (Dry bean yield 779 kg/ha), II-67 x NC 29/66 (Dry bean yield 1006 kg/ha), II-67 x NC 42/94 (Dry bean yield 847 kg/ha).

An experiment with 14 accessions in the clonal evaluation programme revealed that the accession Na242 recorded the highest dry bean yield (0.827kg/plant/year). In the four progeny trials for the hybrid evaluation programme, the progenies belonging to Na33 x ICS, I-56 x II-67, ICS6 x Sca6 and II-67 x NC42/94 performed better in terms of dry bean yield. In vitro screening of majority of the available germplasm against the black pod disease using isolates of prevailing three *Phytophthora* spp. viz., *P. palmivora, P. capsaici, P. citrophthora* has indicated a few good lines with certain degree of tolerance and one among them has been NC 51 (parentage being C 44).

2.3.2 Crop production programme

2.3.2.1 Grafting Soft wood grafting technique for multiplication of quality planting materials was standardized

2.3.2.2 Planting Cocoa seedlings are to be planted in pits of 60 cm3 at a spacing of 2.7 m x 5.4 m in 2.7 m x 2.7 m spaced areca garden. In coconut, cocoa seedlings can be planted either in single hedge in the centre of two rows of coconut palms with a spacing of 3 m between cocoa plants or in double hedge system with spacing of 3 m x 3 m in the centre of two rows of coconut palms.

2.3.2.3 Integrated nutrient management An annual application of 100g N, 40g P2O5 and 140g K2O per tree in two equal splits during April- May and An annual application of 100g N, 40g P2O5 and 140g K2O per tree in two equal splits during April- May and September –October.

2.3.2.4 Irrigation As cocoa is sensitive to water stress it should be irrigated once in a week during November - December, once in 6 days during January- March and once in four- five days during April- May with about 175 liters of water.

2.3.2.5 Pruning Formation pruning was standardized to restrict the jorquetting height to 1-1.5 m and it can be adjusted by nipping the fan branches close to the jorquette immediately after development. This pruning will decide the number of jorquettes per tree, fan branches per jorquette and height of first jorquette. It also involved removal of number of unwanted chupons arising from the main stem.

Structural pruning is standardized to shape the canopy to desired size and architecture. Pruning of seedlings is followed with adjusting the height of first jorquette between 1 to 1.5 meters and 3-4 fan branches are retained with vertical height restricted to first jorquette and an umbrella-shaped canopy. The canopy spread of 3.8 to 4.0m and height 2.7m are the ideal canopy architecture for optimum yield.

2.3.3 Protection Technologies

2.3.3.1 Disease management

Black pod disease (*Phytophthora palmivora*) Spraying of Bordeaux mixture (1%) at 15 days interval starting from the onset of south- west monsoon along with periodic removal of infected pods is effective in controlling the disease in severely affected gardens.

Cherelle wilt (*Colletotrichum*) Occurs as a physiological thinning mechanism. Large numbers of young pods (cherelles) of 2-3 months age dries up and remain on the tree as mummified fruit. Bavistin WP (carbendazim 0.05%) and Indofil M-45 (mancozeb) 0.2% are found be promising fungicides for the control of *Colletotrichum* infection on cocoa.

Cocoa wilt For the control of the disease phytosanitation measures such as removal and burning of infected trees is recommended. Propiconazole 0.2% +Imidacloprid 0.2%, combined application after cutting the infected portion of the trees gives significant control of about 78% recovery and with only 10.62% of fresh infection.

2.3.3.2 Pests Management

Mealy bugs (*Planococcus lilacinus* and *P. citri*): The best way to get effective control of mealy bugs is to have spot sprays on the initial foci of infestation with fenthion (lebaycid) 5 ml in 10 l of water or dimethoate (Rogor) 16 ml in 10 l of water. A number of natural enemies are found to feed on mealy bugs viz, *coccinellids*, *lycaenids*, *cecidomyids* etc.

3. FUTURE STRATEGIES

This institute envisages the following strategies during XIth Five Year Plan to augment the production and productivity of mandate crops.

- Collection, conservation and cataloging of Coconut germplasm possessing specific traits viz., drought tolerance, disease resistance, liquid endosperm (makapuno) aroma and cocoa germplasm for high yield and disease resistance.
- Development of TxD, DxT and TxT hybrids with drought tolerance/resistance to root(wilt) disease and DxD hybrids with superior tendernut qualities
- Supply of *in vitro* regenerated elite/disease free planting materials of coconut and arecanut
- Marker assisted selection criteria for drought tolerance/disease resistance
- Technology for higher productivity through increased water and nutrient use efficiency in mandate crops

- Technology for four fold increase in net profit at farm level by developing land use systems for multifunctional agriculture and enterprise diversification
- Effective bio formulations of agriculturally important microbes and their supply to farmers
- Organic farming practices for coconut based farming cropping and cocoa
- Early diagnostic techniques for root(wilt) of coconut and yellow leaf disease of arecanut
- Management packages with bioagents and botanicals for coconut root(wilt) disease, leaf rot and bud rot diseases of coconut and yellow leaf disease of arecanut.
- Improved strains of bioagents for managing Opisina arenosella and biocontrol strategy
- Documentation of invasive and emerging pests for effective quarantine services
- Cultivar suitable for elevated CO2 and temperature conditions and mitigation strategies for climate change
- Carbon and virtual water trade mechanism for coconut and arecanut based systems
- Machineries and processing technologies for virgin coconut oil production and herbal virgin coconut oil, minimally processed tendernut
- Machinery for digging / planting pits for coconut, climbing devices
- Periodical analysis of domestic and international trade scenario of mandate crops
- IT enabled farm advisory services through video conferencing, e-mails, telephone etc., and participatory technology transfer for the benefit of farmers of major coconut growing regions
- Community Based Organizations (CBO) of farmers and farm women for better utilization of technologies for higher income and employment generation.