

ACHIEVEMENTS OF KERALA AGRICULTURAL UNIVERSITY IN PLANTATION CROPS RESEARCH CHALLENGES, FUTURE PROSPECTS AND RESEARCH PRIORITIES

**T. R. Gopalakrishnan^a, P. C. Balakrishnan^b,
Prasannakumari Amma^c, Jose Mathew^d, V. S. Sujatha^e**

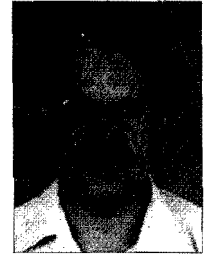
^a Director of Research, Kerala Agriculture University, Vellanikkara

^b Associate Director of Research (Coconut Mission), Kerala Agriculture
University Vellanikkara

^c Professor & Head, Cocoa Research Centre, Vellanikkara

^d Professor & Head, Cashew Research Station, Madakkathara

^e Professor & Project Coordinator, Plantation Crops & Spices, College of
Horticulture, Vellanikkara



Plantation crops contribute a major share in the economy of Kerala. Coconut, Arecanut, Cocoa, Spices are the major crops grown in the state. Kerala Agricultural University has been involved in research on the above crops since its inception and is done at Regional Agricultural Research Station, Pilicode, Coconut Research Station, Balaramapuram, Pepper Research Station, Panniyur, Dept of Plantation crops and Spices, College of Horticulture, Vellanikkara, Cashew Research Station, Madakkathara, Cashew Research Station Anakkayam and Cardamom Research Station, Pampadumpara. A brief account of the research done and achievements are presented in this report.

COCONUT

HISTORY OF RESEARCH

Coconut research in Kerala commenced in the year 1916 with the establishment of four research stations in the erstwhile Malabar, at Pilicode by the then Government of Madras. In these stations, research was initiated to study the genetics of the palm

and agronomic and cultural requirements of the crop in relation to different soil types. The coconut research stations at Nilesishwar, Pilicode, Balaramapuram and Kumarakom functioned under the Department of Agriculture till 1972 and were transferred to the Kerala Agricultural University in 1972.

Coconut and coconut-based farming system research received a further fillip when the Kerala Agricultural University came within the fold of the National Agricultural Research Project. Subsequently, the coconut research stations at Pilicode and Kumarakom were elevated to the status of the Regional Agricultural Research Stations with mandate for research on coconut and coconut-based farming systems including integrated coconut-livestock-fishery systems, respectively.

MAJOR ACHIEVEMENTS

Crop improvement

The introduction of coconut types for yield evaluation was started as early as 1923 at Pilicode with the ultimate objective of

identifying elite types having high yield. The station has an excellent collection of coconut germplasm consisting of exotic (35) and indigenous (40) types.

Earlier studies on the performance of the introduced types revealed that Lakshadweep Ordinary, Lakshadweep Small, Andaman Ordinary, Philippines and Cochin China were promising. Among the exotic varieties, Cochin China and Philippines were outstanding in quality for their tender nuts.

High yielding coconut hybrids

The first hybrid coconut was developed prior to the formation of the Kerala Agricultural University as T x D (Tall x Dwarf) which became very popular throughout the State.

Realising the importance of hybridization as a potential tool for genetic improvement of coconut, a number of hybrids involving different parental combinations were produced and tested at the Regional Agricultural Research Station, Pilicode. In 1947, Gangabondam, a semi tall cultivar of Andhra Pradesh, was used as pollen parent and crossed with six tall cultivars viz., Lakshadweep Ordinary, Andaman Ordinary, West Coast Tall, Java, Lakshadweep Small and Cochin China. Lakshadweep Ordinary x Gangabondam was found to be superior to all other hybrids in respect of annual nut production, setting

percentage, per palm yield of nuts and copra out turn per year. This hybrid was released as **Lakshaganga** in 1987. Later in 1988-89, two more hybrids were released based on the studies conducted at the Regional Agricultural Research Station, Pilicode. They are **Anandaganga** and **Keraganga**, developed by a cross of Andaman Ordinary x Gangabondam and West Coast Tall x Gangabondam, respectively.

Coconut hybridization work at Pilicode gained momentum in 1973 with the planting of 15 hybrid combinations of tall and dwarf palms for studying the extent of heterosis in coconut. West Coast Tall x Malayan Yellow Dwarf was better than the other cross combinations, based on early flowering, average number of nuts and copra out turn and it was released as **Kerasree**.

Another hybrid **Kerasowbhagya** (West Coast Tall x Strait Settlement Apricot) was released in 1993 based on its uniform performance and high yield.

High yielding coconut cultivars

'**Komadan**', an ecotype of the southern districts of Kerala was found superior to West Coast Tall and Natural Cross Dwarf in respect of nut yield (163 nuts palm⁻¹ year⁻¹), weight of husked nut (550 g), copra content (177 g nut⁻¹) and oil percentage (65.23). It has been released and recommended for large

Performance of released hybrids

Hybrid	Nut yield palm-1 year ⁻¹ (No.)	Copra content nut ⁻¹ (g)	Copra yield Palm ⁻¹ year ⁻¹ (kg)
Lakshaganga	108.3	194	21.06
Anandagana	95.2	216	20.56
Keraganga	100.2	201	20.14
Kerasree	140.0	216	30.24
Kerasowbhagya	130.0	195	25.35

scale cultivation in the southern region of Kerala. An open pollinated variety **Kerasagara** was released from RARS, Pilicode during the year 2007 by the State Variety Release Committee.

The exotic coconut variety **Kudat** was found promising among the new introductions.

Identification of quality seedlings

The criteria for selecting quality seedlings at nursery stage could be standardized based on the time taken for germination, number of leaves, girth at collar and early splitting of leaves. The recovery of quality seedlings was estimated to be about 60-65 per cent.

CROP MANAGEMENT

Density of planting

The spacing adopted by the coconut farmers of Kerala varies from 5.6 to 9.0 m. Based on the studies on the yield response of the coconut cultivar West Coast Tall, conducted in the various research stations of the Kerala Agricultural University, a spacing of 7.5 x 7.5 m was identified as the optimum under average fertility conditions.

Moisture conservation

Moisture conservation is of vital importance in coconut, especially in the northern districts with prolonged spells of drought. Surface mulching of coconut basins with waste coconut leaves (12 basin⁻¹) or burying of coconut husks in linear trenches of 1.80 x 0.45 m in between rows of coconut palms helped moisture conservation and increased nut yield. The beneficial effect of burying husks was observed to last for six years.

Fertilizer requirement

At the Coconut Research Station, Balaramapuram a fertilizer trial involving

three levels of N, P and K in factorial combination has been in progress since 1964.

The study made so far indicates that potassium can independently influence the nut yield. Nitrogen influences the yield only in combination with phosphorus or potassium.

Trials conducted at Pilicode indicated that irrigated coconut hybrids require a fertilizer dose of 0.5:0.5:1.5 kg NPK palm⁻¹ year⁻¹ in two split doses. For reclaimed clayey soil as in Kuttanad, a fertilizer dose of 0.25:0.35:0.90 kg NPK palm⁻¹ year⁻¹ has been recommended.

The response of magnesium, a secondary element has been tested in two different soil types *viz.* laterite and alluvial. In laterite soil, the yield of coconut increase due to magnesium application.

However, this trend was not observed in alluvial soil. Diagnosis and Recommendation Integrated System (DRIS) was found applicable to coconut. DRIS could be used for the nutrient management in conjunction with critical level approach. Routine leaf analyses for the diagnosis of latent deficiencies of N, K and C1 and correction of these deficiencies based on foliar critical levels have been recommended.

An efficient method of fertilizer application was developed from radio tracer studies employing ³²P based on the most effective root zone. It was observed that over 80 per cent of active roots of coconut reside in a soil column of radius 2.0 m to a depth of 60 cm. Accordingly, fertilizers and manure are to be applied in a circle of radius 2.0 m around the palm for best results. Adoption of this method ensures maximum utilization of the applied nutrients.

Response to irrigation and drainage

Coconut responds well to irrigation during dry months (January to May) from the third year onwards. Irrigating the crop with 500 litres of water in basins of 1.8 m radius at CPE value of 50 mm (approximate interval of 12 days) is the most economical.

Irrigation at IW/CPE 1.0 and a fertilizer dose of 0.5, 0.5, 1.5 kg NPK palm⁻¹ year⁻¹ was found to be ideal for Tall x Gangabondam hybrids.

The ratio of consumptive use to pan evaporation (crop co-efficient) was computed under different irrigation regimes and the mean was estimated as 0.75. The water requirement of coconut seedlings could be estimated using this crop co-efficient, if pan evaporation values are known.

The observations on growth characters recorded during 1985 and 1986 indicated that the treatment receiving drip irrigation at IW/CPE 0.50 and a fertilizer dose of 0.50, 0.32 and 1.20 kg NPK palm⁻¹ year⁻¹ was superior to the rest.

In a study conducted at Nileshtar, it was found that surface drains of 1.5 m depth, provided in between rows of coconut, increased the yield by 84.8 per cent (pre-treatment yield; 35.7 nuts palm⁻¹; post treatment yield; 66.1 nuts palm⁻¹). The crop was irrigated during summer months.

Impact of drought on coconut yield

The adverse effect of drought on coconut yield was observed in the succeeding year, starting from the eighth month to the twentieth month after the drought, the peak decline being in the twelfth and thirteenth months. The effect of drought during summer on low yielders of coconut was less, when compared to that of high yielders, including coconut

hybrids. However, the number of nuts was high (69.3 nuts palm⁻¹ year⁻¹) in high yielders even in drought years, when compared to that of low yielders (45.2 nuts palm⁻¹ year⁻¹).

There is a general belief that the coconut palms will be affected if irrigation is discontinued in the mid summer due to scarcity of water. Hence, the coconut growers are reluctant to irrigate the palms during summer (December to May) even though water is available upto February. Studies have shown that irrigating the palms @ 450 l palm⁻¹ week⁻¹ during summer, till water for irrigation is available, is not detrimental for crop production. The yield of nuts was found to increase due to summer irrigation even for a few months.

Forecasting coconut production

Using the data from 1949-50 to 1993-94, a multiple regression model could be developed for forecasting the total coconut production of the State seven months ahead, based on agro climatic indices viz, index of moisture adequacy (Ima) and humidity index (Ih). The R² was 0.97.

Micrometeorological studies

Micrometeorological studies were conducted to understand solar and the net radiation profiles in coconut gardens. Relationship was worked out between bright sunshine and solar and net radiation.

Quantification of incident light at different developmental stages in coconut garden is helpful for selecting suitable intercrops. Light infiltration in coconut-based homesteads increases with increase in plant height up to 6.4 m (corresponding to the height of nine year old palms). A reverse trend was observed beyond this stage. A prediction technique for light infiltration

based on measurements of crop parameters was evolved.

Coconut based integrated farming systems

Farming strategies that ensure sustainable advances in production is a chosen alternative to high technology farming. Such a regeneration farming approach that blends different farming practices through biological diversification and nutrient cycling is most relevant to the coastal wetlands of Kerala, where coconut is the principal perennial crop. At the Regional Agricultural Research Station, Kumarakom in Kuttanad, the coastal low land of Kerala, long term as well as short term studies have been taken up, focussing on the farming system involving integration of diverse allied enterprises, blending complementary and interactive farming viz., raising of intercrops fodder, livestock, poultry and fish in low lands, wherever possible. Three fundamental models of integrated farming have been evolved and tested viz., (1) coconut-intercrops-livestock-fish, (2) coconut-duck-fish and (3) coconut-livestock-prawn. These facilitated complementary interactions and organic matter recycling.

Economics of homestead farming with and without livestock components showed that livestock enterprise had a healthy and synergistic interaction with crop components in a farm. This could be profitably exploited to form an income generating and employment generating activity in the home garden. The system including livestock was found to be more eco-friendly and also sustainable as it provided scope for better nutrient recycling and minimum use of external inputs.

On-farm research on homesteads indicated that the species diversity was more

in farms with crops alone than in farms with crop and livestock, indicating a larger number of crop species in the category of farms with only crops.

Several experiments have been conducted to optimise the intercropping systems in coconut. Root production in banana was found to vary between the plants grown in the coconut garden and in the open. Rain fed banana in the coconut garden developed a spreading root system, while irrigated banana developed a compact root system. When banana and cassava were grown as intercrops, 75 per cent of the fertilizer dose recommended for each crop was found sufficient for obtaining high yield

The economic feasibility of growing pepper as a component crop of coconut was confirmed in an experiment conducted at the Regional Agricultural Research Station, Kumarakom. Panniyur-1 was found to be the best variety for the system. Yams were observed to be suitable intercrops of coconut in the reclaimed alluvial soil.

Ginger collections from Kuravilangad, Nedumangad, Kuruppampadyand Kumarakom were found suitable for intercropping in coconut gardens.

Growing the medicinal plant *Coleus vetiveroides* as an intercrop in coconut garden was found to be remunerative. *Piper longum* performed well under 50 x 50 cm spacing with an application of 20 t FYM ha⁻¹ and 30:30:30kg NPK ha⁻¹

Intercropping in coconut gardens of about 20 years age, using forage grasses and legumes has been standardised and recommended. Crop combinations of grasses like guinea grass, setaria, hybrid napier and *Panicum maximum* and legumes like cowpea and stylosanthes, as pure and mixture at 3:1 ratio were found suitable.

Among the green manure crops and cover crops tried in coconut basins, *Crotalaria striata* and *Pueraria phaseoloides* produced the greatest quantity of dry matter.

CROP PROTECTION

Disease management

The debilitating and dreaded root (wilt) disease is affecting the production and productivity of coconut in Kerala. The estimated annual loss in yield due to the disease during 1976 was 340 million nuts and during 1984-85, 968 million nuts. Most often death of the palms occurs subsequently, due to the infection by the fungal pathogen, *Helminthosporium haloides* as well as due to infestation by red palm weevil. In case a root (wilt) affected plant is not attacked by leaf rot or red palm weevil, the palm can continue to produce fairly good yields for several years. Spraying the foliage with 1.0 per cent Bordeaux mixture before the onset of monsoon and root injection of Monocrotophos has been found to be very effective for the purpose. Detailed studies on the etiology of root (wilt) are in progress.

Concentrations of rare earth elements (REEs) in the leaves of the diseased and apparently healthy palms of the disease-affected tract and healthy palms of the disease-free area covering three major soil types viz., alluvial, laterite and sandy were studied. The results reflect the probable geochemical differences between disease affected tracts and disease-free tracts. The probable role of soil chemical constituents in the incidence of root (wilt) disease, either as a causative agent or as a pre-disposing factor, implies that the occurrence of the disease should be understood based on its distribution and not on its spread. The presence or absence of the disease delineates

two geographical regions in the State based on soil chemical differences.

Stem bleeding, a lethal disease threatening coconut cultivation in the North, could be effectively managed by painting hot coaltar on the cleared surface, applying neem cake @ 5.0 kg palm⁻¹ year⁻¹ and drenching the soil with 25 ml calixin in 25 l water at monthly intervals.

A homothallic *Phytophthora* (*P. katsurae*) infecting coconut palm and causing bud rot was identified. This is highly pathogenic and can also cause foot rot disease of pepper. It produces oospores in large numbers in the infected palm.

Pest management

The coried bug, *Paradasynus rostratus* is a serious menace to coconut cultivation in Kerala. It was estimated to cause 24 per cent loss in copra and 35 per cent loss in oil content. Spraying Carbaryl 0.1 per cent or Endosulfan 0.1 per cent on the newly opened inflorescence, after the receptive phase of the female flowers, and the entire crown excluding leaves and other bunches, was recommended for managing the pest. Cashew and guava were identified as potential alternate host of this pest.

A severe outbreak of the coconut mite *A. guerreronis* was reported from Kerala during 1998. The reports from other countries have clearly shown that the acarophagous fungus species belonging to the genus *Hirsutella* are the specific fungal pathogens and the promising biocontrol agent of coconut mite.

Extensive surveys were conducted and nut samples were collected from the mite-infested areas for isolation of fungal pathogens. Accordingly the specific fungal pathogen *Hirsutella thompsonii* var.

synnematosa could be isolated consistently from the dead mites. The pathogenicity of the fungus was later confirmed under laboratory condition.

Being a newly reported pathogen, further basic studies have been taken up on several aspects including the standardization of laboratory culturing techniques.

Simultaneously a mycoacaricide namely 'mycohit' has been formulated with *Hirsutella thompsonii* from PDBC, Bangalore. Field experiments were conducted with Mycohit (wettable powder formulation) during 2000 and 2001. About 70 to 90 percent mite mortality could be recorded in the preliminary trials. The field trial will be continued with newer versions of 'Mycohit'.

Our scientists have also isolated local strains of the *H. thompsonii* and are now trying to isolate and characterize the strains that are better in their infectivity and adapted-possible routes of administration including utilization of the pollinators are being explored.

As part of the NATP/CGP project, attempts are being made for the isolation and identification of improved strains of *Hirsutella* and other mite pathogens suitable for Kerala.

Infestation of rhinoceros beetle could be reduced by treating manure pits and other possible breeding sites with Carbaryl 0.01 per cent on w/w basis every three months. Leaf extracts and chopped leaves of *Clerodendron* and neem when mixed with cowdung at the rate of 1:10 and 1:20 by weight prevented the normal growth and development of the grubs.

Incidence of the black headed caterpillar of coconut (*Opisina arenosella*) could be effectively controlled by liberating parasites (Braconid/Bethylid/Elasmid) in the early stage

of infestation. When infestation is very severe and bio-controls is not likely to be effective, spraying the under surface of the fronds with Dichlorvos 0.02 per cent or Malathion 0.05 per cent is recommended. After the application of the insecticide, larval and pupal parasites should be released from the 21st day to re-establish the host-parasite balance.

The important alternate hosts of the cockchafer beetle, *Leucopholis coneophora*, were observed to be colocasia, tapioca, pepper, arecanut, rose, bhindi, groundnut and casuarina.

Studies on stored products of coconut were conducted. It was observed that even well preserved and good quality copra was damaged by pests like *Necrobia rufipes* and *Oryzaephilus surinamensis* when stocked for more than five months. Drying of copra to 4.0 per cent moisture level and storing the same in the netted polythene bags was recommended for reducing pest incidence. When stored in gunny bags, the bag should be disinfested by applying 0.4 per cent Malathion or 0.8 per cent Fenitrothion on the outer surface and dried in the shade. Fumigation of godowns with Aluminium phosphide @ 3.0 g/m³, with two days exposure period, was effective in saving pest infested copra.

Post harvest technology and product diversification

Research in processing and product diversification of coconut inflorescence sap (CIS) under NATP/CGP at Pilicode campus resulted in a modified method for collection of coconut inflorescence sap. Processing methods have been developed for preservation of coconut inflorescence sap as RTS (CIS RTS), coconut inflorescence sap concentrate (CIS honey), coconut inflorescence sap granules (CIS granules). The minimum storage life of RTS is 60 days

and that of CIS honey is 1 year. Processing methods have also been standardized for the preparation of jam and toffee from CIS products. Method for the production of palmgur has been improved to enhance the quality and shelf life.

Sap exuding from the coconut inflorescence has a TSS of 17.5° B and pH 7.3. The total sugar present in CIS is 16.33 of which 15.79 is non reducing sugar. Important minerals present in CIS are potassium (89.8 ppm) followed by Calcium (50 ppm) and Phosphorous (13 ppm).

Sap yield varied significantly among the palms 1.36 to 3.14 litre/day). Seasonal variation in the sap yield was also significant.

ONGOING PROGRAMMES

Coconut Mission activities

Efforts were made to enhance the production of hybrid coconut seedlings at various centers of KAU. Additional mother palms were identified in the traditionally producing centers viz. RARS, Pilicode and COA, Padannakkad. New production programme was started at IF, Vellayani, ORARS, Kayamkulam and CRS, Balaramapuram. During the 2010-11 season, 21000 hybrid coconut seedlings will be ready for distribution. At present the production is about 10000 hybrid coconut seedlings per year.

An RKVY project "Production and distribution of coconut seedlings and other planting materials adopting seed village concept" was sanctioned with a financial outlay of Rs. 35 lakhs. Hybridization work already started by identifying 400 mother palms in farmer's field at Nileshtar for the production of Kerasree and Keraganga hybrid coconut seedlings. This will produce an additional 8000 hybrid coconut seedlings by 2012 season onwards. By implementing a

project "Development of production units for hybrid coconut seedlings and other planting materials in three districts of Kerala" 80000 hybrid coconut seedlings can be produced per year from various centres as listed below.

Control of Bud rot

Bud rot disease of coconut became a serious problem in Calicut, Kannur and Kasaragod districts. Concerted efforts were taken to curtail the spread of the disease in Maruthangara Grama Panchayath of Calicut district with the physical and financial help from the Department of Agriculture. Fifty thousand dead palms were cut and removed from the affected areas and preventive measures were taken up for 1,60,000 palms based on fruitful intervention.

Bud rot control activities were also implemented through of Department Agriculture in Balal, West Eleri and East Eleri Grama Panchayath in Kasaragod district with the help of Coconut Development Board. The details of the dead palms removed and the fund disbursed is as follows.

S. No.	Name of panchayath	Dead palms removed	Amount @ Rs. 250
1	East Eleri	32313	8078250
2	West Eleri	19046	4761500
3	Balal	15061	3765250
Total		66420	16605000

Prophylactic measures were taken up in 459258 palms covering in the three districts.

Under RKVY, management of root (wilt) affected palms is going on in Thazhakkara and Pathiyoor Grama Panchayath of Alleppy

district by providing better management practices and need based application of plant protection measures in selected 2000 palms and the programme will be continued for another one year.

MACHINERY DEVELOPED

a. Coconut dehusker

A simple and light hand operated coconut husking device, **KERAMITRA** was developed for domestic use. Consisting of a stationary wedge, a movable wedge, a lever and a pedestal, this device could husk a nut in 8-20 seconds, depending on the variety, maturity etc. The technology was transferred for commercial exploitation. This tool is fast spreading in Kerala

b. Tender coconut punch

Another tool, useful for punching a hole on tender coconut has been designed and fabricated.

BY-PRODUCT UTILIZATION

Coir pith utilization

Large quantities of coir pith – a by-product of coir industry is being wasted and is a serious pollutant. Coir pith can not be used as such for agricultural purpose. Methods could be standardized for coir pith composting utilizing the fungus *Pleurotus* and urea. Coir pith compost is found to be an excellent potting media for plants. Techniques could be standardized for using coir pith as a substrate for growing edible mushrooms.

Coir based geotextiles are being tested for soil conservation, soil structure improvement and weed management.

Ongoing projects under the coordination group of Coconut and Other Palms in Kerala Agricultural University:

- **Utilisation of existing germ plasm and description of varieties:** At present

Availability of coconut seedlings in different institution/ locations under Kerala Agricultural University during the year 2011 and 2012.

S. NO	Station	WCT		Hybrids			Total
		2011	2012	2011	2012	2013	
1	RARS, Pilicode	2000	2500	10000	10000	10000	25500
2	COA, Padannakkad	2000	2000	6000	6000	6000	18000
3	IF, Vellayani	10000	10000	400	4000	4000	24400
4	CRS, Balaramapuram	12000	15000	7000	10000	10000	44000
5	ORARS, Kayamkulam	5000	6000	2000	2000	2000	18000
6	RARS, Kumarakom	2000	2000	—	—	-	4000
7.	FSRS, Sadanathapuram	3000	3000	—	—	-	6000
8.	PPNMU, Vellanikkara	5000	5000	—	—	10000	27500
9.	ADR, Coconut Mission	4000	5000	—	10000	10000	19000
10	PRS, Panniyur	-	4000	-	-	10000	18000
11	CRS, Anakayam	-	4000	-	-	10000	18000
12	KCEAT, Tavanur	-	4000	-	-	8000	18000
Total		45000	50500	25400	42000	80000	186400

there are 40 indigenous and 35 exotic cultivars in the collection. Some of the collections were used for the development of hybrids released. Kerasagara is the variety released through selection

- **Morphological and biochemical characterisation of coconut:** The project was concluded.
- **Screening coconut cultivars for tender nut purpose:** Completed first phase of the programme and the data is being processed.
- **Variability and character association in the coconut cultivar Chowghat Dwarf Green with emphasise on resistance to root (wilt) disease and mite infestation:** Seed nuts collected from selected palms were sown in the nursery for replanting.
- **Development of short statured high yielding coconut variety with good nut quality:** Desirable types identified in the farmers field were used for the production of interse and hybrid coconut seedlings. The interse seedlings developed are coming up well in the nursery and the hybrid seed nuts developed will be ready for sowing by April-May
- **Trial of promising seed materials:** Hybrids are found superior to WCT and other types in nut yield.
- **Evaluation of coconut hybrids:** The crosses of LM x AYK and AYK x WCT are performing better in nut yield.
- **Multilocational trial of coconut hybrids:** Among the four varieties studied, hybrid WCT x CGD ranked top and was on par with Kerasree and Kerasankara. The project is going on at Nileshtar and Kumarakom
- **Hybrid seedling production in coconut:** Hybrid seedling production started from 2006-07.
- **NPK fertiliser experiment starting from seedling stage:** In the absence of potash, nitrogen application has antagonistic effect on growth and yield of coconut.
- **Spacing cum manurial trial:** The optimum spacing for coconut established as 7.5 x 7.5 m.
- **Permanent manurial trial:** The treatment differences are not significant.
- **Fertiliser management for clove mixed cropped in the coconut gardens of south Kerala:** The performance of clove is very good in the fertiliser applied plots.
- **Water management practices for coconut based cropping system:** Treatment was imposed only during the summer- 2008.
- **Survey and identification of root (wilt) disease free palms in coconut and evaluation of tolerant genotypes through selection and hybridisation:** The programme is going on as envisaged.
- **Establishment of model organic coconut farm:** The project started during August, 08
- **Studies on yellowing of Areca nut in Kannur Dt:** Observations are taken in the farmer's field.
- **OFFER (On Farm Exploratory Research) stem remedies against root (wilt), leaf rot and coconut mite:** The programme in the farmers field was started during August, 2008.
- **Management of root wilt affected coconut garden:** The project is going on in ward no. V of Thazhakkara

Gramma Panchayath and ward no. XVI in Pathiyoor GP from May 2008 onwards. The project is going on with active involvement the scientists and farmers.

COCOA

Cocoa, *Theobroma cacao* L. was introduced in India in the early 20th century, but its exploitation as a crop of significant economic value is just five decades old. From the cocoa “boom” in 1982, the crop suffered a severe set-back due to collapse of marketing system. After about 20 years of stagnant growth, the crop began to revive in a big way. This success was due to the systematic exploitation of research on genetic upgradation of planting stock and agro techniques. Though it is recommended as an inter crop in Kerala and Karnataka, cultivation as sole crop is also coming up in a big way on account of remunerative returns. The re-acceptance of the crop by the farmers of Kerala owes to its superiority as compared to other plantation crops. The total area under cocoa in the state is presently 20,000 ha and is expected to touch 25,000 ha by next year. Kerala is the leading cocoa growing state in the country with 60 per cent of production. The productivity of cocoa in state is above 1 kg dry beans/ tree/year and this is one of the highest in the world.

HISTORY OF RESEARCH

As cocoa is an introduced crop, technology for successful cultivation had to be developed for conditions prevailing in India. Cocoa cultivation was comparatively problem-free during the initial years of its introduction. As cultivation intensified, problems arose one by one in due course necessitating organized research. With the objective of evolving cocoa varieties and

develop production technologies relevant to our country, cocoa research was initiated in Kerala Agricultural University in 1979, when a World Bank-aided research project, ‘Kerala Agricultural Development Project (KADP)’ was initiated. Cocoa research was intensified from April 1987 with the establishment of Cadbury- KAU Co-operative Cocoa Research Project.

MAJOR ACHIEVEMENTS

Crop improvement

Germplasm of cocoa

The KAU has established the biggest germplasm of cocoa in India with 564 accessions including imported types. The collection contains very useful accessions like SCA 6, ICS 6 and IMC 67 and these are being fruitfully exploited in the breeding programmes.

Release of high yielding cocoa clones

Performance evaluation of the germplasm resulted in the identification of 194 superior trees. Seven varieties/clones viz., M16.9, M13.12, GI 5.9, GII 19.5, GII 18.5, GVI 55 (IMC 10) and GVI 56 (EET 272) were released respectively as CCRP 1- 7.

Hybridization

Hybridization to combine high yield, bold bean size, processing qualities and resistance to vascular streak die back and *Phytophthora* pod rot, were undertaken in Kerala Agricultural University.

a. Yield improvement

From 1987 to 1993, 159 parents were selected; 239 crosses were made, 21819 F₁ hybrid seedlings were produced and based on vigour in the nursery 2886 hybrid seedlings were field planted in eight trials

Series IV, Progeny Trials, I, II, III, and IV from 1988 onwards.

Evaluation of hybrids in PI (PI 1.21), SI (SI 4.13) and SII (SII 7.3) over twelve years led to the release of 3 elite hybrid clones (CCRP 8, 9 and 10) with very high yield, desirable pod and bean traits and resistance to vascular streak die back disease. Based on yield and pod and bean traits, selection was carried out from SI, SII, SIII and P I. Five top yielders were selected from SI, 11 from SII, 3 from SIII and 25 from PI. These were laid out in Comparative Yield Trial IV along with GI 5.9 as control. Selection was also carried out in Progeny Trials, II, III, IV, Series IV and VSD tolerant hybrids. Altogether 39 clones were planted in Comparative Yield Trial V for comparison.

b. Breeding for resistance to Vascular Streak Die back

From 1990 vascular streak die back disease began to spread to all cocoa growing areas of the state. As this disease cannot be controlled by the use of fungicides, breeding programme for production of disease resistant planting materials received further thrust. Under this programme (from 1994-2005), 234 resistant parents were used in evolving 1012 crosses. The 45,000 F₁ hybrids thus derived from the crosses were screened for resistance to the disease by subjecting them to high inoculum load and also by keeping them in the midst of infected seedlings. The disease escapes were selected after one year and the vigorous seedlings (2435) were field planted from 1998 onwards in five lots.

Evaluation of these hybrids showed that there are a number of high yielding plants with resistance in this population. Combining ability analysis indicated nine plants to have high GCA viz. VSD1 10.13,

11.11 (SCA 6 x GIV 18.5), 23.21, 29.9, 30.8, 31.87, 33.4, 33.8, 33.9 and these have been planted in polyclonal garden 7 during 2010. These were multiplied clonally and planted in CYT 5 also.

c. Improved bean size

Small bean size often poses problems to the growers particularly during summer. Thus, breeding programmes to develop varieties with bold bean appeared to be essential and as such programmes were taken up during 2003 and 2007. Twenty six parents with above 2.0 g dry bean weight were selected, 137 crosses were made and 26 crosses were obtained. Out of the 644 hybrid seedlings thus obtained, 120 seedlings were selected based on the vigour and were field planted. These hybrids are presently under evaluation. The hybrids showed wide variability in bean size ranging from 0.75 g to 2.5 g.

d. Improvement of bean quality

Criollos are considered to yield quality cocoa with superior processing qualities. To combine the Criollo quality to the superior clones, a programme was taken up during 2004 and 2005. One hundred and fifty nine crosses were made using 17 parents which resulted in 514 F₁ hybrid seedlings. After screening for vigour, 240 hybrid seedlings were field planted. These hybrids are under various stages of evaluation.

e. Resistance to *Phytophthora* pod rot disease

This disease is of serious concern in many cocoa growing countries of the world and estimated to cause about 20-30% global crop loss. Although chemical control measures have been developed to reduce yield losses from the disease, they are expensive and often beyond the reach of average cocoa

farmers. Development of high yielding resistant material is generally agreed to be a more effective, environment- friendly and economic disease management method. This disease is also very serious in India. Hence breeding programmes to tackle the disease through development of resistant planting material was initiated from 2005. Under this programme, 93 parents were selected, and 300 crosses were made. Fifty three crosses were successful and obtained 2166 F_1 hybrid seedlings. Out of these, 650 selected seedlings were field planted from 2007 onwards. These hybrids are under evaluation.

Establishment of clonal gardens

The better combiners arising out of breeding work are being multiplied clonally and regularly planted in new clonal gardens. Six poly clonal gardens and one biclonal garden were established using 86 prepotent parents. The total number of plants in these gardens comes to 4137. The anticipated seed pod production by the year 2010 is 2.00 lakh, sufficient enough to produce 50 lakh hybrid seedlings.

Inbreeding programme

With the objective of producing fully homozygous plants and ultimately securing maximum hybrid vigour and uniformity by crossing between two unrelated inbreds, inbreeding programme was undertaken from 1988 onwards. This long term programme was initiated by selfing high yielding self compatible plants from the germplasm and hybrid population. Each selfed generation of a genotype is planted @ 20 plants or depending upon the availability of land.

a. Production of inbreds

The highly complex genetic nature of this crop makes production of inbreds a very difficult task and thus many of the breeding

institutes dropped the programme after 2nd generation. However, Kerala Agricultural University has succeeded in producing the first ever fifth generation inbred in the world of one genotype after 21 years of continuous effort. At present, the University maintains S_4 generation of two genotypes, S_3 of 5 genotypes, S_2 of 9 genotypes and S_1 of 51 genotypes.

b. Inbred crossing

Inbred crosses aimed at producing highly vigourous and uniform progeny using early generations of genetically distant genotypes were taken up in 2007, 2008 and 2009 and the evaluation of the inbred crosses is in progress.

Crop management

Root activity pattern

Studies on root activity pattern showed that soil layer upto a depth 30 cm accounted for 42 per cent of the total root activity within the soil column of 2.5 m radius whereas the relative densities of active roots at 15 and 60 cm depths were 25 and 28 per cent, respectively. Beyond 60 cm depth, concentration of active roots declined sharply to about 5 per cent. Lateral spread of active roots was mainly restricted to one metre from the plant which accounted for 75 per cent of the total root activity. An area of 1.5 m radius around the plant accounted for about 90 per cent of the total root activity. Thus it was found that application of fertilizers upto 30 cm depth and 1.5 m radial distance will lead to maximum efficiency of applied nutrients.

Standardization of Seed and vegetative propagation methods

Standardized seed and vegetative propagation methods viz, rooting of cutting, grafting and budding.

Response of cocoa to shade and irrigation

In a trial involving shade manipulation, continued for ten years, the results indicated that there is increase in the growth of the plants and yield with increasing levels of illumination. More than five times increase in yield was observed in the open compared to the highest intensity of shade level (25%) tried.

Training and pruning of cocoa

Cocoa is recommended as an intercrop in coconut and arecanut plantations. When it is raised as intercrop, the growth is to be controlled for ease in cultivation practices of both main and intercrops. So it is desirable to restrict growth to 1-2 tiers. For maintaining the plants to this height, frequent removal of chupons which arise from the base, along the main trunk and quite often from fan branches is necessary.

Cocoa grows laterally also to unmanageable levels. These are also to be pruned, usually twice a year. The first pruning must coincide with the onset of rains. The twigs touching the ground, growing towards the main trunk, weak branches, diseased and damaged branches are pruned. The canopy top is pruned to have an open centre to let in more light and air to the main trunk.

The next pruning is done by December. This is done to prepare the plants to face ensuing summer. The plants are pruned in such a way to have a closed centre to reduce sun scorch. This will ensure that the leaves in inner layers of the canopy are not damaged. When cocoa is grown as mono crop and labour for different cultural operations is not a problem, cocoa can be grown without much pruning. In this case, the shoots arising around the main trunk are to be removed at regular intervals.

Top working

Top working, a method of rejuvenating old and unproductive cocoa trees has proved to be successful in cocoa. The studies carried out at Kerala Agricultural University, during 1988-89 led to the standardization of a procedure for top working in cocoa. The results suggested that when yield declines, due use of poor genetic stock or due to old age, top working holds better promise than replanting. This enables the farmer to get income right from the second year.

Crop protection

Survey on diseases prevalent in Kerala

A massive survey was conducted in the major cocoa growing tracts of Kerala and the following diseases were identified as prevalent in Kerala.

Among these, the most serious were *Phytophthora* pod rot and vascular streak die back. *Phytophthora* pod rot is of universal occurrence and the only effective method of controlling this disease will be through the genetic means. As a result of survey in farmers' field KAU hybrid population a number of resistant types were identified.

Among the nursery diseases, seedling blight caused by *Phytophthora palmivora* was found to be the most serious.

Pests

Survey on pest complex

Research work to identify the pest complex of this crop was initiated in 1976 at Vellanikkara. Pests like mealy bugs, citrus aphid, cow bug, tea mosquito, red banded thrips, red borer, leaf feeders, stem girdler and greenish weevil were identified. Research in subsequent years was

concentrated on evolving control measures against important pests. The important observation that was consistently made from these studies was that the mammalian pests were the most serious and difficult to control. Experimental observations and experience over the years have shown that the degree of damage can range from as low as five to as high as 100 per cent depending upon the control measures adopted.

Post harvest handling

The technology for small-scale fermentation for quantities ranging from 2 kg to 50 kg wet beans was standardized. The methods of drying and storage were also standardized

In order to safeguard the interests of the growers, studies were taken up to standardize technology for small scale secondary processing that can be taken up on home scale. The results pointed out that a number of cocoa based products could be at home level and that too with low investment. The limitations of short shelf life of these chocolates were found to be compensated by the farm fresh natural taste.

Impact of cocoa research on farming sector

Kerala Agricultural University has established clonal gardens with better combiners. The number of hybrid seedlings which can be produced from these gardens is about 50 lakh/year. These are being distributed to the growers in South India through Cadbury India Ltd. The superior varieties from the University have spread to all cocoa growing belts of Kerala, Tamil Nadu and Andhra Pradesh. The increase in yield through the use of improved planting material of KAU is 100%. Increased income from cocoa has helped the growers in Idukki, Wayanad and Kottayam to tide over the

periods of low demand and low price of coconut in Kerala in recent years. During the last 8 years, more than about 10,000 ha have been additionally brought under cultivation / rejuvenated in Kerala with high yielding varieties/ hybrids released from the project. This has helped to engage more than 50,000 families in cocoa farming in the state. The cocoa gardens established in different parts of the state using KAU planting materials and adoption of KAU technology for cultivation have proved their merit in terms of yield recording upto 5kg dry beans/ plant and this is the highest yield record of cocoa in the world.

ONGOING PROGRAMMES

1. Germplasm collection, maintenance and evaluation
2. Hybridization for improvement in yield
3. Hybridization for resistance to vascular streak die back
4. Hybridization for resistance to Phytophthora pod rot
5. Hybridization for developing varieties with bold bean size
6. Hybridization for improved processing qualities
7. Inbreeding to produce fully homozygous inbreds
8. Inbred crossing programme
9. Identification of prepotent parents for establishment of clonal gardens
10. Organic farming

CHALLENGES AND FUTURE PROSPECTS

Cocoa is the crop of the coming century on account of the following facts.

- 1) It is a highly suited intercrop for coconut and arecanut plantations. Studies show

that cocoa - coconut and cocoa - arecanut combinations complement each other and are mutually benefited.

- 2) Cocoa tolerates heavy shade to a level which is not tolerated by any other crop. This peculiarity makes its adaptable to extremely shaded environments of the homesteads of Kerala.
- 3) Cocoa ensures maximum utilization of solar energy through its fast spreading canopy.
- 4) In an intercropping system, the sunlight reaching the ground is significantly reduced and thus there is reduction in weed growth and cost of weeding.
- 5) Growth of cocoa is regulated by training and the height is restricted to 5-7 ft. This makes the cultural operations to be less labour intensive and women friendly.
- 6) The price is attractive at present with Rs.45-50/-per kg of wet beans and Rs.150-160/- per kg of cured beans. Intercropping with cocoa provides an additional /regular income of about Rs. 50,000/ ha/year
- 7) Intercropping with cocoa reduces the risk of price fluctuation as experienced in a monocropping system.
- 8) The statistics of demand and supply scenario in India suggests that production of cocoa in the country meets only 1/3rd of its demand.
- 9) The consumption of cocoa has registered a rapid rate of about 10- 15 per cent every year even in the midst of economic recession in the recent past. The consumption is likely to increase substantially in the coming years.
- 10) Cocoa has immense potential for export also. The quality of Indian cocoa is comparable to those produced in other

major cocoa producing countries of the world.

- 11) The number of large and small manufacturers of chocolate and other cocoa based products have increased substantially recently and this enabled a tight competition for cocoa in the market. Thus the likelihood of non-procurement as experienced during the initial years is quite remote.
- 12) All parts of the plant are useful, nibs for chocolate industry; pod husks as mulch, manure, cattle feed; cocoa shells as mulch and manure for orchids, anthurium and ornamentals; cocoa sweatings for making soft drinks, jam, jelly etc. and timber as fire wood.

RESEARCH PRIORITIES

Development of varieties resistant to *Phytophthora* pod rot, varieties with bold bean size and better processing qualities continues to be the important breeding thrusts. Exploitation of biotechnological tools to speed up resistance breeding programmes currently in progress in the Kerala Agricultural University forms an important research priority. The technology for organic farming is also to be standardized

CASHEW

HISTORY OF RESEARCH

Cashew research in Kerala was started in 1952 with the setting up of a research station at Kottarakkara, together with three other stations at Vittal (Karnataka), Bapatla (Andhra Pradesh) and Vengurla (Maharashtra), under an ICAR adhoc project. The financial assistance of ICAR to the above project was terminated in 1962. Subsequently, the Government of Kerala has

started a full-fledged Cashew Research Station at Anakkayam in 1963 under a scheme included in the third five year plan.

Cashew Research Station, Anakkayam, was one of the four centers of the All India Co-ordinated Spices and Cashew nut Improvement Project of the ICAR, when the latter was started in 1971. The station has been brought under the Kerala Agricultural University, when the University was established in 1972. Cashew Research Station at Madakkathara was started under Kerala Agricultural University on 1.5.1973. Subsequently the centre of the All India Co-ordinated Spices and Cashew nut Improvement Project was shifted to Madakkathara from Anakkayam.

In addition to the research programmes conducted at the Cashew Research Stations of Anakkayam and Madakkathara, several research projects on cashew were carried out under the Kerala Agricultural Development Project (KADP), Vellanikkara during 1978-79. The World Bank aided Multi State Cashew Research Programme (MSCRP) was implemented at Madakkathara during 15.2.82 to 3.9.86 during the 8th five year plan. The All India Co-ordinated Spices and Cashew nut Improvement Project was bifurcated in 1986 and an independent All India Co-ordinated Research Project (AICRP) on Cashew was started in 1986 with its head quarters at National Research Centre for Cashew, Puttur, Karnataka. Since then, Madakkathara station is continuing as one of the centers of AICRP on Cashew. During 1989 research and extension programmes in cashew were started at RARS, Pilicode under National Agricultural Research Project (NARP). During February 1993, Regional Agricultural Research Station, Pilicode has been recognized as a sub-centre of the AICRP on Cashew.

MAJOR ACHIEVEMENTS

CASHEW RESEARCH STATION, MADAKKATHARA

Crop improvement

The station has released 11 high yielding varieties of cashew which is widely cultivated in the state.

1. **Madakkathara 1:** A selection released during 1990. The mean annual nut yield / tree is 13.8 kg. The nut weight is 6.2 g and the shelling percent is 26.8. The export grade is W 280.
2. **Madakkathara 2 (NDR. 2 -1):** A selection released during 1990. The mean annual nut yield /tree is 17.0 kg. The nut weight is 7.25 g and the shelling percent is 26.0. The export grade is W 210.
3. **Dhana (H- 1608):** A hybrid released during 1993. The mean annual nut yield / tree is 10.7 kg. The nut weight is 8.2 g and the shelling percent is 29.8. The export grade is W 210.
4. **Kanaka (H - 1598) :** A hybrid released during 1993. The mean annual nut yield / tree is 12.8 kg. The nut weight is 6.8 g and the shelling percent is 30.6. The export grade is W 280.
5. **Sulabha (K -10-2):** A selection released during 1996. The mean annual nut yield / tree is 21.9 kg. The nut weight is 9.8 g and the shelling percent is 29.4. The export grade is W 210.
6. **Priyanka:** A hybrid released during 1995. The mean annual nut yield / tree is 17.0 kg. The nut weight is 10.8 g and the shelling percent is 26.6. The export grade is W 180.
7. **Amrutha:** A hybrid released during 1998. The mean annual nut yield / tree

is 18.4 kg. The nut weight is 7.2 g and the shelling percent is 31.6. The export grade is W 210.

8. **K-22-1:** A selection released during 1987. The mean nut yield/ tree is 13.0 kg. The nut weight is 10.2g and shelling percentage is 26.5. The export grade is W 280.
9. **Raghav (H-1610):** A hybrid released during 2002. The mean annual nut yield tree in 14.6 kg. The nut weight is 9.2 g and the shelling percent is 26.6. The export grade is W 210.
10. **Damodar (H-1600):** A hybrid released during 2002. The mean annual nut yield / tree in 13.7 kg. The nut weight is 8.2 g and the shelling percent is 27.3. The export grade is W 240.
11. **Poornima (H 1593):** A hybrid released during 2006. The mean annual nut yield per tree is 14.08 kg/ha. The nut weight is 7.8 g and kernel weight is 2.6 g. The shelling percent is 31%. The export grade is W 210.

A clonal germplasm conservation block with 132 accessions is being maintained and evaluated at the station.

A total of 1637 hybrid seedlings were evolved and planted in the field during the period 1993-2010 and are being continuously evaluated for their yield and characters.

Plant propagation

Technology for softwood grafting

The technique of softwood grafting was developed in the late 80s, which is found to be the best method for the vegetative propagation of cashew. Anakayam-1, Madakkathara-1 and K-22-1 were identified as the best rootstocks at 45 days after sowing during March-April. Plants with more

height, girth and internodal length are the best. Ideal age of the scion is identified as 3 to 4 months. Nuts having maximum weight, volume and L/ B ratio give vigorous seedlings in the nursery.

Technology for flush grafting

Flush grafting, developed and perfected at this centre, overcomes the limitations of softwood grafting. Flush grafting enables large-scale multiplication of elite types, as scions of three weeks old (flushes) can be successfully grafted on 21 day old rootstock. The ideal season is January to September.

Technology for air layering in cashew

Studies on effects of hormones on rooting of air layers revealed that the application of 250 ppm IBA /IAA at the girdled portion of the selected shoot promotes rooting. Wood shaving was found to be the best medium for air-layering followed by sand: sawdust in equal proportion. For transplanting the rooted air-layers, polythene bags filled with ordinary potting mixture (sand, topsoil and powered cowdung at 1:1:1 ratio) were found to be the best.

Technology for top working in cashew

Top working, a technique developed for rejuvenating unproductive cashew trees, has been refined at the station. The trees are to be cut at one metre height during January. Softwood grafting is to be done during March-April on the new shoots.

Crop management

Standardization of planting densities for cashew

The planting may be done at a spacing of 7.5 m for poor and 10 m for rich and deep

soils and sandy coastal area. On very sloppy lands, the rows may be spaced 10-15 m apart with spacing of 6-8 m between trees in a row. Either the square or triangular system of planting can be adopted.

Development of high density planting technique

High density planting ensures optimal utilization of solar radiation and land in the initial years. It yields almost double during the early years, as compared to normal planting. It involves thicker planting during early years and selective felling during later years, on development of canopy pressure and root level competition. Cashew will be planted initially at a spacing of 4m x 4 m or 5m x 5m, and maintained up to a period of six to seven years. Later, trees are removed in a planned manner, to provide a spacing of 8m x 8 m or 10m x 10m.

Formulation of a fertilizer schedule for cashew

A fertiliser dose of 750g N, 325 g of P_2O_5 and 750g K_2O per plant is recommended for cashew. $1/5^{th}$ of the dose is to be applied after the completion of the first year, $2/5^{th}$ dose during second year and thus reaching full dose from 5th year onwards. Broadcast the fertiliser within an area of 0.5 to 3m (15cm deep) around tree and incorporate by raking.

Intercropping

Pineapple is the most profitable intercrop in cashew plantations in the early stages of growth. Paired row of pineapple suckers can be planted in each trench at 60 cm between rows and 40 cm between two suckers within the row. These trenches can be opened across the slope at 1.0 m spacing between two rows of cashew. Lemongrass and tapioca are also suitable as intercrops.

Coleus has been identified as another intercrop with high yield and good economic return.

Root activity studies

Studies on the root activity of cashew using radio isotopes revealed that 75% of the feeder roots are located within a depth of 30 cm from soil surface.

Pruning

Pruning of light branches is found to result in the production of vigorous proleptic branches that are sturdy and productive. The best time of pruning is in the dormant stage preferably during the month of August. By pruning 25% of five branches at an interval of three years, coupled with high density management practices, the yield of cashew can be almost doubled.

Regulation of flowering

A comprehensive package for regulating flowering in cashew is evolved. It involves spray application of cultar at the rate of 1g/litre together with KNO_3 1% to mature lateral shoots of cashew before flushing during late October.

Vermi compost from cashew apple residue

The cashew apple residue from the processing unit has been successfully utilized for the production of vermicompost having nutrient composition of 1.69 % N, 0.44 %P, and 0.58 % K.

D. Crop Protection

1. A large number of insecticides have been evaluated for the control of tea mosquito bug (TMB). Some of the insecticide which has been recommended by the station for the effective and economic

control of TMB includes monocrotophos, *endosulfan, carbaryl, quinalphos and phosphamidon (40% SL).

2. A rational rotation of insecticides is recommended for the control of TMB to counteract the tendency of the pest to develop field resistance. The spray schedule includes 0.05% *endosulfan, 0.1% carbaryl, 0.05% quinalphos and 0.03% phosphamidon.
(* use of endosulphan on cashew stands temporarily withdrawn at present)

3. Formulated the following technology package to control the pest- disease complex of TMB and Anthracnose in cashew.

- Remove and destroy the affected plant parts to reduce the source of inoculums
- Prophylactic spray of 1% bordeaux mixture or 0.3% copper oxychloride during second week of May (before monsoon)
- First combined spray with monocrotophos 0.05% and copper oxychloride 0.2% during October-November (flushing stage)
- Second combined spray with quinalphos 0.05% and mancozeb 0.2% during December- January (flowering stage)
- Third spray during nut initiation stage (January- February) with carbaryl 0.1%.

4. Formulated an integrated package for the control of cashew stem and root borer. Removing the dead trees and trees in advanced stages of infestation at least once in 6 months can reduce

further infestation. Prophylactic treatment by swabbing the trunk region (up to 1m height from the ground level) and exposed roots, with a suspension of mud slurry + carbaryl 0.2% or coal tar and kerosene (1:2) or 5% neem oil twice a year during March- April and November – December along with soil application of sevidol 4 G @ 75 g/tree is found to check the incidence of cashew stem and root borer.

5. Recommended control measures for the management of pests and diseases of cashew nursery
6. Twenty insects have been recorded as pests of cashew at the station
7. Pest calendar has been prepared for the seasonal occurrence of insect pests of cashew

E. Processing technology

The station is in the forefront in the national and international level in developing technologies for the production of various value added products from cashew apple and employing these technologies for commercial production.

For intensifying research and transfer of technology activities in cashew apple processing, a cashew apple processing unit with FPO license was established at the station in 1997 and commercial production was started in 2000. It is the only unit in India, which is producing cashew apple products in a commercial scale. The first product of the unit was cashew apple juice. Subsequently, the activities of the unit have been expanded to make it economically more viable by diversifying the product range. At present, the unit undertakes commercial production of Cashew apple-Mango (*Cashewman*) Mixed Jam, Cashew Apple

Pickle, Cashew Apple Drink (Ready-To-Serve (RTS) form) and Cashew Apple Candy and sale is conducted through KAU Sales Counters and exhibitions organized by KAU.

Under a mega project funded by National Horticulture Mission entitled "Transfer, demonstration and refinement of technologies for cashew apple processing" implemented at the station during 2007-08, the following ten technologies has been developed for cashew apple processing:

- Clarification of cashew apple juice with sago
- De-tanning of whole ripe/ green cashew apples
- Off- season storage of cashew apple juice, pulp and green pieces
- Modified procedure for preparation of cashew apple syrup
- Procedure for preparation of cashew apple RTS beverage
- Procedure for preparation of cashew apple- pine apple squash
- Procedure for preparation of cashew apple- pineapple blended RTS
- Procedure for preparation of cashew apple - mango mixed fruit jam
- Procedure for preparation of cashew apple pickle
- Procedure for preparation of cashew apple candy

Under the project, several transfers of technology initiatives on cashew apple processing have also been implemented.

CASHEW RESEARCH STATION, ANAKKAYAM

The station has released the following five high yielding varieties of cashew.

1. **Anakkayam-1:** It is the first cashew variety released by the Kerala

Agricultural University. The high yielding seedling type BLA-139-1 was released as *Anakkayam-1* in 1982.

2. **Dharasree:** a middle season flowering hybrid which was released in 1996 has average yield of 15 kg per tree.
3. **Akshaya:** This hybrid with large nuts was released in 1998. The flowering occurs during the middle of the season. The average yield per tree is 11.8 kg. The export grade is high (W180)
4. **Anagha:** This variety, with an annual yield of 13.7 kg/tree/annum, was released in 1998. This is a mid season flowering variety
5. **Sree (Selection 990):** It is a clonal variant of the released variety Anakkayam1. Unlike Anakkayam 1, raw nuts of this clone are bold and bigger with high kernel content. The clone is quite early and harvest can be completed before April. The clone shows field resistance to tea mosquito attack Average yield is 18.5 kg per tree per year. Average weight of nuts is 10.4 g and that of kernel is 3.3 g.

REGIONAL AGRICULTURAL STATION, PILICODE

The station has identified 81 diverse cashew types, of which 43 types were planted. PLD-4 was found to be superior in yield. PLD -57 (TPB 1), a dwarf type, was used for hybridization with Anakkayam 1 and Madakkathara 1.

SPICES

Spices constitute an important group of agricultural commodity considered indispensable for flavouring foods and beverages, pharmaceutical, perfumery and cosmetic industries. India, the land of spices

continues to be the largest producer, consumer and exporter of spices in the world.

Indian spices are unique and valued world over for their high intrinsic qualities. Spices play a prominent role in the national economy. India commands a formidable position in the World Spice Trade with 48% share in volume and 44% in value. In 2009-10 the export of spices from India has been 502,750 tonnes valued Rs. 5560.50 crores (MLN US \$ 1173.75 million) registering an increase of 7% in volume and 5% in rupee value over the previous year.

India is a major producer of spices like black pepper, ginger, turmeric, cardamom, coriander, celery, cumin, fennel and fenugreek. Major share of the spices produced in the country comes from Kerala. The State occupies a prime position among other states with respect to production of black pepper, cardamom, ginger, nutmeg and cinnamon. Cochin ginger, Alleppey Finger Turmeric and Tellichery Bold Pepper are considered as premium spice items in the international market.

HISTORY OF RESEARCH

Research on spices in Kerala was initiated in late forties with the establishment of a few centres under the Department of Agriculture in the erstwhile state of Travancore-Cochin. Initially, research programmes were confined to development of improved cultural practices in major spices. Subsequently, spices research in the State was strengthened by the establishment of Pepper Research Scheme at Panniyur and Cardamom Research Scheme at Pampadumpara in 1949. Further, with the implementation All India Co-ordinated Spices and Cashew Improvement Project (AICSCIP) by ICAR in 1971 and with the

formation of Kerala Agricultural University in 1972, the research on spices has taken a new dimension. A statutory department of Plantation Crops and Spices also came into existence in the university in 1972 so as to impart teaching, research and extension activities in the field of Plantation Crops and Spices. By the concerted efforts of scientists, seventeen varieties in various spice crops could be released from Kerala Agricultural University. Panniyur 1 to 8 in black pepper, PV 1 and PV 2 in small cardamom, Kanthi, Sobha, Sona and Varna in turmeric, Athira and Karthika in ginger and Sugandhini in cinnamon are the spice varieties released so far.

MAJOR ACHIEVEMENTS

Black pepper

Black pepper, *Piper nigrum* L. is an important spice crop and foreign exchange earner. The species originated in the Western Ghats. India is the major producer of pepper in the world. As per 2006-07 statistics, the area under pepper in India was 236177 ha, production was 50000 t and productivity was 212 kg/ha. The export earning from pepper during the period was Rs. 51950 lakh.

- Germplasm collection of black pepper and related species are being maintained at two main centres, College of Horticulture, Vellanikkara and Pepper Research Station, Panniyur. Over 15 species of *Piper* and 250 accessions of *Piper nigrum* are maintained in the University. The species and varieties have been characterised in detail morphologically, cytologically, using isoenzymes and DNA markers.
- Crop improvement programme has resulted in the release of seven improved varieties of pepper Panniyur

1, Panniyur 2, Panniyur 3, Panniyur 4, Panniyur 5, Panniyur 6 and Panniyur 7. Performance of improved varieties is being evaluated in different pepper growing tracts of Kerala.

- Six cultivars of pepper are found low input responsive viz. Karimunda, Neelamundi, Vattamundi, Kotta, Vadakkanmunda and Karuvali. Variety Karimunda is most popular in southern districts of Kerala.
- Evaluation of 13 pepper varieties revealed that Panchami, Panniyur-4 & Panniyur 3 are suitable for high ranges of Kerala.
- Black pepper variety Karimunda is found to be the most popular one in southern districts of Kerala. The other important varieties are Panniyur 1, Neelamundi, Kaniyakkadan, Narayakodi and Perumkodi. Under high elevation, the maximum coverage was recorded by the variety Neelamundi (91.6%).
- Based on the morphological, physiological, biochemical and anatomical characters, varieties Poonjarmunda, Panniyur 5 and Padarpan are rated as water stress tolerant, Kalluvally, Uthirankotta and Kumbakodi are rated as moderately tolerant and Panniyur 1 as sensitive variety.
- Inter varietal crosses and open pollinated seedlings are being evaluated for resistance/tolerance to Phytophthora foot rot. Tolerant/resistant plants are field evaluated for horticultural attributes.
- A viable protocol for in vitro mass multiplication of black pepper has been developed. Protocol for callus mediated

organogenesis in pepper was also standardised. Somaclonal variation has been observed for disease reaction to Phytophthora foot rot. Resistant types are being evaluated in the field. Studies on agro bacterium mediated genetic transformation for Phytophthora foot rot tolerance is initiated.

- Among the pathogenesis related enzymes studied, α -1,3-glucanase and phenylamine ammonia lyase were found to have a positive role in the defence mechanism of black pepper in relation to Phytophthora foot rot disease.
- Long term fertilizer experiments have shown that 50 g N, 50 g P O and 150 g K O per vine per year is optimum for good growth and yield of pepper. Nutrient deficiency symptoms of major and minor elements have been studied in detail.
- The vegetative growth of bush pepper was superior with 16 l drip (October-May) and pot watering 10 l per day. But the yield and quality were superior in plants irrigated with 8 l drip and the least in 2 l drip. Best expression of growth and early flowering in bush pepper was under 50 per cent light
- Etiology and symptomatology of Phytophthora foot rot has been studied in detail and methods for rapid screening of seedlings against disease was developed. Difference in anatomical and biochemical characters were observed between *Piper* species immune to *Phytophthora* and susceptible species.
- Soil solarisation with 150 gauge polythene sheets for 45 days and treatment with *Trichoderma viride* was effective in controlling *Phytophthora* foot rot in nursery.

- Physiology of flushing and flowering in pepper has been studied in detail. Germplasm evaluation for response to water stress showed Panniyur 5 and Padarpan to be tolerant to water stress and Panniyur 1 susceptible. Anatomical and biochemical differences were observed in susceptible and tolerant types.
- Studies on nitrate reductase activity in black pepper showed seasonal variations in the character. Significant positive correlation between NRA and NO₃ content was observed.
- Two node cuttings from middle 1/3rd portion of runners were recommended for propagation in pepper. Satisfactory rooting was obtained with out growth regulator treatment.
- A viable protocol (over 70% success) for bush pepper production has been standardised.
- Pepper plants responded favourably to mulching with organic material during summer months.
- Three isolates of AMF fungi viz. Is-6, Pi-11, Pi-9, Glomous fasciculatum, Gigosporana garita were effective in stimulating growth and nutrient uptake of black pepper. Effective control/preventive measures for the major diseases of pepper have been developed. Effective control measures have been developed for other major pests and diseases.
- Significant suppression of mussel scale was observed in vine sprayed with Dimethoate (0.05%) closely followed by Monocrotophos (0.05%). Among the biorationals evaluated, Neem Gold was found effective in the suppression of scale population
- Combined application of *T. harzianum* and consortium of bacteria was found

synergistic than application of consortium of bacteria alone in suppressing the *Phytophthora* foot rot disease of black pepper.

Cardamom

Cardamom is indigenous to the evergreen forests of the Western Ghats of South India. In India, cardamom is cultivated in the southern States of Kerala, Karnataka and Tamil Nadu. Kerala accounts for 56.5 per cent of area and 76.1 per cent of production,

- Research on germplasm collection and evaluation started at Cardamom Research Station, Pampadumpara as early as 1956. The research was intensified with the launching of AICSCIP in 1971. Now the station maintains a germplasm collection of 152 types of cardamom.
- The flowering habits, fruit set and capsule development in three popular cardamom cultivars viz., Malabar, Mysore and Vazhukka were studied in detail. The investigations on growth and development revealed that the Vazhukka cultivar possessed more tillering ability than Malabar and Mysore. Fruit set was maximum in plots where four beehives were colonized per hectare.
- Histological studies conducted in the genotype PV-1 (Malabar) showed that differentiation of panicle primordia was more during November to March. Shoot primordium originates as a conical meristem whereas panicle primordium appears as an arc-like structure.
- Important breeding methods followed in cardamom are selection, hybridization and mutation breeding. Two improved varieties viz PV1 and

PV2 have been released for cultivation among farmers and a few are under evaluation.

- Thousands of seedlings were screened for resistance to katte disease. However, resistant genotypes could not be identified in the seedling progeny.
- In order to standardise the best time of collection of cardamom seed capsules, germination studies were conducted by collecting capsules from September to November. Seeds collected in September and November recorded the same germination percentage. However, September sowing is advantageous as it gives more vigorous seedlings due to longer period in nursery.
- Studies were also conducted to improve seed germination in cardamom by adopting various seed treatments and by using seeds collected from capsules of different maturity stages. Over ripe seeds exhibited higher germination percentage than fully ripe or just ripe seeds. Among the different seed treatments, treatment with gibberellic acid, scarification+hot water and cowdung slurry recorded higher germination percentage.
- Storing capsules in polythene lined gunny bags was found as the best method of storage. Seed rate of 10 g/m² and sowing of seeds at row spacing of 6 to 10 cm gave vigorous seedlings than at wider spacing of 12 cm and 14 cm.
- Field survival, plant growth and productivity in cardamom as influenced by number of suckers of secondary nursery seedling were studied. Survival percentage was higher in planting material having two suckers or more. But tillering ability was high for planting materials with four suckers and above.
- Techniques of micro propagation was standardised in cardamom using shoot bud explants. Tissue culture plants were stable cytologically. Their performance was on par or better than seedlings of similar size.
- Total P and K contents of soils of cardamom plantations were low when compared to the adjacent forest which indicates inefficient bio-cycling associated with the cardamom plantation and loss of bases from the system by leaching and soil erosion.
- The gross nutrient uptake revealed that for the production of one kilogram of dry cardamom capsules, the Vazhukka cultivar depleted less amounts of nutrients (779.50 g) than the Mysore cultivar (1617.88 g).
- Manurial experiment indicated that application of fertilizers @ 100:100:175 kg NPK in two to three splits during two monsoon periods increased the plant height, number of panicles per clump and yield per plant.
- The radiotracer studies based on the fixation of ¹⁴CO showed that the photosynthetic efficiency was more under subdued light intensities of 500 to 1500 lux.
- For effective weed control upto 90 days, application of paraquat 0.4 kg/ha at bimonthly interval or glyphosate 0.8 kg/ha are as effective as two hand weedings. Majority of cardamom plants came to flowering in the second year of hand weeding. In the unweeded plots none of the plants flowered, indicating the adverse effect of weed competition on growth of cardamom plants.

Analysis of economics of weed control operations revealed that more than Rs. 6000 per hectare could be saved if weed control by chemical methods are adopted.

- Seven rounds of insecticide application per year are being recommended for the management of cardamom thrips (*Sciothrips cardamomi*) and stem borer (*Conogethes punctiferalis*). Bee safe insecticides such as Phosolone (0.07%) and Quinalphos (0.05%) are advised during peak flowering period (June–September) and skipping of insecticide application coinciding monsoon is also recommended.
- Thiodan (0.1% spray) was effective against cardamom shoot and capsule borer.
- Use of yellow sticky traps coated with castor oil or poly vinyl butanol and application of neem oil @ 0.5 per cent on leaves suppressed cardamom white fly population. New record of an entomopathogenic fungus *Verticillium* sp. infecting on cardamom white fly was reported from Pampadumpara Panchayat, Idukki district for the first time.
- The effect of eradication of Katte affected plants in reducing the incidence of the disease was studied. The percentage of infected plants was reduced as a result of continuous eradication of affected plants.
- Spraying of Nimbecidine 0.2% and Fish Oil Insecticidal Soap (FOIS 2.5%) resulted in reduced cardamom yield and increased itch symptom on cardamom capsules.
- Evaluation of various insecticides revealed that plots drenched with

Chlorpyrifos @ 0.03% was very effective in the management of root mealy bug.

- Bordeaux mixture (1%) as spray or drench or both was the most effective method to control capsule rot disease of cardamom.
- Gas chromatographic estimation of cardamom oils at major seed maturity stages revealed that the flavour components 1, 8-cineole, terpene -4 ol, ? terpeniol, linalyl acetate and geraniol were comparatively more at the black and ripe seed stages than at other stages. The Mysore genotype, PR-107 was found superior in quality because of the high content of esters, alpha terpenyl acetate, geranyl acetate and linalyl acetate.

Ginger

India is the largest producer (721539 tonnes from 129014 ha) and exporter of ginger in the world. Cochin and Calicut ginger traded from Kerala is reputed in the international market.

- Twenty five ginger types were studied in detail to fix up morphological characters for identifying different types, to screen ginger types with high yield, high quality and resistance/tolerance to pests and diseases. The type Maran was relatively tolerant to soft rot whereas Rio-de-Janeiro was the most susceptible type. For higher yield of dry ginger, Nadia, Bajpai and Maran were recommended for cultivation in plains of Kerala.
- Cytogenetic studies in nine ginger varieties revealed a chromosome number of $2n=22$ in all the varieties. The mitotic index was maximum at 5-6 am. During meiotic studies it was seen that the genome of

ginger is highly unstable. Abnormalities like bridges and laggards were also present which will lead to the formation of micronuclei. The high amount of meiotic irregularities may be leading to high percentage of pollen sterility.

- Peroxidase zymogram of forty seven ginger types showed no difference among cultivars.
- The histological examination of ovules of flowers on the day of anthesis revealed the presence of viable egg cell. Ginger flowers carry enough pollen grains in the single bilobed anther. But a large number of pollen grains were sterile. Pollen fertility has been found variable depending on the cultivar and ranged from 14.15% to 32.58%. The flowers abscise within 12 h and so the possibility of pollen tube reaching the ovule is remote. The study also suggested the involvement of incompatibility for failure of seed set. Attempts to develop a medium which will support pollen germination and tube growth resulted in the identification of ME3 medium with 12 % PEG as osmoticum at 4 to 8.0 pH.
- Two autotetraploids were derived from the variety Himachal Pradesh treated with 0.25 per cent colchicine by injection method and Rio-de-Janeiro treated with 0.10 per cent colchicine by hole method. The autotetraploids recorded higher rhizome yield than the corresponding diploids consistently during the second year also.
- The protocol for rapid multiplication of ginger has been standardized. Sprouting buds were identified as the best source of explants for initiating *in vitro* culture of ginger. Of the different basal media

tried, MS medium was found ideal. BA 2.5 mg/l was found most effective for getting maximum number of multiple shoots.

- Protocol for callus induction and indirect organogenesis were perfected. Pseudostem base and sheathy leaf base were identified as the best explant for induction of calli. The regenerates were normal and healthy. Good field establishment was observed for the regenerants. Yield during the first year was comparatively low. Wider variation was observed for yield (10 to 85 g plant⁻¹) and soft rot infection.
- Investigations carried out to standardise *in vitro* pollination and fertilization technique for seed set in ginger showed that the flower buds collected on the day of anthesis and one day after anthesis were suitable for *in vitro* pollination. Ginger ovary developed under *in vitro* condition in ½ MS, SH or Nitsch media when supplemented with growth regulators and coconut water. Among the successful methods of *in vitro* pollination tried, placental pollination is the best, as it registered maximum number of seeds per culture with minimum effort. The mean seed set per culture in this method in favourable media combinations was 61.56 per cent. The mean number of well developed seeds per culture was 6.87 at 80 days after pollination. 6.0 to 8.0 per cent sucrose is the optimum for ovule development. The auxins as well as cytokinins alone induced ovule development but combination proved to be better. The combination of NAA 0.5 to 1 mg l⁻¹ with varying concentration of BAP from 2 to 10 mg l⁻¹ had shown positive effect. The solid as well as liquid

form of favourable media combinations supported ovule development after *in vitro* pollination. The ovary and ovules developed at 26 °C as well as 28 °C but the lower temperature was better from the visual assessment of ovary and ovule appearance. With respect to light intensities, they developed in dark, diffused light and light intensities of 500 and 1000 lux.

- The testing of seed viability with tetrazolium salt showed that seeds of 40 and 80 DAP are viable. A few seeds, developed through *in vitro* fertilization, germinated when 80 days old. Seeds were incubated initially in the medium of ½ MS with 2,4-D 8 mg l⁻¹ for two months and then in hormone combination of BAP 9 mg l⁻¹ and 2,4-D 0.1 mg l⁻¹. The seeds developed through *in vitro* fertilization showed erratic germination.
- As rainfed crop, first week of April was found to be the best time of planting for getting maximum yield under Kerala conditions registering 200 per cent increase in yield compared to planting in first week of June. For irrigated ginger, the best time for planting was found to be middle of February.
- The optimum size of seed bit was found as 15 g with one or two viable buds and seed rate as 1500 kg ha⁻¹.
- The diagnostic leaves for ginger have been identified as 5th to 12th leaves from the tip and 90 to 120 days after planting as the best time for the detection and assessment of nutrient status of the crop.
- Applications of leaf mulch immediately after planting and later six weeks after planting using a total of 20 tonnes ha⁻¹ of green leaves resulted in 200 per cent increase in yield over the non-mulched crop and this was found sufficient under Wynad conditions. In the plains, mulching the crop with 30 t ha⁻¹ of green leaves has been recommended. Among the different mulch materials, leaves of panal, *Glyricidia maculata* and jack were found superior.
- The dry ginger recovery was highest at 270 days after planting. The percentage of oleoresin, oil and fibre contents were maximum at 165 days after planting.
- Seed treatment with Captan 0.2 %, Captafol 0.2 per cent and Dithane M 45 0.3 per cent gave higher germination and low incidence of soft rot. Trials to find out suitable management to minimize loss due to soft rot disease under field condition revealed that application of Dithane M 45 @ 0.3 per cent twice after planting and 60 days after planting reduced the post emergence rot and increased the yield of ginger. Ridomil and mancozeb @ 0.25 per cent and 0.4 per cent respectively were more effective in controlling post emergence rot and gave high green yield of rhizomes.
- The plot in which the antagonists *Trichoderma viride*, *Aspergillus niger* and *A. flavus* were applied in combination at 60 and 120 DAP, recorded minimum rhizome rot incidence compared to other treatments. Among the different fungicides screened *in vitro*, Fytolan and Bordeaux mixture completely inhibited the growth of the pathogen.
- Application of AMF inoculum on ginger rhizome after starch coating was very effective for rapid and early colonization of AMF. Significant effect of solarization with 150 gauge polythene was observed

in controlling the pre and post-emergence rotting in ginger. Studies on the control of bacterial wilt of ginger showed that the incidence of bacterial wilt was reduced by drenching soil and foliar spraying with 1 percent Bordeaux mixture. It also recorded maximum rhizome yield. Need based spraying of Dimethoate or Quinalphos 0.05 per cent emulsion controlled shoot borer effectively.

- Soaking the rhizomes in solutions with Quinalphos at 0.025 per cent for 30 minutes could effectively control the scales. Fenthion 0.025 per cent was also found effective in controlling the pest. Integrated control of root knot nematode in ginger has been tried. Treatment of soil with neem cake @ 1.0 t ha⁻¹ at planting plus application of Carbofuran @ 1.0 kg ai ha⁻¹ at 45 days after planting significantly reduced nematode population.

Turmeric

Turmeric is the third important spice crop of India, next to chillies and black pepper. India is the largest producer and exporter of turmeric. As per the 2006-07 statistics the crop occupies an area of 1.84 lakh ha with production of 8.56 lakh tonnes and productivity of 4657kg ha⁻¹.

- Germplasm collection, maintenance and evaluation were done at RARS, Ambalavayal and College of Horticulture, Vellanikkara. Nineteen turmeric types were subjected to detailed morphological and quality evaluation. The study revealed that morphological characters are not reliable to classify the turmeric types, although some of them can be distinguished by rhizome characters.

The morphological characters such as height of plant, length and breadth of leaf, leaf area index, petiole length, number of leaves per tiller, number of roots per plant, length of root, length of primary fingers and girth of mother rhizome were positively correlated with yield. The type VK5 (Mannuthy Local) showed minimum incidence of pest and diseases. The types VK47 and VK82, VK 146 and VK 96 which had shown consistently superior performance in multi location testing and farm trials were released as Kanthi, Sobha, Sona and Varna respectively.

- The optimum time for collection of roots for mitotic studies in turmeric was found to be between 6.30 am and 7.00 am. The somatic chromosome number of short duration cultivars VK70 and Suvarna was found as $2n = 84$ and that of medium duration cultivar Kanthi as 63.
- Isoenzyme variation was studied for esterase, peroxidase and GOT banding pattern of 39 genotypes of *C. longa* and 18 species of *Curcuma*. Classification of varieties and species were done based on isozyme variation.
- Floral biology of turmeric has been studied in detail. Crop improvement through evaluation of open pollinated seedlings, hybridization and mutation breeding is in progress. Among the various methods of pollination tried, ovule/seed development was observed in intra ovarian, placental and modified placental pollination techniques.
- Early planting gives more time for vegetative growth resulting in more yields. Middle of May planting was considered as ideal. Whole mother rhizomes as planting material

contributed for maximum yield. Split mother rhizome was superior to finger and gave more vigorous sprouts. For planting one hectare, 2500 kg rhizome was needed. 25 x 25 cm spacing on raised beds was optimum for realizing maximum yield per unit area. Planting in small pits of 10 cm depth was found ideal.

- For analyzing the nutritional status of the crop, third leaf from top has been identified as the diagnostic leaf. Kerala Agricultural University recommends 30 to 40 tonnes of farm yard manure ha⁻¹ supplemented with N, P O₂ and K O₂ at 30:30:60 kg ha⁻¹.
- Yield of raw turmeric, driage, curcumin content and per hectare yield of curcumin and oleoresin were found maximum on 270th day after planting. The uncured turmeric samples recorded higher content of oleoresin and curcumin than that of cured samples.

Vanilla

In India vanilla is grown mainly in Karnataka, Kerala and Tamil Nadu. Various crop management practices like method of planting, training and pruning, manuring and post harvest curing of beans were standardised at RARS Ambalavayal and these practices are being adopted by the farmers.

- Vanilla is commercially propagated through stem cuttings and the natural variability available is low. To induce genetic variability through *in vitro* techniques, *in vitro* seed culture, *in vitro* mutagenesis and inter specific hybridization were attempted. *In vitro* raised seedlings were field planted and the variability is assessed through morphological and biochemical

analyses. Irradiation doses above 50 Gy and higher doses of chemical mutagen EMS were found lethal for vanilla. Lower doses of α irradiation and EMS were found to enhance *in vitro* response

- More than 50 per cent pod set was observed in the interspecific hybridisation between *V. planifolia* and *V. valsalensis*. Seeds from these crosses were germinated *in vitro* and sub cultured for better proliferation.
- For seed germination, ½ MS medium supplemented with BA and NAA was found best. Germinated seedlings were separated and multiplied in ½ MS medium supplemented with BA and IAA each at 1 mg l⁻¹. By reducing the level of BAP to 0.2 mg l⁻¹, better elongation of the shoots was achieved. The ideal rooting medium identified was ½ MS supplemented with IAA 0.5 mg l⁻¹ and BAP 0.2 mg l⁻¹.
- Among the different fertilizers and manures tried in vanilla, neem cake was found the best. It was also noticed that there may be a chance of fungal infection of the crop by continuous manuring of the crop.
- Aerial roots and younger leaves of vanilla are the major nutrient absorbing media. Aerial roots can absorb about 80-90% and younger leaves about 40-50% of applied quantity. This shows that foliar nutrition can be very well practiced in vanilla.
- Technology was developed for powdering of cured vanilla beans without loss of volatile constituents which was submitted for patenting through patent cell of KSCSTE.

Nutmeg

In India nutmeg is cultivated throughout Kerala, parts of Tamil Nadu,

Karnataka and Assam with more than 90 per cent of the area distributed in Kerala where the crop is mainly grown in homesteads in coconut and arecanut gardens.

- Morphological biochemical and molecular markers did not give clear indication for dioecy in nutmeg. Nutmeg is found recalcitrant to in vitro propagation.
- Inarching gave the highest percentage of success in vegetative propagation (about 95 per cent) during the month of June. Among the different methods tried for top working in nutmeg, forkert method was most successful. Forkert budding using bud selected from brown bud wood with fallen leaves and buds inserted by leaving space on all four sides gave maximum success.
- Detailed studies have been conducted on deficiency symptoms of nutrient elements in nutmeg.
- The processing techniques for products like nutmeg leather, wine and pickle were standardised. The storage behaviour of the products studied for a period of six months revealed that the products had good shelf life

Clove

In India clove is mainly grown in Tamil Nadu, Kerala and Andaman and Nicobar Islands.

- Significant positive correlation was obtained between the maximum temperature during the sixth to tenth fortnights before differentiation and the percentage of flower buds differentiated. Sunshine hours during ninth to twelfth fortnight prior to differentiation showed a positive correlation with the percentage of flower bud differentiation. Flower bud

differentiation was maximum during the month of August.

- Multiple shoots were induced from nodal explants cultured in WPM supplemented with BAP (3.0 mg l^{-1}) and kinetin (1.0 mg l^{-1}).
- Seeds collected and sown during the month of June recorded the highest germination. However, the May seeds were superior with respect to rate of growth and vigour of seedlings.
- Nutrient deficiency symptoms were studied and described in detail. The requirement of different nutrients by the crop was in the order of $\text{K} > \text{N} > \text{Ca} > \text{Mg} > \text{S} > \text{Mn} > \text{P} > \text{Fe} > \text{Cu} > \text{B} > \text{Zn}$.
- The volatile oil in clove, was more at the immature stages and it progressively decreased at the peak harvesting stages. Eugenol, the chief component in clove oil was maximum at the flowering stage.

Cinnamon

In India cinnamon is cultivated in Karnataka, Kerala and Tamil Nadu.

- In the Aromatic and Medicinal Plants Research Station Odakkali, 234 accessions of cinnamon are maintained. The evaluation of these accessions for growth, yield and quality for the period from 1992-94 paved way for the release of a variety 'Sugandhini' which is considered as a good option for perfumery due to high leaf oil content.
- Air layering by ring method utilizing sphagnum moss as the rooting medium with IBA 250 ppm treatment was found suitable for vegetative propagation in cinnamon. Hardwood cuttings were better than semi hardwood cuttings with respect to sprouting and rooting. However, final establishment of the

sprouted cuttings was very low (5-10%). The *in vitro* techniques for multiplication of cinnamon were standardised. Multiplication rate up to 20 had been reported. However, the response of multiple shoots in subsequent sub culturing was poor.

CHALLENGES AND FUTURE PROSPECTS

India is known from prehistoric times as the land of spices. Till the seventies, India had the lead role in the international trade of spices. Entry of Vietnam in pepper, Guatemala in cardamom and China in ginger is creating stiff competition to Indian spices. India possesses many advantages over other spices producing countries –like vast area and suitable agroclimate. However, our productivity in many spices is very low compared to other spice producing countries. One of the major reasons for low productivity is poor adoption of improved technology by farmers and practice of traditional methods of cultivation including use of high yielding varieties. Development of cost effective agricultural practices and proper dissemination of technologies to farmers is the only solution to overcome this problem. In the present context of shortage of cheap and skilled labour especially in the state like Kerala possibilities of mechanization of cultivation should be worked out. In agricultural commodities, especially export oriented crops, developing

integrated pest and disease management practices for increasing productivity and development and popularization of good agricultural practices for quality spices production are important. The productivity and production could be improved by using improved high yielding varieties, through use of quality planting material and adopting scientific methods of cultivation. Major field problems like viral disease, EGW, Phytophthora foot rot, root mealy bug, drought etc. in pepper, soft rot, bacterial wilt, shoot borer, rhizome scale and maggot in ginger, rhizome rot in turmeric, capsule and clump rot, fusarium stem rot, Katte, thrips, stem borer, root grub, nematode etc in cardamom should be addressed with out over use of chemicals. Evolving cost effective production technologies in spices is required for sustainable production. Over and above these, the technologies developed should reach the farmers in an effective way so that production and productivity are improved.

SUMMARY

The challenges faced by the farmers of plantation crop sector are many. The priorities have been fixed to meet those challengers through research and development. The current change in climate also poses significant effect of the performance of plantation crops. Thrust will be given for studies to cover the impact of climate change in the traditional crop growing tracts of Kerala. ■