भाकृअनुप
ICAR

वार्षिक प्रतिवेदन
Annual Report
2017-18

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भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान, कोषिक्कोड
ICAR-Indian Institute of Spices Research
(Two times winner of Sardar Patel Outstanding ICAR Institution Award)
Kozhikode

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कोषिक्कोड, केरल, भारत Kozhikode - 673012, Kerala, India

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PREFACE

The Year 2017-18 was a very successful year for ICAR-Indian Institute of Spices Research. The Institute was recognised nationally in all fields. Two startups from ICAR-IISR viz., Kodagu Agritech, Karnataka and Natura Nursery, Kozhikode were selected for presenting their technologies to Hon'ble President of India during the Festival of Innovation and Entrepreneurship (FINE), hosted at the Rashtrapathi Bhavan, New Delhi during 19-21 March 2018. Two of our scientists bagged national awards. Dr E. Jayashree, Principal Scientist received National Academy of Sciences India - ICAR award for Innovation and Research in Farm Machinery. Dr B. Sasikumar, Former Principal Scientist and Head won the National Award for Outstanding Efforts in Science & Technology Communication through Print Media including Books and Magazines (Category-B) instituted by DST, Govt. of India. He also bagged Karshaka Bharathi Award for farm journalism instituted by Govt. of Kerala. Dr R. Dinesh, Principal Scientist was awarded the Fellow of National Academy of Agricultural Sciences and Dr D. Prasath, Principal Scientist was awarded Endeavour Fellowship instituted by Govt. of Australia and he also won Dr D.P. Ghosh Young Scientist award instituted by Horticultural Society of India. Dr. S. Shanmugavel of KVK bagged Ksheera Bandhu award. Ms. N. Prasannakumari, Senior Technical Officer was awarded "Rajbhasha Sevi Samman" by Bhasha Samanvaya Vedi on 21 September 2017. Many of our scientists won best paper awards in various seminars. Our ITM-BPD unit signed thirteen license agreements for technology commercialization/services during 2017-18. The institute technologies on biocapsules and micronutrient mixtures are greatly appreciated by the farmers for their useful effects.

The Parliamentary Standing Committee on Agriculture headed by Shri. Hukamdeo Narayan Yadav visited IISR Regional Station, Appangala, Madikeri on 28 April 2017. The Committee appreciated and congratulated the institute for its excellent research work in the field of spices and also suggested a few points for further strengthening of spices research in the country based on national needs. Shri Chhabilendra Roul, Additional Secretary (DARE) & Secretary (ICAR) also visited Appangala on 4 July 2017.

In the research front, management of rhizome rot of ginger using Bacillus licheniformis and calcium chloride was demonstrated in farmers field in Wayanad. Multifarious plant growth promoting traits of Lecanicillium psalliote was reported for the first time. Complete genome sequencing of Banana bract mosaic virus was carried out. Pythium deliense, a new pathogen causing yellowing and wilt in black pepper and a new report on leaf blight of ginger caused by Bipolaris rostrata were identified and new databases were developed. Germplasm explorations were conducted to North East India including Karbi Anglong and Dima Hasao districts of Assam and Janitia hills of Meghalaya to look for enhanced genetic diversity of spices. Site specific soil fertility management in black pepper and nutmeg enhanced the yields. Promising soil Zn solubilizing bacteria (ZnSB2) identified may help in alleviating Zn deficiency. Hypoglycemic potential of cinnamon and turmeric extracts provide new insights on controlling diabetes. Two spices varieties were released by Central Varietal Release Committee. Institute got external funding for two major projects viz. for Development of

Pesticide Residue Lab from State Horticulture Mission and Establishing a value chain incubation facility for processing of spices from Govt. of Kerala. During the AICRPS workshop which was held at Guntur, five spices varieties were recommended for release. Institute also organized a Symposium on Spices and Aromatic Crops at Nagaland University, Medziphema, Nagaland which suggested a well guided road map for spices production in North East. The institute and the SAARC Agriculture Centre, Dhaka jointly organised Regional Expert Consultation Meeting on Technology Sharing of Spice Crops in SAARC countries during 11-13 September 2017 at ICAR-IISR, Kozhikode in which representatives from SAARC countries attended the meeting. KVK conducted 122 training programmes in various disciplines during the year, benefitting 4761 participants out of which 18 were on value addition alone. KVK in collaboration with the institute organized Sankalp Se Siddi Programme which was inaugurated by Shri M K Raghavan, Hon'ble MP Kozhikode. KVK celebrated silver jubilee on 12 February 2018 to observe the completion of 25 years of its establishment. Adv. Shri V S Sunil Kumar, Honourable Minister for Agriculture Development and Farmers Welfare, Government of Kerala, inaugurated the Turmeric fest held at ICAR-IISR during 19-20 January 2018. On tribal development and welfare, the institute organised three training programmes in the tribal regions of Chintapalle, Paderu and Arku of Vishakapatnam on "Scientific cultivation of black pepper and turmeric" in collaboration with Spices Board, Guntur and AICRPS centre, HRS Chintapalle which were well attended by the tribal farmers of the region. The institute is developing seed villages in Andhra Pradesh and Telengana for the production of certified seeds in turmeric. Institute took up swachhta programmes with great commitment. Institute distributed soil health cards to farmers based on soil test results. Quality planting material of spices were distributed to farmers from different regions of the country.

I thank the spice fraternity consisting of all the scientific, administrative and non-scientific staff of the institute, farmers, researchers and all the stake holders for their continued support for the cause of spices. Still we have to go a long way in achieving the supremacy we once had in spices but I am sure, we can bring back the past glory with our united efforts and hard work.

I place on records the encouragement and guidance given by Dr T. Mohapatra, Secretary, DARE and Director General, ICAR. I sincerely acknowledge the strong support and guidance received from Dr A.K. Singh, Deputy Director General (Horticulture Science) and Dr T. Janakiram, Assistant Director General (Horticulture Science). I thank the ICAR for the financial and administrative support for carrying out various programmes. Finally, I thank the editors for bringing out this publication in time.

K. Nirmal Babu

Kozhikode
15 June 2018

CONTENTS

EXECUTIVE SUMMARY

BLACK PEPPER

Genetic resources

Germplasm explorations were conducted to North East India including Karbi Anglong and Dima Hasao districts of Assam and Janitia Hills of Meghalaya. Forty four accessions were collected from the forests of North Eastern Region. Among the *Piper* spp. collected *Piper beteloides* was found to be the widely distributed. About 3466 accessions are maintained in the nursery, while the field gene bank at Peruvannamuzhi holds 200 accessions. The alternate field gene bank at CHES, Chettalli holds 735 accessions. Besides, a field gene bank comprising of 223 accessions is maintained at the Chelavoor campus.

Crop management

Spiking intensity and fruit setting as influenced by rainfall

Spiking intensity and berry set percentage were recorded in 19 plantations in different locations with varying rainfall. Spike intensity ranged from 15 to 71.11 per 0.5 m^2 canopy area with mean of 31.55 per 0.5m^2. Number of developed berries ranged from 12.27 to 93.1 with a mean of 54.53 per spike, while undeveloped berries ranged from 10 to 50.87 with mean of 25.38 per spike. Berry set percentage ranged from 26.14 to 89.1 with a mean of 63.83. Low berry set percent was recorded in low rainfall areas and less managed plantations.

Mitigation of climate change effects

Anti-transpirants like spray lime (1.5%), spray lime (1.5%) + muriate of potash (0.5%), kaolin (2%), kaolin (2%) + muriate of potash (0.5%); Miracle (3 ml/litre) were sprayed to yielding vines during January 2018 for second consecutive year to mitigate drought. Data revealed that yield was relatively higher in sprayed vines compared to control.

Differential gene expression under drought

The Illumina data of leaf transcriptomes from the drought tolerant accession 4226 exposed to drought stress was analyzed to identify differentially expressed genes under stress. Digital gene expression analysis of the data showed 2862 transcripts up-regulated and 2052 transcripts down-regulated under water deficit stress.

Scheduling fertilizer dose for fertigation

Supplemental application of NPK and micronutrients as foliar sprays over and above fertigation increased the leaf concentration of K, P, Zn and B. Soil supplementation of fertilizers and foliar spray of NPK and micronutrients recorded higher yield (30.15 kg fresh/standard) followed by fertigation + soil supplementation and foliar micronutrients alone (26.1 kg fresh) over fertigation alone. Additional investment of Rs. 10 to 15 per standard yielded an additional profit of Rs. 360 - 900 per standard, over and above fertigation.

Site-specific soil fertility management

The adoption of site-specific soil fertility management helped in increasing the yield of black pepper by 76 - 97% over control (farmers practice). Increase in yield (15-30%) was observed in

demonstration plots too. Quality of the produce was also improved due to site-specific fertility management.

Delineation of efficient black pepper producing zones in India

Based on the relative spread and yield index, out of 97 black pepper growing districts in India, 84 were delineated as efficient producing zones with 26 districts in Assam, 2 districts in Goa, 19 districts in Karnataka, 9 districts in Kerala, 10 districts in Meghalaya, 7 districts in Nagaland and 11 districts in Tamil Nadu.

Plant health management

Field evaluation of strobilurin fungicides against foot rot and slow decline diseases

The promising strobilurin fungicides, kresoxim methyl and RIL significantly reduced yellowing of black pepper vines. No incidence of *Phytophthora* was noticed in any of the treatments. Metalaxyl-mancozeb + carbsosulfan resulted in significant reduction in soil nematode population.

Evaluation of novel fungicide molecules against *Phytophthora* under pot culture conditions

In an *in planta* assay, six new fungicide molecules (Curzate 0.2%, Melody duo 0.4%, Antracol 0.2%, chlorothalonil 0.2%, Equation Pro 0.1%), that showed 100% *in vitro* inhibition against *P. capsici*, were compared with the recommended fungicide metalaxyl-mancozeb for controlling *Phytophthora capsici* and the lowest infection was noticed with metalaxyl- mancozeb treatment.

Molecular characterization of *Colletotrichum* spp. causing anthracnose disease

DNA from two leaf blight inciting isolates of *Colletotrichum* was isolated, internal transcribed spacer (ITS) and β tubulin (TUB) gene regions were amplified and sequenced. Sequence comparison with other *Colletotrichum* species indicated that the fungus is closely related to *Colletotrichum fructicola* and *C. gloeosporioides*.

Pythium deliense, a new pathogen causing yellowing and wilt

Pythium species was frequently observed in soil samples drawn from the rhizosphere of yellowing and wilt affected vines in several parts of Kerala. Morphological and molecular characterization revealed its identity as *Pythium deliense*. *P. deliense* (MP1 & MP2) grows at a pH range of 4.5-10.0, temperature range of 15-40°C with optimum temperature of 28-32°C.

Tripartite interaction proteomics

The label-free proteomics on tripartite interaction revealed that *Trichoderma* induces systemic resistance pattern in black pepper against *Phytophthora*. The enrichment of strong ROS related activity suggests that the ROS mediated signaling as major component in *Trichoderma* induced ISR (T-ISR) in black pepper and also the involvement of ET synthesis in the ISR development.

CARDAMOM

Genetic resources

A total of 599 cardamom accessions are presently being maintained at National

Active Germplasm Site (NAGS) consisting 430 accessions which includes 7 related genera from Appangala, 72 accessions from Pampadumpara, 41 accessions from Mudigere and 56 from Sakaleshpur. The NAGS was enriched with 29 accessions from Cardamom Research Station, Pampadumpara. One Malabar type of cardamom was collected from BR hills of Karnataka.

Breeding

Twenty three inter-varietal F_1 hybrids (PET III) were evaluated for yield and their reaction to pest and diseases. Plant number 2 (Mudigere 1 x IISR Vijetha) recorded highest yield followed by Plant number 14 (ICRI 4 x IISR Vijetha). Three lines *viz.*, GG x IISR Vijetha, Mudigere 1 x IISR Vijetha and Mudigere 2 x IISR Avinash were found to be highly susceptible to *Katte*.

Crop management

Physiology of cardamom as affected by shade levels

The highest net photosynthetic rates and stomatal conductance, more number of opened stomata were observed under 75% shade. Highest total phenol and epicuticular wax contents were observed in plants grown in open condition. Chlorophyll *a* and *b* contents increased with increased shade levels. Plant height, chlorophyll content and photosynthetic parameters may have a role in shade adaptation in cardamom.

Organic farming v/s integrated and conventional management

Integrated management recorded significantly highest fresh capsule yield (930 g plant^{-1}) followed by fully organic management (660 g plant^{-1}) and lowest yield was recorded in conventional chemical management. In pest management trial, higher capsule yield was recorded in alternate application of spinosad and *Lecanicillium* and spinosad with *Trichoderma* and *Pochonia* than control with <4% incidence of thrips damage on capsules.

Plant health management

Evaluation of IPM strategies

Evaluation of IPM strategies against cardamom thrips continued at Wayanad, Kerala for the second year in a partnership mode with M/s A. V. Thomas and Company, Meppadi. The results of the trial showed that soil application of *Lecanicillium psalliotae* was very effective in controlling thrips and the level of control was on par with chemical treatment (Quinalphos). Two sprays of spinosad (0.0135%) and soil application of *L. psalliotae* twice alternatively during March, April, May and August were also found effective.

Plant growth promoting traits of *Lecanicillium psalliotae*

Lecanicillium psalliotae, an entomopathogenic fungus on cardamom thrips exhibited both direct and indirect plant growth promoting characters. The fungus was also antagonistic to *Phytophthora capsici* and *P. meadii*, the major fungal pathogens of black pepper and cardamom, respectively. This is the first report on the multifarious plant growth promoting traits of this fungus.

Complete genome sequencing of *Banana bract mosaic virus*

The complete genome of *Banana bract mosaic virus* (BBrMV), a *Potyvirus* belonging to the family Potyviridae causing chlorotic streak disease of cardamom (*Elettaria cardamomum*) in India was determined for the first time from a naturally infected cardamom var. Njallani Green Gold. The complete genome has 9708 nucleotides excluding poly (A) tail and has the genome organization similar to that of BBrMV isolates infecting banana and flowering ginger (*Alpinia purpurata*).

GINGER

Genetic resources

Six hundred and sixty eight ginger accessions are being maintained in the field gene bank. The germplasm conservatory was enriched with 20 accessions and 6 *Zingiber* sp. collected from Meghalaya and Assam. Among the eight accessions evaluated during 2017-18, accession 278 was found to be promising for high yield and low fibre content.

Breeding

Three potential mutants identified against *Pythium* sp. (V 0.5/2, R 0.8/1 and R 1.25/4) and three potential mutants against *Ralstonia solanacearum* (HP 0.5/2, HP 0.5/15 and M 0.5/1) were multiplied for further evaluation.

Induction of polyploidy

The rhizome buds of IISR Rejatha (0.1/48/3 and 0.1/48/5) treated with 0.1% colchicine for 48 h confirmed tetraploidy (2n=44) in two of them. These two promising tetraploids are being multiplied and characterized.

Crop management

Fertigation

Fertigation studies revealed that, 75% of recommended dose of fertilizers (RDF) supplied through fertigation produced significantly higher rhizome yield compared to 100% and 50% RDF supplied through fertigation or 100% RDF applied as solid fertilizers at monthly intervals. But partitioning to rhizomes was significantly reduced under fertigation treatments and these rhizomes had lower starch and fibre content compared to rhizomes obtained from the field (soil) grown ginger supplied with solid fertilizers at recommended dose.

Plant health management

Viral diseases

Genotypic variation was observed for the incidence of the chlorotic streak disease in ginger. Among the genotypes scored, 182, 72 and 58 accessions showed mild, moderate and severe symptoms respectively while 177 accessions did not show any symptoms. The leaf dip electron microscopy of plants infected with chlorotic streak disease showed presence of isometric and flexuous rod shaped particles.

Isolation of pathogens associated foliar diseases

Different fungi were isolated from infected samples of ginger and turmeric collected from various locations. The fungi included *Bipolaris rostrata*, *Fusarium oxysporum*, *Fusarium* spp., *Colletotrichum gloeosporioides*, *C. capsici* and unidentified cultures.

Leaf blight caused by *Bipolaris rostrata*, a new report

Based on morphological characterization the fungal isolate causing leaf blight disease prevalent in Mysuru and Chamarajanagar districts of Karnataka was identified as *Bipolaris rostrata* (Drechs.) Shoemaker [synonym-*Exerohilum rostratum*]. Phylogenetic analysis based on ITS and β-tubulin regions grouped the ginger isolate GF5 with *B. rostrata/Setosphaeria rostrata/ Exserohilum rostratum* isolates from NCBI with 100% bootstrap support.

Pathogenicity of leaf blight pathogens

Pathogenicity trials with *Bipolaris rostrata* on varieties IISR Rejatha and Rio-de-Janeiro produced reddish brown oval discrete spots with yellow halo on the margin and distal end of the lamina which later coalesced leading to blighting of the entire leaf. On the other hand *Colletotrichum gloeosporioides* and *C. capsici* produced elliptic or oblong whitish spots surrounded with dark brown margin and yellow halo.

Host physiology as affected by foliar pathogens

Ginger plants infected with leaf spot (*Phyllosticta* sp.) and leaf blight (*Bipolaris rostrata*) diseases showed decreased activity of catalase and increased activity of peroxidase and polyphenol oxidase enzymes. The infection also reduced photosynthetic rate, stomatal conductance, total carbohydrates and total phenols.

Screening of fungicides against foliar pathogens

Ten fungicides were evaluated under *in vitro* conditions against *Bipolaris rostrata* and *Colletotrichum gloeosporioides*. The fungicides tebuconazole, carbendazim + mancozeb, cymoxanil + mancozeb and hexaconzole were found to be effective under *in vitro* conditions.

Front line demonstrations on management of bacterial wilt

Integrated management of bacterial wilt using the biocontrol agent, *Bacillus licheniformis* (GAP107 MTCC 12725) and calcium chloride was demonstrated in collaboration with Directorate of Arecanut and Spices Development (DASD), Kozhikode in two farmer's plots in Wayanad. No bacterial wilt was observed in ginger plots which were solarized prior to sowing and treated with either *B. licheniformis* or calcium chloride while control and adjacent plots showed more than 30% disease incidence. However, highest yield was observed in plots amended with calcium chloride than *B. licheniformis*.

Incidence of shoot borer (*Conogethes punctiferalis*) in relation to crop phenology and date of planting

The incidence of shoot borer in relation to crop phenology was studied by recording incidence of pest at fortnightly intervals during the cropping season. The shoot borer infestation was first observed during the second fortnight of August and was high during the first week of November when planted in June. When the planting was advanced to May, incidence of the pest was first observed during the second fortnight of August and the peak reached in the second fortnight of October.

TURMERIC

Genetic resources

One thousand four hundred and four *Curcuma* accessions are being maintained

in the field gene bank. The germplasm conservatory was enriched with 32 *Curcuma longa* accessions and 13 *Curcuma* sp. collected from Meghalaya and Assam.

Breeding

High pollen fertility in second generation inbreds

Pollen fertility analysis of second generation inbreds namely 138/11/1/I_1-12/I_2-1, 138/11/1/I_1-12/I_2-2, 138/11/1/I_1-12/I_2-3 showed high pollen fertility (>85%) on staining. Inbred 138/11/1/I_1-12/I_2-2 showed 74.63% pollen fertility on *in vitro* germination in B&K medium containing 5% sucrose. This inbred produced more than 200 third generation inbreds on self-pollination.

Plant health management

Pathogenicity studies of leaf blight

In turmeric varieties IISR Prathibha and BSR-2, *C. gloeosporioides* and *C. capsici* infection developed as small elliptic spots of different sizes with yellow halo on leaf lamina. The center of the spots was greyish white in colour which later coalesced into irregular patches.

Screening germplasm accessions against foliar diseases

Germplasm accessions (100 nos) were screened for foliar diseases. Leaf blotch caused by *Taphrina maculans* was found to be severe in Narendra Haldi, BSR 1& 2, Co-2, Rajendra Haldi etc. and the percent disease intensity ranged from 0 to 59.50. Genotypes BSR 2, SC 61 and accession 219 were found to be infected with leaf spot caused by *Colletotrichum* spp. with percent disease intensity ranging from 0 to 27.50.

Incidence of shoot borer in relation to crop phenology and date of planting

The incidence of shoot borer infesting turmeric in relation to crop phenology was studied at fortnightly intervals. The pest incidence was observed during second fortnight of August and the peak incidence was in second fortnight of October when the crop was planted in June. When planting of the crop was advanced to May, the pest infestation was observed first during the first fortnight of July and was high during the second fortnight of August.

Post harvest technology and value addition

Concentrated solar thermal unit for curing

Considering the minimum time required for drying and optimum retention of quality of dried material, 60 minutes curing of turmeric in concentrated solar thermal curing unit fitted with cooking vessel was considered optimum based on the maximum retention in the essential oil content and the minimum drying time required.

Studies on enhancing the bioavailability of curcumin

Cheminformatics data clearly indicated that bioactive compounds from spices can improve memory in Alzheimer's patients. A freeze dried powder extracted from fresh turmeric juice of variety Prabha is being tested to enhance the bioavailability of curcumin through its extractability in virgin coconut oil and olive oil. More than 80% extractability of curcumin could be obtained in both the oils indicating its potential for developing a product against Alzheimer' disease.

VANILLA

Plant health management

Fungal antagonists of *Fusarium oxysporum* in vanilla

Forty bacterial isolates were evaluated under *in vitro* conditions against *Fusarium oxysporum* f.sp. *vanillae* and maximum inhibition of 53.33% was recorded in VREN1. Thirteen fungal isolates were tested and FVLEP3 showed maximum percentage inhibition of 68.89. VREN1 is tentatively identified as *Bacillus amyloliquefaciens*. It produces IAA, siderophores and GA and recorded higher growth promotion activity.

TREE SPICES

Genetic resources

Three clove accessions *viz.*, Madagascar clove, little leaved clove and Zanzibar clove and three accessions of cinnamon were added to the tree spices germplasm. In *Garcinia*, three promising *G. gummigutta* accessions from NBPGR Regional Station, Thrissur and seven *Garcinia* species from North East (*G. lancifolia*, *G. pedunculata* and three unidentified species and two exotic species (*G. forbesii*, one unidentified sp.) were added to the germplasm. Air layering in nutmeg was standardized.

Management practices to enhance productivity in nutmeg

In nutmeg, application of amendments (lime and lime + dolomite) along with site-specific nutrients and micronutrients, termed as best management practice (BMP) increased the yield significantly over the farmer's practice. The yield increase was up to 50% in the treated plots in the experimental condition and from 10-25% (an increase in income of Rs. 30,000-40,000) in farmer's demonstration plots as compared to farmer's practice.

SPICE CROPS

Entomopathogens and other natural enemies

Surveys for natural enemies of insect pests of spice crops (black pepper, cardamom, ginger, turmeric, and nutmeg) in 16 locations (Wayanad and Kozhikode districts of Kerala and Chamarajanagar and Mysuru districts of Karnataka) resulted in the documentation of three entomopathogenic fungi, one each from *Protopulvinaria longivalvata* (IISR-EPF-16), an unknown caterpillar infesting ginger (IISR-EPF-17) and *Mimegralla coeruleifrons* (IISR-EPF-18).

Surveillance and documentation of pests and diseases

Leaf spot incidence in ginger was recorded in two locations of Kerala (Kozhikode and Wayanad). In Kodagu, the incidence of black pepper anthracnose ranged from 15-25%. During surveys, in Somwarpet, Kodagu, occurrence of giant African snail causing damage to ginger and black pepper was noticed. Surveys indicated that, the incidence of foliar diseases in turmeric in Andhra Pradesh and Telangana was very high (60-80%). Rhizome rot (5-25% incidence) and nematode infestation (42.4% incidence) were also noticed.

Ecologically safe management of shoot borer

Three insecticides (spinosad, flubendiamide, chlorantraniliprole), which were found effective in earlier

trials and also a treatment with spraying of chlorantraniliprole and spinosad alternatively were tested under field conditions at Peruvannamuzhi farm for dose optimization against shoot borer infesting ginger and turmeric. All the insecticides were very effective in the management of the pest even at the lowest dose (0.3 ml L^{-1}) tested. The treatments with spraying of chlorantraniliprole and spinosad alternatively was also equally effective in controlling the insect.

Hypoglycemic potential of cinnamon and turmeric

Study conducted using diabetic rats to test the hypoglycemic potential revealed that extracts based on cinnamon could reduce blood glucose level up to 85% followed by 75% reduction with cinnamon–turmeric extract combination and 80% with turmeric extract alone in one month's time after feeding the extract indicating their potential in developing an anti-diabetic product. The compounds responsible for the observed action are being evaluated.

Promising soil Zn solubilizing bacteria

Out of the six promising Zn solubilizing bacteria (ZnSB), ZnSB2 (*B. megaterium*, KY687496) was found to be the most potential strain owing to its enhanced Zn solubilization *in vitro*, in liquid culture and in soil *per se*. The study indicated that, ZnSB2 strain was a potential candidate for enhanced Zn dissolution in soil, which would allow reduced inorganic Zn application rates.

SPICES ECONOMICS

Yield advantage of spices varieties

The yield relative which measures the advantage of improved varieties from ICAR-IISR with respect to the farmer yield levels attained over the XII plan period clearly indicated the potential benefits from varietal technology adoption. A conservative estimate of impact of nutmeg varietal improvement in terms of output showed that an annual additional production of 1000 tonnes could be attributed to the improvement in varietal profile of the crop.

Impact of micronutrient technology in spices

Crop-specific designer micronutrient mixture for spice crops was developed at ICAR-IISR during the XII Plan period and the technology was released during 2013-14. The incremental production resulting from adoption of micronutrient technology in spices by the farmers is estimated to be about 366 tonnes in black pepper, 1755 tonnes in dry ginger, 1995 tonnes in dry turmeric and 15 tonnes in cardamom.

Turmeric survey in Andhra Pradesh and Telangana

A field survey of turmeric growers was conducted in Andhra Pradesh and Telangana, which together account for a significant share in area (38.64%) and production (58.98%) of turmeric in India. The study flagged several issues like low level of varietal awareness, the need to offer better cropping choices complementing the specific turmeric varieties, the high cost of plant protection arising from wrong time, wrong chemical and wrong method of pesticide use, need for rationalizing water use etc.

EXTENSION AND TRAINING

Farmers training in tribal area of Vishakapatnam, Andhra Pradesh

Three training programmes on "Scientific cultivation of black pepper and turmeric"

were held in the tribal regions of Chintapalle, Paderu and Arku of Vishakapatnam during 17, 18 & 19 November 2017, respectively. It was jointly organized by ICAR-Indian Institute of Spices Research, Kozhikode, Spices Board, Guntur and AICRPS centre, HRS Chintapalle of Dr. Y.S.R. Horticultural University. Rooted cuttings of seven black pepper varieties brought from ICAR-IISR, Kozhikode were multiplied and distributed in this region. About 125 farmers attended training on these three days.

Area wide integrated management

Demonstration of managing foot rot and slow decline diseases using biologicals and chemicals was continued in Muthappanpuzha and Thamarassery in Kozhikode district, Rajakkad in Idukki district and Adikolli in Wayanad district of Kerala. Under this programme five nurseries were established in all these locations and rooted cuttings of improved varieties of black pepper were multiplied and distributed to the farmers. Field visits and farmer's awareness programmes were also undertaken in these areas.

INSTITUTE TECHNOLOGY MANAGEMENT - BUSINESS PLANNING AND DEVELOPMENT UNIT

Recognition for ICAR-IISR startups

ICAR-IISR was selected for participation in the Festival of Innovation and Entrepreneurship (FINE), a week-long annual event hosted at the Rashtrapathi Bhavan during 19-21 March 2018. Two startups from ICAR-IISR *viz.*, Dr. Chaitra Narayanan, Kodagu Agritech, Karnataka and Mrs. Thabeera K, Natura Nursery, Kozhikode were selected for presenting their technologies. Hon'ble President of India accompanied by Dr. Trilochan Mohapatra visited the startup stall of ICAR-IISR. Dr. Chaitra Narayanan, presented a brief summary about her initiative on biocapsules. The ITM-BPD unit signed thirteen license agreements for technology commercialization/services during 2017-18.

Programmes of national importance

Institute is taking up Prime minister's flag ship programmes sincerely. Institute has major programmes in tribal areas of north eastern states, Andhra Pradesh and Kerala focusing on social upliftment and income enhancement. We are harnessing the renewable energy especially solar energy to meet our energy needs up to 25 kWp. Institute is advocating cultivation of spices as intercrops in young orchards and plantations for doubling farmers income. Swacchta programmes are conducted with great enthusiasm and spirit. Carbon budgeting and water conservation aspects are being taken care of to make it carbon neutral and to enhance crop per drop. Organic farming is being encouraged for eco friendly and pesticide free agriculture. Recycling of organic wastes and making institute plastic free are given priority. Soil health cards are issued to farmers and farmers are advised based on their soil test reports.

INTRODUCTION

History

Intensive research on spices in the country was initiated with the establishment of a Regional Station of Central Plantation Crops Research Institute (CPCRI) at Kozhikode, Kerala, during 1975, by the Indian Council of Agricultural Research (ICAR). This Regional Station was upgraded as National Research Centre for Spices (NRCS) in 1986 by merging with it the Cardamom Research Centre of CPCRI at Appangala, Madikeri, Karnataka. The NRCS was further elevated to the present Indian Institute of Spices Research (IISR) during 1995.

Location

The laboratories and administrative offices of the institute are located at Chelavoor (50 m above MSL), 11 km from Kozhikode (Calicut), Kozhikode District, Kerala, on the Kozhikode - Kollegal road (NH 212), in an area of 14.3 ha. The research farm is located 51 km North East of Kozhikode at Peruvannamuzhi (60 m above MSL), on the Peruvannamuzhi-Poozhithode road in Kozhikode District, in an area of 94.08 ha. The Regional Station (920 m above MSL) is located at Appangala, Kodagu District, Karnataka, on the Madikeri-Bhagamandala road, 8 km from Madikeri, in an area of 17.4 ha.

Mandate

- To extend services and technologies to conserve genetic resources of spices as well as soil, water and air of spices agroecosystems.
- To develop high yielding and high quality spice varieties and sustainable production and protection systems using traditional and non-traditional techniques and novel biotechnological approaches.
- To develop post harvest technologies of spices with emphasis on product development and product diversification for domestic and export purposes.
- To act as a centre for training and technology upgradation of spices and to coordinate national research projects.
- To monitor the adoption of new and existing technologies to make sure that research is targeted to the needs of the farming community.
- To serve as a national centre for storage, retrieval and dissemination of technological information on spices.

The spice crops on which research is being conducted at the institute include black pepper (*Piper nigrum* Linn.), cardamom (*Elettaria cardamomum* Maton), ginger (*Zingiber officinale* Rosc.), turmeric (*Curcuma longa* Linn.), cinnamon (*Cinnamomum verum* J. Presl.), cassia (*C. cassia* Nees ex Blume), clove (*Syzygium aromaticum* (L.) Merrill & Perry), nutmeg (*Myristica fragrans* Houtt.), allspice (*Pimenta dioica* (L.) Merrill & Perry), Garcinia (*Garcinia gummi-gutta* (L.) N. Robson and *G. indica* Choisy) and vanilla (*Vanilla planifolia* Jacks. ex Andrews).

Organization

The Director is the administrative head of the institute. The Institute Management Committee, Research Advisory

Committee and Institute Research Council assist the Director in matters relating to management and research activities of the institute. Research on various aspects of the mandate crops is conducted in three divisions, namely, Division of Crop Improvement and Biotechnology, Division of Crop Production and Post Harvest Technology and Division of Crop Protection and a Social Sciences Section. The other facilities available at the institute include Agricultural Technology Information Centre, Agricultural Knowledge Management Unit, Bioinformatics Centre and Krishi Vigyan Kendra. The institute also functions as the headquarters for the All India Coordinated Research Project on Spices (AICRPS). The institute has also linkages with several universities, research institutes, and developmental agencies for collaborative research and developmental activities in spices.

Budget

The total budget of the institute was 1796.00 lakhs during the year.
Resource generation: Institute earned a total of 69.64 lakhs through sale of planting materials, biocontrol agents, training, publications and consultancy services.

Staff

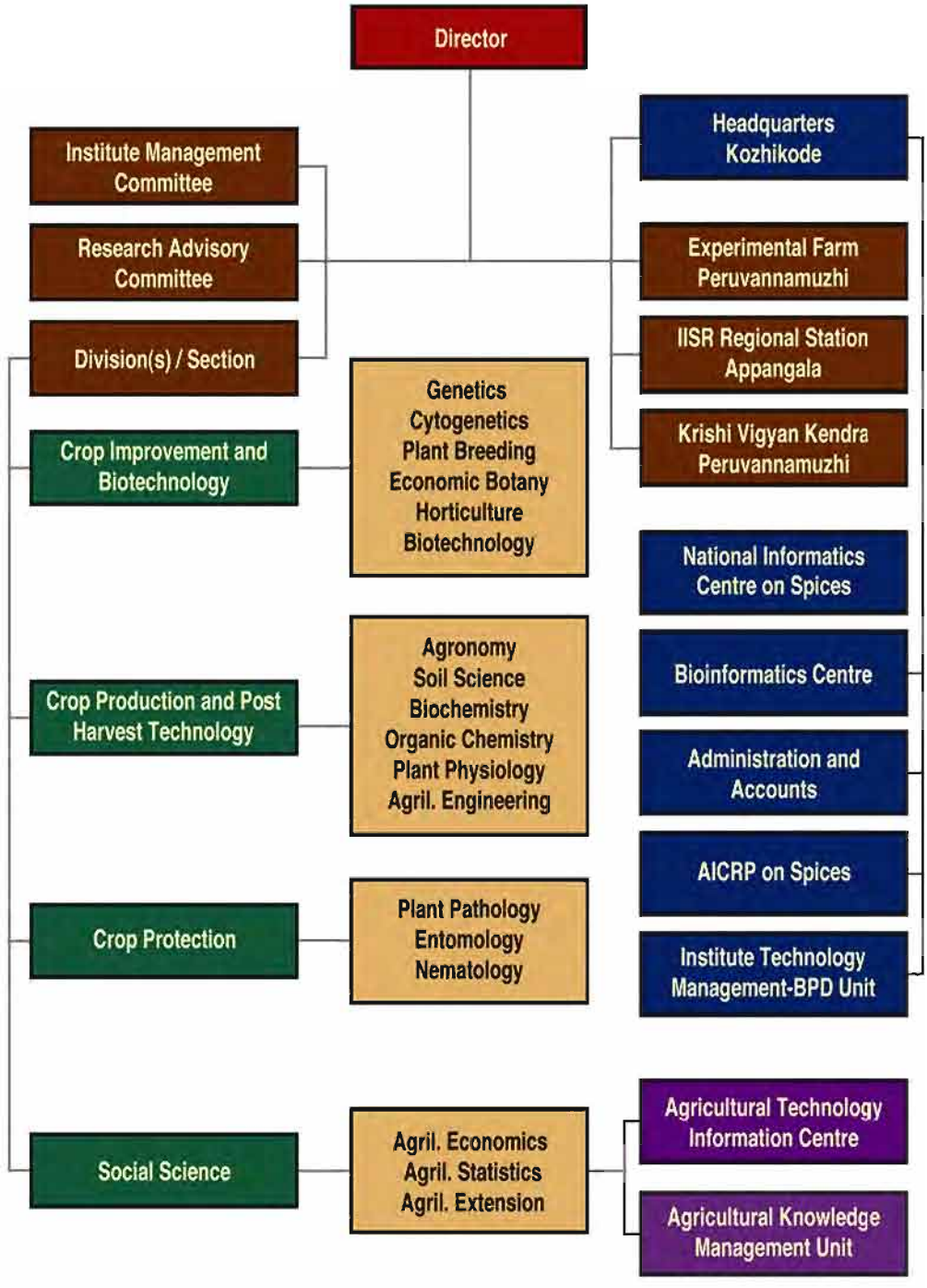
The institute has a sanctioned strength of 48 scientific, 24 administrative, 35 technical and 61 supporting staff, of which 40, 18, 25 and 11 of scientific, administrative, technical and supporting staff, respectively are in position. The KVK has a sanctioned strength of 2 administrative, 11 technical and 2 supporting staff.

Staff position of the institute as on 31 March 2018

Category	*Sanctioned*	*Position*			*Total Position*	*Vacant*	*Total*
		Kozhikode	*Peruvanna muzhi*	*Appangala*			
Scientific	**48**	**34**	**0**	**06**	**40**	**08**	**48**
Technical	**35**	**15**	**07**	**03**	**25**	**10**	**35**
Administrative	**24**	**16**	**0**	**02**	**18**	**06**	**24**
Supporting	**61**	**02**	**02**	**07**	**11**	**50**	**61**
Total	***168***	***67***	***09***	***18***	***94***	***74***	***168***

Staff position of KVK

Category	*Sanctioned*	*Position*			*Total Position*	*Vacant*	*Total*
		Kozhikode	*Peruvanna muzhi*	*Appangala*			
Scientific	**01**	**–**	**01**	**–**	**01**	**0**	**01**
Technical	**11**	**–**	**10**	**–**	**10**	**01**	**11**
Administrative	**02**	**–**	**01**	**–**	**01**	**01**	**02**
Supporting	**02**	**–**	**02**	**–**	**02**	**0**	**02**
Total	***16***	**–**	***14***	**–**	***14***	***02***	***16***



Organizational chart of ICAR-Indian Institute of Spices Research, Kozhikode

PAST ACHIEVEMENTS

Black pepper

Germplasm collections obtained over the years through explorations are being maintained at ICAR-IISR as well as in other alternate sites *viz.*, Appangala and Chettali of Karnataka for developing improved varieties for yield, quality, abiotic and biotic stresses. The genetic stock has lead to the release of nine improved varieties such as Sreekara, Subhakara, Panchami, Pournami, PLD-2, IISR Thevam, IISR Girimunda, IISR Malabar Excel and IISR Shakthi. Two accessions, INGR 8099 - *P. thomsonii* (IC 398863) - for its unique character for sex change and INGR 8100 - *P. nigrum* (IC 563950) – a novel spike variant with proliferating spikes, were registered with NBPGR, New Delhi. Endangered species *viz.*, *P. barberi* and *P. hapnium* were located and collected from Sabari Hills. Microsatellites developed for *Piper* species were successfully used to detect polymorphism in black pepper cultivars. Germplasm catalogue consisting of characterization and evaluation data of 530 accessions was prepared. Assembly and functional annotation of sequences derived from the transcriptome of *P. colubrinum* and *P. nigrum* helped in the identification of many genes involved in defense and secondary metabolism. Seedlings of *P. colubrinum* on screening for *P. capsici* showed segregation of the resistance character, 21 plants being resistant to *Phytophthora,* two plants susceptible and the rest showing moderate resistance. Putative transgenic black pepper plants with *osmotin* gene conferring resistance to drought and *Phytophthora capsici* have been developed. *In vitro* and *in vivo* propagation methods were standardized. Plantlets developed through micropropagation were established in farmer's field in Kerala and Karnataka.

Soils from all all the Panchayats of Kerala have been analyzed for their physico-chemical properties and nutrient advisory cards have been generated for distribution to the farmers. The spacing, nutrient and water requirements were standardized for different soil types of pepper growing regions. Irrigating pepper vines once in a fortnight from March to May months at the rate of 50 L vine^{-1} enhanced yield substantially. High production technologies and mixed cropping systems were developed for increasing productivity. Organic production technology for black pepper has been standardized. Crops such as ginger, tapioca, coleus, amorphophallus and hybrid napier were found suitable for intercropping in black pepper gardens that are more than 15 years old. Intercropping medicinal plants (*Vetiveria zizanioides* and *Alpinia calcarata*) in juvenile black pepper garden was found to be profitable with a B:C ratio of 2.3. Cost effective method for production of disease-free rooted cuttings was developed. A machine was fabricated in collaboration with ICAR-CIAE, Coimbatore centre which is capable of mixing, pulverizing, sieving, and filling of potting ingredients in poly bags at desired quantity. Mathematical models for optimum climatic factors for high production of black pepper have been developed. Targeted yield equations for predicting nutrient requirements for fixed yield targets in soils with varying fertility levels were standardized with minimum deviations in black pepper. Major pests, pathogens, viruses and their insect vectors and nematodes affecting black pepper

were characterized and documented. Morphological and molecular characterization of black pepper isolates of *Phytophthora* further revealed that, isolates shared the characters of both *P. capsici* and *P. tropicalis*.

A RNA virus, *Cucumber mosaic virus* (CMV) and a DNA virus, *Piper yellow mottle virus* (PYMoV) are found to be associated with stunt disease of black pepper. A method for simultaneous isolation of RNA and DNA from infected black pepper plants and multiplex PCR for simultaneous detection of CMV and PYMoV in a single reaction was standardized. SYBR green based real-time PCR was developed for detection of PYMoV and CMV in black pepper. Phytoplasma with phyllody symptoms was most closely related to members of Aster yellows group (16SrI) of Phytoplasma. Integrated strategies involving cultural methods, biocontrol agents, plant products and resistant varieties were developed for the management of pests and diseases including nematodes that resulted in substantial increase in yields and pesticide-free produce.

Large scale multiplication of biocontrol agents such as *Trichoderma* and *Pseudomonas* for distribution to farmers for management of disease was also undertaken. These organisms were deposited in the national repository of microorganisms at IMTECH, Chandigarh for future reference. Species-specific primers were developed for detection of *R. similis* in soil and plant samples. The presence of β-1, 4 endoglucanase, a major secretory cellulose enzyme in nematodes, was located in *R. similis* through EST analysis. Black pepper accessions, HP-39 and Acc. 1090 were found to be resistant to nematodes besides being rich in caryophyllene. Endophytic bacteria effective against *Phytophthora capsici* and *R. similis* in black pepper have been isolated. Culture filtrates of BRB 13 at 40µL mL^{-1} caused 100% mortality of *R. similis* within 24 h. Basal application of *T. harzianum* and aerial spray with 1% Bordeaux mixture was found effective in controlling anthracnose disease. A PGPR formulation for enhanced growth promotion and disease management in black pepper has been developed and licensed for large scale production. A novel method for targeted delivery of PGPR by encapsulation has been developed and non-exclusively licensed for mass production.

An integrated pest management schedule for management of root mealy bug has been developed. Metalaxyl-mancozeb sensitivity of 81 *Phytophthora* isolates was tested and the EC_{50} and EC_{90} values ranged from 0.0002 to 14.4 ppm and 1.1-68.5 ppm, respectively. Among the new chemicals tested *in vitro* against *P. capsici*, Acrobat 50 showed 100% inhibition at 50 ppm concentration. Profiling and activity prediction of biochemical compounds using *in silico* tools were completed for *Pseudomonas putida* BP 25 and *Bacillus megaterium* BP 17. PCR-based techniques were developed for identification of traded black pepper and to detect adulterants in commercial black pepper powder. The existence of fungicide sensitive or resistant isolates among the field populations of *C. gloeosporioides* infecting black pepper was noticed in Pollibetta and the isolate from this locality was tolerant to recommended doses of Bordeaux mixture and carbendazim. Post harvest technologies for drying, processing, storage and production of value-added product like white pepper production were standardized.

Genetic diversity of *Phytophthora* isolates from black pepper was studied by SSR profiling and ITS sequencing with the universal primers ITS 6 and ITS 4. A native isolate of *P. capsici* (Is. No. 98-93) infecting black pepper was completely sequenced using next generation sequencing platform, Illumina - Solexa GA II. ITS region of *R. similis* was amplified with universal primers. A new database, *Phytophthora* Genome Database (http://220.227.138.212/genomedb/) based on *Phytophthora* whole genome sequencing and annotation was developed. PhytoWeb, a comprehensive portal on *Phytophthora* diseases of horticultural crops in India was developed. Phytolib, an electronic database of research publications on *Phytophthora* and database on *Radopholus* genus RADOBASE were developed and launched.

Impact studies on adoption of IISR varieties of black pepper in farmer's fields indicated that, the mean yield for high yielding varieties was 1160 kg ha^{-1} with the adoption of scientific packages as compared to 620 kg ha^{-1} for traditional varieties. The estimated cost benefit ratio was 2.48. The level of adoption studies of recommended technologies indicated that, the adoption level for aerial spraying of Bordeaux mixture for the control of fungal diseases was 57.14 % and for application of biocontrol agents was 64.2 %. The adoption level for application of soil fungicides, fertilizers and pesticides were very low at 21.14 %, 7.7 % and 7.6 %, respectively. *Karshika Sankethika Darshanam* and Media Meet were organized to mobilize mass media support for sharing agro-information. Video film on Augmenting black pepper production – a success story (Malayalam, English, Hindi) was produced.

Cardamom

Germplasm collections obtained over the years through explorations are being maintained at IISR Regional Station, Appangala, Karnataka and IC numbers have been obtained for all the available germplasm. Meanwhile, four germplasm accessions bearing unique characters have been registered with NBPGR, New Delhi. The improved varieties such as Appangala-1, IISR Vijetha, IISR Avinash and Appangala-2 (hybrid) have been developed. Coupled with production technologies, these varieties resulted in increasing productivity of cardamom.

Molecular profiles were developed for 100 accessions of small cardamom germplasm using 25 ISSR markers for studying the genetic diversity and dendrogram of similarity was prepared. Molecular profiling of Indian cardamom revealed the existence of two genetically distinct clusters such as "Kerala cluster" and "Karnataka cluster' among the germplasm collections. Characterization of export grade cardamoms from India, Sri Lanka and Guatemala based on physical, biochemical parameters and molecular techniques revealed the superiority of Indian produce. GC-MS study confirmed superiority of Indian cardamom over Guatemalan and Sri Lankan cardamom. High production technology has been standardized. Drip irrigation and sprinkler irrigation once in 12 days significantly improved yield attributing characters. Soil and water conservation measures have been standardized in cardamom based cropping system. Cardamom accessions APG 257, APG 414 and APG 434 were found to be promising for drought tolerance.

A procedure for total RNA isolation and detection of *Cardamom mosaic virus*

(CdMV) through reverse transcription–polymerase chain reaction (RT-PCR) using primers designed for the conserved region of coat protein was standardized. A protocol for SYBR green based real-time RT-PCR for detection of CdMV and *Banana bract mosaic virus* (BBrMV) in cardamom was developed. Surveys conducted in Karnataka and Kerala, revealed the prevalence of BBrMV infection. A reliable RT-PCR based method was also developed for detection of the virus in plants. The survival of *C. gloeosporioides* infecting cardamom in infected plant part (leaves) was studied under laboratory, greenhouse and field conditions. A new bacterial wilt disease on small cardamom was noticed in Wayanad, Kerala. Phenotypic and genetic characterization revealed that, the causative organism is *Ralstonia solanacearum* biovar 3 phylotype 1. Multiplex-PCR based phylotyping, 16s rDNA and recN gene sequence based comparison and MLST based comparative genetic analysis further revealed that, the strain is 100 % similar to the ginger strain of *R. solanacearum*.

Ginger

Germplasm repository at ICAR-IISR is the largest with several unique collections. Six hundred and sixty eight accessions are being maintained in field germplasm conservatory. Three varieties namely, IISR Varada, IISR Rejatha and IISR Mahima were released for their high yield and quality. Cross specific amplification of rice microsatellites was successfully done in ginger. Acc. 195, a tetraploid having 2n = 44, showed mean pollen fertility of 67.73 % by glycero-carmine staining and 60.31% by *in vitro* germination and is suitable for future studies on induction of seed set. Identified three potential mutants through gamma ray irradiation which showed resistant reaction against bacterial wilt caused by *Ralstonia solanacearum*. A relationship between leaf P/Zn ratio and soil P/Zn ratio to rhizome yield has been established. Targeted yield equations for predicting nutrient requirements for fixed yield targets in soils with varying fertility levels were standardized with minimum deviations. The economic optimum in terms of profitable response for money invested was found to be Rs. 3.75 bed^{-1} for N, Rs. 1.30 bed^{-1} for P and Rs. 0.60 bed^{-1} of $3m^2$ for K.

Post harvest technologies for processing and technologies for preparation of value added products such as salted ginger were standardized. Comparison of essential oil constituents of fresh and dry rhizomes indicated that, fresh rhizomes contained higher level of monoterpenes namely, *Z*-citral and *E*-citral whereas the dry rhizomes were predominated by the sesquiterpene hydrocarbons *viz.*, zingiberene, farnesene and sesquiphellandrene. Ginger strain of *R. solanacearum* was found to infect turmeric, cardamom, *Curcuma aromatica, C. zedoaria, Kaempferia galanga, Zingiber zerumbet* and tomato. Indian mango ginger, *Curcuma amada* was found to be free from bacterial wilt even under inoculated conditions. The species of *Pythium* causing rhizome rot of ginger in Kerala, Karnataka, Uttar Pradesh and Sikkim was identified as *P. myriotylum*.

Nine actinomycete isolates from ginger soil were found to be antagonistic to *R. solanacearum*. Technique for ginger seed rhizomes treatment (for elimination of bacterial wilt pathogen) and integrated disease management strategy for soft rot and bacterial wilt diseases and shoot borer was developed. *Bacillus amyloliquefaciens* (GRB 35) was

effective for disease control and plant growth promotion. PGPR formulation to enhance nutrient mobilization and growth, yield and biocontrol was developed and commercialized.

The life cycle of shoot borer (*Conogethes punctiferalis*) was studied on six resistant and six susceptible accessions. The infectivity of EPNs strains IISR-EPN 01 to 08 was tested against shoot borer larvae under *in vitro* conditions. One species of EPN belonged to *Oscheius gingeri* and was identified as new species on the basis of morphological and molecular characterization. The improved varieties and technologies developed on cropping system, nutrient and water requirement, pest and disease management and post harvest processing techniques were disseminated to farmers and other agencies through publications, training programmes and demonstrations. Large scale multiplication and distribution of elite planting material were also undertaken.

Turmeric

The germplasm collected over the years have been conserved in the field gene bank and were characterized for yield, quality and resistance to pests, diseases and drought. Seven high curcumin and high yielding varieties, Suvarna, Sudarsana, Suguna, IISR Prabha, IISR Prathiba, IISR Alleppey Supreme and IISR Kedaram were released for commercial cultivation. Open pollinated seedling progenies generated over the years are being evaluated for their yield and quality characters.

Molecular genetic fingerprints of sixteen *Curcuma* species using RAPD and ISSR markers revealed high degree of polymorphism among the accessions. A total of 140 microsatellites containing genomic DNA fragments were isolated adopting the selective hybridization method with di and trinucleotide biotinylated probes. Two synonymous *Curcuma* species *viz.*, *C. zedoaria* and *C. malabarica* showed identical SSR profiles for 40 microsatellite loci. Efficient protocol for plant regeneration through organogenesis and somatic embryogenesis was standardized. Variations in rhizome morphology were observed among calli-regenerated somaclones indicating somaclonal variation. Accessions with high curcumin and root knot nematode resistance were identified. About 40 seedling progenies with higher curcumin (>3 %) and dry recovery (>20 %) were identified. Three different curcuminoids (curcumin, de methoxy curcumin and bis de methoxy curcumin) could be separated from oleoresin by employing chromatographic techniques. Turmeric oil components have been characterized by GC-MS. A PCR based method was developed to detect adulteration of turmeric powder with wild *Curcuma* species.

Targeted yield equations for predicting nutrient requirements for fixed yield targets in soils with varying fertility levels were standardized with minimum deviations. The economic optimum in terms of profitable response for money invested was found to be Rs. 0.65 bed^{-1} for N, Rs. 0.40 bed^{-1} for P and Rs. 0.85 bed^{-1} of $3m^2$ for K. Increase in curcumin content was recorded when sprayed with micro nutrients like zinc and boron. Processing with or without boiling or different drying methods did not lead to variation in oil, oleoresin and curcumin contents. The optimum spacing, nutrient and water requirement were standardized for

different soils and organic farming system was developed for turmeric.

Basic data on distribution, bioecology, population dynamics of shoot borer (*Conogethes punctiferalis*) and its natural enemies and crop loss due to shoot borer was generated. Lamda cyhalothrin 0.0125 % was more promising in reducing the percentage of shoots infested by the shoot borer. The improved varieties and technologies were disseminated to farmers and other agencies through publications and demonstrations. The adoption of released varieties like IISR Prathiba in Andhra Pradesh, Karnataka and Tamil Nadu were studied. A novel soil pH based micronutrient mixtures for enhancing growth, yield and quality of turmeric, ginger, black pepper and cardamom were developed. Video film on success story of a 'Prathiba' grower was produced.

Tree spices

The germplasm holdings of three important tree spices, nutmeg, clove, cinnamon including cassia, garcinia and allspice are being conserved. IC Numbers for cinnamon, clove, nutmeg and allspice accessions were obtained from NBPGR, New Delhi. Cassia C1 (IC 370415) has been registered as INGR 05029 with NBPGR, New Delhi for its high oleoresin content (10.5 %) besides a dwarf clove accession. The cassia elite line A1 (IC 370400) has been registered with NBPGR for high cinnamaldehyde content in bark oil (81.5 %) and leaf oil (80.5 %). Two high quality cinnamon varieties, Navashree and Nithyashree and a nutmeg variety, Viswashree were released. Nutmeg accession, A11/25 was found to be promising for high yield. Nutmeg accession A9-71 (IC-537220), as a source of high sabinene (45 % sabinene in nutmeg oil and 41.9 % sabinene in mace oil) was registered with NBPGR. Tissue culture protocols have been developed for nutmeg. Protocols for DNA isolation from nutmeg have been standardized. Performance of nutmeg on *M. malabarica* continued to be better than other rootstocks for productivity. Green chip budding with orthotropic buds was standardized in nutmeg on *Myristica fragrans* rootstock with 90-100 % success.

GC-MS study revealed the presence of two chemotypes in *Cinnamomum verum*. Drying and processing methods for cinnamon, nutmeg and mace have been developed. Antioxidant properties and food color value are being studied in tree spices. GC-MS analysis of the chemical constituents of essential oils in leaves of *Cinnamomum sulphuratum*, *C. glaucescens*, *C. glanduliferum*, *C. macrocarpum* and *C. perrottetti* revealed that, the major chemical constituents in these oils were α-phellandrene, β-phellandrene, camphor, t-*caryophyllene* and *germacrene*-D, respectively. Vegetative propagation techniques were standardized for nutmeg, cassia and cinnamon. Major pests and diseases on tree spices were documented. The improved varieties and technologies developed on propagation and post harvest processing were disseminated to farming community.

Four species of *Garcinia viz.*, *G. kydia* (Kuji Thekera), *G. lancifolia* (Rupohi Thekera), *G. pedunculata* (Bor Thekera) and *G. xanthochymus* (Tepor Tenga) were located in Meghalaya, Assam and Nagaland. Hot water extraction and solvent extraction (methanol/chloroform - 1:1) of *G. gummigutta* and *G. tinctoria*

yielded 50 % butter with yellow colour and pleasant aroma.

Vanilla

Vanilla germplasm is being maintained in the repository, which includes a flower colour variant collected from Andaman and Nicobar islands. Comparative anatomical analysis of different vanilla species was carried out. Interspecific hybridization was made between *Vanilla planifolia* and *V. aphylla*. Reciprocal crosses were conducted between *V. planifolia* and *V. tahitensis* (species reported as resistant to root rot disease) and high percent of fruit set was observed in both the crosses. Fifty interspecific hybrids each of *V. planifolia* x *V. tahitensis*, *V. tahitensis* x *V. planifolia* and selfed progenies of *V. tahitensis* were established *ex vitro*. Chromosome number analysis of two interspecific hybrids between *V. planifolia* and *V. tahitensis* showed 2n = 30 in one (PT-5) and 2n = 32 in other (PT-17).

Protocols for micropropagation through direct shoot multiplication as well as callus regeneration were standardized. Root rot and wilting were found to be the major problems in most of the plantations. Root rot incidence ranged from 5 to 100 %. Mosaic and necrosis were also observed in all the plantations and the incidence ranged from 2 to 80 %. *Cucumber mosaic virus* (CMV) of vanilla was characterized on the basis of biological and coat protein (CP) nucleotide sequence properties, which showed that, CMV infecting vanilla belongs to subgroup IB. A virus causing mild chlorotic mottle and streaks on leaves of vanilla was identified as a strain of *Cymbidium mosaic virus* (CymMV) based on coat protein gene sequence comparison and phylogenetic studies. Another virus associated with necrosis and mosaic on vanilla was identified as a strain of *Bean common mosaic virus* (BCMV) based on coat protein gene sequence comparison and phylogenetic studies.

Paprika

The germplasm collected from various places of cultivation were characterized for various morphological, yield and quality characters such as oleoresin, pungency and colour value. Considerable variability was observed in total extractable colour and capsaicin content (pungency) of selected paprika accessions. The lines ICBD-10, Kt-pl-19 and EC-18 were found promising with high colour value and low pungency. PCR-based technique was developed to detect adulterants in commercial chilli powder.

RESEARCH ACHIEVEMENTS

BLACK PEPPER

Genetic resources and characterization

Three thousand four hundred and sixty six accessions are conserved at the black pepper germplasm conservatory in the Experimental Farm, Peruvannamuzhi, Kerala. A field gene bank with 200 accessions was established at Peruvannamuzhi. A block of released varieties and local cultivars consisting of 104 accessions were also established on non-living standards. Presently the field gene bank at CHES, Chettalli consists of 727 cultivar accessions and 100 new accessions were added. The field gene bank at Kozhikode comprise of 223 accessions. Among the accessions, Coll. No. 7232 (Kaniakadan) recorded the maximum yield of 15.6 kg vine^{-1} followed by Coll. No. 7243 (Karimunda) 11.4 kg vine^{-1}, Coll. No. 7221 (Mundi) 9.1 kg vine^{-1} and Coll. No. 7255 (Arakulamunda) 6.1 kg vine^{-1}, respectively.

An exploration programme along with ICAR-NBPGR, Shillong was conducted in Karbi Anglong and Dima Hasao districts of Assam and Janitia Hills of Meghalaya. A total of 44 accessions were collected out of which 39 accessions were established. Among the *Piper* species collected, *Piper beteloides* is found to have maximum distribution (Fig. 1a). Besides *Piper* species, an economically important species, *Houttuynia cordata* (Fig. 1b) popularly known as fish mint plant, a close relative to the genus *Piper* of the family Saururaceae was also collected and established.

Fig 1. Characteristic collections: (a) *P. beteloides* (b) *Houttuynia cordata*

DNA fingerprinting

Ademane pepper

The ISSR profiling of two black pepper varieties *viz.*, Karimalligesara and Ademane pepper was done using universal UBC primers. Primer UBC 826 showed a band (900 base pairs) polymorphic to Ademane pepper that may be used as a marker to distinguish between the two pepper varieties and for PPV and FRA registration.

Panniyur 9

The ISSR profiling of new black pepper variety Panniyur 9, released by Kerala Agricultural University, Thrissur was done and compared with Panniyur 3 using universal UBC primers. Total genomic DNA was isolated from replicate leaf samples of Panniyur 3 and Panniyur 9 using the protocol of Dhanya *et al.* (2007). Primer UBC 826 showed polymorphic bands of size ~650 bp in Panniyur 3 and a ~540 bp in Panniyur 9. These bands may be used as markers to distinguish between the two pepper varieties for PPV and FRA registration of Panniyur 9.

Genomics of drought tolerance

Amplicon sequencing of four important genes involved in drought tolerance *viz.*, dehydration responsive element binding protein (*DREB*), *NAC gene*, thaumatin-like protein (*TLP*) and dehydrin (*DH*) was done to study sequence variation in selected drought responsive genes of tolerant and susceptible genotypes. Good number of SNP variations was identified in all the samples and indels were few. Many SNPs were located in the coding region of the genes studied resulting in altered amino acids. In the study, clear cut distinction between the tolerant and susceptible genotypes could not be found for all the genes. However, unique SNPs were found in specific accessions. In case of *DREB*, three SNPs were discovered in the coding region of the Acc. 4216 (tolerant) and accumulation of these three SNPs in the same gene can lead to introduction of an intron in the coding region and hence complete disruption of the gene function. In the most susceptible accessions *viz.*, Acc. 5641and Acc. 6730, an amino acid change from "E" to "D" was noticed at the 77th position in case of DH gene. More studies on sequence variations in promoter and other control elements can give more relevant information for marker development and its utilization in breeding.

Identification of differentially expressed genes involved in drought tolerance

The Illumina data of leaf transcriptomes from the drought tolerant Acc. 4226 exposed to drought stress and their control were analyzed to identify differentially expressed genes. Gene ontology of these key genes identified represented unique molecular functions. Sixteen transcription factors sub-categorized into six groups to be differentially up-regulated and these could be directly related in drought tolerance. The transcription factors identified include, *AP2/ERF-ERF*, *MYB*, *WRKY*, Zinc finger protein and *ZFP5*. Two important protein kinases, *CAMK*-like checkpoint kinase 1 and *MAP3K* gene were also found to be up-regulated. Further, other genes like glycosyltransferases, cullin-like protein1, *TRAF*-like protein, clathrin heavy chain, damaged DNA binding protein 1 B, dynamin-like family protein, ribonuclease T2, glyceraldehyde-3-phosphate dehydrogenase, mannose/glucose-specific lectin family protein, multi-copper oxidase type 1 family protein and syringolide-induced protein were also found to be up-regulated under water deficit.

Identification of detoxification genes involved in drought tolerance

Sequences matching to arginine decarboxylase, ascorbate peroxidase, metallothionein, galactinol synthase,

glutathione peroxidase, *MYB* transcription factor and peroxidase genes, involved in detoxification reactions under drought stress were retrieved from the transcriptome sequences of drought tolerant Acc. 4226.

Crop management

Production of healthy planting materials in black pepper

Spraying and drenching aqueous extract of *Moringa oleifera* leaf (3 %) + *Vetiveria zizanioides* root (3 %) on black pepper cuttings three times at 25 days interval is effective in producing quality planting materials.The treatment stimulated growth parameters *viz.*, shoot and root length, number of leaves per plant, shoot and root dry weight per plant (Fig. 2).

It also increased physiological and biochemical characters *viz.*, total chlorophyll, carotenoids, soluble protein, photosynthetic rate, instantaneous water use efficiency and chlorophyll fluorescence.

Black pepper zonation in India

The data on black pepper area and production collected from Ministry of Agriculture and Farmer's Welfare, Government of India indicated that, black pepper is cultivated in 97 districts of Assam, Goa, Karnataka, Kerala, Meghalaya, Nagaland and Tamil Nadu. Relative Spread Index (RSI) and Relative Yield Index (RYI) were calculated and 84 districts were identified as efficient black pepper producing districts based on RSI and RYI (Table 1), while only one district *viz.*, Dindigul in Tamil Nadu has been delineated as the most efficient zone. Two districts, one each in Tamil Nadu (Theni) and Nagaland (Kohima) were in Zone 1a i.e., most efficient with annual yield variations. Four districts were in zone 2 (efficient zone) and 30 districts were in 2a zone (efficient zone with little year to year variations), 9 districts were in 2b (efficient zone with medium year to year yield variations) and 38 districts were in 2c (efficient zone with greater year to year yield variations) (Fig.3). Thirteen districts were not efficient zones which fell in the category of 3 and 4.

Fig 2. Increased growth parameters in black pepper treated with *Moringa oleifera* + *Vetiveria zizanioides*

Table 1: Delineation of efficient black pepper zones in India								
Efficient black pepper zones in India								
Zone	**Assam**	**Goa**	**Karnataka**	**Kerala**	**Meghalaya**	**Nagaland**	**Tamil Nadu**	**Total**
1	-	-	-	-	-	-	1	1
1a	-	-	-	-	-	1	1	2
2	-	-	2	1	-	-	1	4
2a	8	1	7	2	4	5	3	30
2b	4	1	-	-	2	1	1	9
2c	14	-	10	6	4	-	4	38
Sub total	**26**	**2**	**19**	**9**	**10**	**7**	**11**	**84**
3	1	-	-	-	-	-	1	2
3a	-	-	-	-	-	-	-	-
4	1	-	1	5	1	-	3	11
Sub total	2	-	1	5	1	-	4	13
Grand total	**28**	**2**	**20**	**14**	**11**	**7**	**15**	**97**

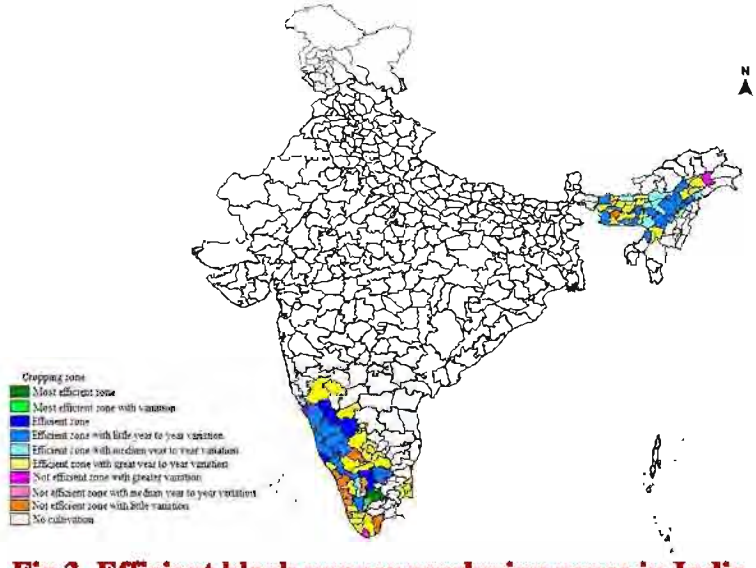


Fig 3. Efficient black pepper producing zones in India

Scheduling fertilizer dose for fertigation in black pepper

An adaptive trial was conducted at Laxmi Estate, Hosahalli, Mudigere to quantify the extra nutrient to be supplemented either by soil application or through foliar over and above the fertigation dosage. Based on the initial soil nutrient status and yield levels, the fertilizer dose was calculated and applied. Supplemental application of NPK and micronutrients as foliar sprays increased the leaf concentration of Mg, P, Zn and B. Soil supplementation of fertilizers and foliar sprays with NPK and micronutrients recorded higher yield (30.15 kg fresh yield standard^{-1}) followed by fertigation + soil supplementation and foliar micronutrients alone (26.1 kg fresh yield standard^{-1}) over fertigation alone (Fig. 4). Additional investment of Rs. 10 - 15 standard^{-1} has yielded an additional profit of Rs. 360 -

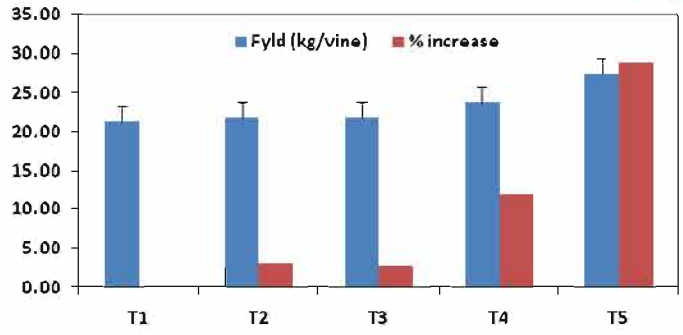


Fig. 4. Effect of treatments on the fresh yield (kg standard^{-1}) of black pepper
(T1 - Fertigation alone; T2 - T1 + Soil supplementation of nutrients; T3 - T2 + Foliar supplementation of NPK; T4 - T2 + Foliar supplementation ofmicronutrients; T5 - T2 + Foliar supplementation of NPK + Micronutrients)

Impact of rainfall on black pepper yield parameters in Karnataka

Monthly rainfall data for 2017 was collected from 15 locations from different estates/locations. The total rainfall ranged from 1001.75 mm (Malligecool, Chikkamagaluru) to 2488.25 mm (Heggade, Sakleshpur) with a mean of 1576.7 mm. Pre-monsoon rainfall (January - May) ranged from 125.75 mm to 434 mm with a mean of 284.14 mm. Pre-monsoon rainfall distribution was good in many locations. The spiking intensity and berry setting were recorded in 20 plantations in Malnad region of Karnataka which ranged from 15 to 71.11 per 0.5 m^2 canopy area with mean of 31.55 per 0.5 m^2. Number of developed berries in a spike ranged from 12.27 to 93.1 with a mean of 54.53 berries spike^{-1}. Number of undeveloped berries in a spike ranged from 10.00 - 50.87 spike^{-1} with mean of 25.38 spike^{-1}. The berry set ranged from 26.14 to 89.1 % with a mean of 63.83 % (Table 2). Low berry set was recorded in low rainfall areas and poorly managed plantations.

Drought management in black pepper

Anti-transpirants such as kaolin (2 %), kaolin (2 %) + MOP (0.5 %), spray lime (1.5 %), spray lime (1.5 %) + MOP (0.5 %) and Miracle (3 ml litre^{-1}) were sprayed to black pepper and cardamom in February 2018 in the farmer's field in Shukravarsanthe and Wayanad and physiological parameters like photosynthetic gas exchange, canopy temperature, chlorophyll fluorescence and yield characters were recorded. The results indicated that, spray lime (1.5 %) showed higher photosynthetic rate while maintaining lower leaf temperature.

Calcium chloride enhances drought tolerance traits in black pepper

Though, abscisic acid could be a good option to induce drought tolerance, due to high cost of ABA, we evaluated the impact of the low cost chemical, $CaCl_2$ on drought tolerance. The results revealed that, the $CaCl_2$ sprayed plants showed reduced membrane leakage and increased relative water content when compared to desiccation control. The significant reduction in stomatal pore size (Fig. 5), reduced hydrogen peroxide levels and increased SOD activities indicated the positive influence of $CaCl_2$ spray in mitigating drought in black pepper. As this study was conducted under controlled conditions, it needs further field validation to recommend $CaCl_2$ spray for drought mitigation in black pepper.

Table 2: Yield parameters of black pepper in Malnad region during 2017 - 18					
Plantation	**No. of spikes/ 0.5m^2**	**Spike length (cm)**	**Filled berries spike^{-1}**	**Unfilled berries spike^{-1}**	**Fruit set (%)**
Heggade, Sakleshpur	34.00	14.56	86.88	10.63	89.10
Manjunatha Estate, Shukravarsanthe	33.80	14.71	74.28	10.00	88.13
Kurram Estate, Chikanalli, Mudigere	47.50	13.50	93.10	15.00	86.12
Regional Station, Appangala	31.60	13.70	74.68	19.00	79.72
Cariyappa, Ikola, Murnad, Kodagu	71.11	15.22	77.89	21.11	78.68
Raxidi Estate, Sakleshpur	36.86	15.31	86.75	23.75	78.50
Chomani, Ikola, Murnad, Kodagu	39.44	12.11	54.67	17.89	75.34
Kalyappan Plantations, Margodu, Madikeri	29.00	12.00	44.00	15.00	74.58
Poonacha, Margodu, Madikeri	25.33	12.78	44.33	15.11	74.58
Aiyanna, Bettageri, Madikeri	24.09	11.18	53.29	19.64	73.07
Heights Estate, Beligeri, Madikeri	32.83	13.81	69.38	37.13	65.14
Bibi Plantations, Suntikoppa, Somwarpet	30.00	14.50	31.00	50.88	62.14
Raju Shetty, Bikodu, Belur	31.18	17.06	88.81	19.90	56.58
Grove Estate, Pollibetta, Virajpet	32.11	13.11	69.67	12.22	54.81
Andagov Estate, Suntikoppa	22.00	11.09	30.00	26.18	53.40
Magalu, Sakleshpur	15.00	12.55	27.91	27.91	50.00
SLN Plantations, Chettalli	31.93	12.25	59.36	15.21	49.98
Sanjay, Panya, Suntikoppa	17.50	10.67	28.95	35.50	38.54
Machaiah, Chettalli	33.80	12.00	17.78	50.22	26.14
Sandesh, Panya, Suntikoppa	11.66	11.45	12.27	60.00	14.66
Average	**31.56**	**12.97**	**54.54**	**25.39**	**63.82**

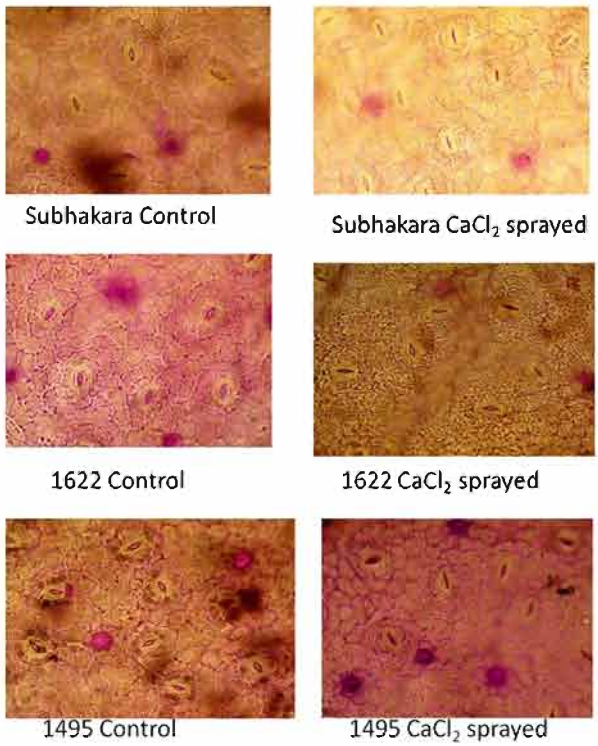


Fig. 5. Effect of $CaCl_2$ on stomatal pore dimension

Influence of altitude on black pepper yield

At altitude higher than 1250 MSL, black pepper growth and yield was found low, while at 900 - 1200 MSL, the vines recorded good yield. Dry recovery ranged 33 - 40 % and litre weight (bulk density) ranged from 503.4 to 583.3 g whereas, 100 seed weight ranged from 4.1 to 6.3 g. Mean oleoresin content ranged from 6.3 to 8.11 %, mean oil content from 2.1 to 2.7 % and mean piperine content from 3.03 to 3.77 %.

Plant health management

Foot rot and slow decline

Collection and maintenance of *Phytophthora* isolates

Five new *Phytophthora* isolates infecting black pepper were collected from Kerala and added to the National Repository. A total of 458 isolates of *Phytophthora* from different hosts are now being maintained in the repository (Fig. 6). The cultures maintained in the repository were shared for research work undertaken on *Phytophthora* by various ICAR institutes and SAU's. The isolates were also used for undertaking different molecular studies at ICAR-IISR.

Evaluation of strobilurin fungicides

The strobilurin fungicides *viz.*, kresoxim methyl and RIL are being evaluated in a farmer's field at Muthappanpuzha, Kozhikode District, Kerala for integrated disease management of foot rot and slow decline diseases (Fig. 7). The treatments were applied as protective sprays and soil drenching during pre- and post-monsoon period. Observations were recorded on soil microbial population, incidence of foot rot, slow decline and yellowing. Incidence of *Phytophthora* was not noticed in any of the treatments. But yellowing was noticed in treatments with metalaxyl - mancozeb alone as well as in control. Association of a *Pythium* sp. was noticed in soil baiting in several plots. Populations of *Pythium* and plant parasitic nematodes were comparatively less in all the treatments except control, the least nematode population observed in metalaxyl - mancozeb + carbosulfan treatment.

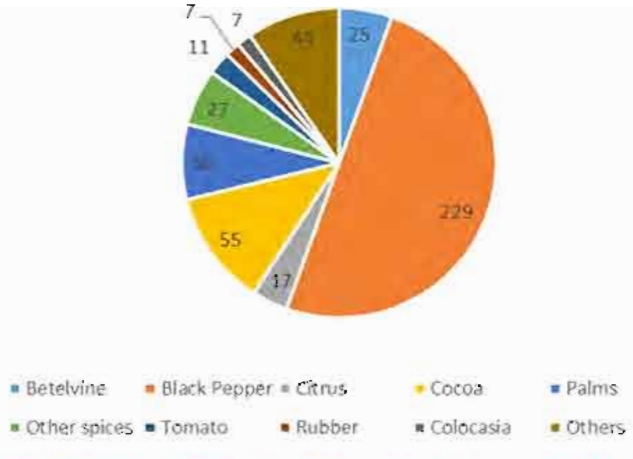


Fig. 6. Crop wise distribution of Phytophthora isolates maintained in the National Repository of Phytophthora.

Fig. 7. Field evaluation of strobilurin fungicides in a black pepper garden at Muthappanpuzha, Kozhikode, Kerala

Evaluation of novel fungicide molecules against *Phytophthora*

Six new fungicide molecules *viz.*, cymoxanil (8 %) - mancozeb (64 %) (Curzate 0.2 %), iprovalicarb - propineb (Melody Duo 0.4 %), propineb (Antracol 0.2 %), chlorothalonil (0.2 %), famoxadone (16.6 %) - cymoxanil (22.1 %) (Equation Pro 0.1 %) that showed 100 % inhibition against *P. capsici* under *in vitro* conditions were tested by challenge inoculation in pot culture. The chemicals were applied prophylactically to one year old potted plants as soil drenching and foliar application and challenged with two isolates of *P. capsici*. Foliar infection was noticed with all the chemicals and the positive control, metalaxyl - mancozeb showed the least infection. Stem infection was noticed only with iprovalicarb - propineb (0.4 %) and root infection only with cymoxanil (8 %) - mancozeb (64 %).

Field evaluation of promising bacterial/actinomycete consortia

A field trial was taken up in farmer's plot with promising combinations of bioagents *viz.*, *Pseudomonas putida* (Bp 25) + *Bacillus megaterium* (Bp 17), *P. putida* (Bp 25) + *Curtobacterium luteum* (TC 10), promising actinomycetes Act 2 + Act 9, Act 5 + Act 9 and *Trichoderma harzianum* + *Pochonia chlamydosporia* (control). The bioagents were given as soil application followed by aerial spraying with Bordeaux mixture (1%) during pre-monsoon and post-monsoon periods. Here the treatments were designed in such a way that each combination contains one antagonist against *Phytophthora* and another against nematodes. Soil samples were collected and analyzed for pH, presence of nematodes, *Phytophthora* and also total microbial load. The nematode population was considerably reduced (upto 87 % reduction) in all treatments compared to control. No *Phytophthora* population or foot rot symptoms were noticed in the trial plot. Another field trial was taken up in farmer's plot with four different varieties of black pepper (IISR Thevam, IISR Shakthi, IISR Girimunda and IISR Malabar Excel) raised by incorporating different *Streptomyces* combinations. The experiment consisted of four treatments *viz.*, *T. harzianum* + *P. chlamydosporia*, Act 5 + Act 9, Act 2 + Act

9 and control. The treatments were imposed during pre- and post-monsoon periods and the plants were observed for growth and disease incidence. No diseases were observed in the initial year of planting. IISR Thevam produced the maximum lateral branches and the experiment is being continued.

Identification of bioactive compounds in actinomycetes

Identification of bioactive compounds from potential *Streptomyces* spp. was done by high resolution UPLC-(ESI) - QToF-MS analysis. A total of 51 compounds were identified from ethyl acetate extract of Act1 (*Streptomyces albulus*) and 11 compounds from butanol extract of Act 25 (*Streptomyces rimosus*) (Table 3). The compounds such as (2E, 6E)-farnesol, (2R)-2, 3-dihydroxypropyl palmitate, dihydrocoriandrin, Gamma-CEHC, N-[(2S, 3R, 4E)-1, 3-dihydroxy-4-octadecen-2-yl] acetamide, salfredin B11, sphinganine, levetiracetam and tetradecenoylcarnitine were first reports from *Streptomyces* spp. The compounds levetiracetam, tetradecenoylcarnitine and N-[(2S, 3R, 4E)-1, 3-dihydroxy-4-octadecen-2-yl] acetamide are not yet reported from any microorganisms (Table 3).

Table 3: List of potential bioactive compounds identified from promising *Streptomyces* spp.

Activity	*Streptomyces albulus* (Act 1)	*Streptomyces rimosus* (Act 25)
Acaricide	-	(2E, 6E)-Farnesol
Antibiotics	brefeldin A, dermadin, fusaric acid, salfredin B11	Naphthoquinomycin B
Antifungal	brevianamide F, chokolic acid B,enniatin B, harzianopyridone 1, harzianopyridone 2, isonitrinic acid E, natamycin, trichodermin and zeaenol	Natamycin and brevianamide F
Growth regulator	harzianolide	-
Herbicide	-	maculosin 6
Mycotoxin	roridin A, D, E, L, and enniatin D	verrucarin A

Field demonstration of integrated disease management

The demonstration plots at Muthappanpuzha, Kozhikode are being maintained by imposing respective treatments *viz.*, *Trichoderma harzianum* + *Pochonia chlamydosporia*, Bordeaux mixture + copper oxychloride + carbosulfan and metalaxyl - mancozeb + carbosulfan and also by recording observations regularly. No disease incidence could be observed in the plots when compared to adjacent plots where foot rot incidence was found serious during the year. The two model nurseries established in Kozhikode district (Omasserry and Muthappanpuzha) for production of disease-free rooted cuttings were continued. In the nursery at Omasserry, seven released varieties of black pepper are being multiplied along with a farmer's variety 'Thommankodi' and the farmer sold 12027 rooted cuttings during 2017 - 18. In the second nursery at Muthappanpuzha, five different varieties such as IISR Girimunda, IISR Malabar Excel, Panchami and IISR Shakthi along with a farmer's variety 'Moopparukodi' are being multiplied and the farmer sold around 1720 rooted cuttings.

Pythium deliense - a new report on black pepper

Pythium species was consistently observed in baiting assays of soil collected from the rhizosphere of yellowing and wilt affected black pepper vines from different parts of Kerala. The infected leaf baits when placed on detached leaves of black pepper showed infection within 24 h. The organism was re-isolated from infected leaf, stem and roots of intact black pepper plants of 3 - 4 leaf stage. Root infection was noticed after nine days with no collar infection. Morphological investigations revealed filamentous inflated/torulated sporangia, smooth oogonia, aplerotic oospores, apical intercalary antheridia and bending of oogonial stalks towards the antheridia which are characteristics of *Pythium deliense* (Fig. 8). ITS rDNA amplification using ITS1 and 4 primers, showed a product of 700 bp with 99 % identity to *P. deliense*. Isolates of *P. deliense* grow at a pH range of 4.5 - 10.0, temperature range of 15 - 40°C with optimum temperature as 28 - 32°C. The isolate of *P. deliense* was found highly sensitive to RIL (400 ppm), metalaxyl - mancozeb (0.125 %), famoxadone - cymoxanil (0.1 %), cymoxanil - mancozeb (0.2 %) and propiconazole (0.2 %). *In vitro* screening of potential bioagents showed inhibition by *T. harzianum* and *Streptomyces* strains.

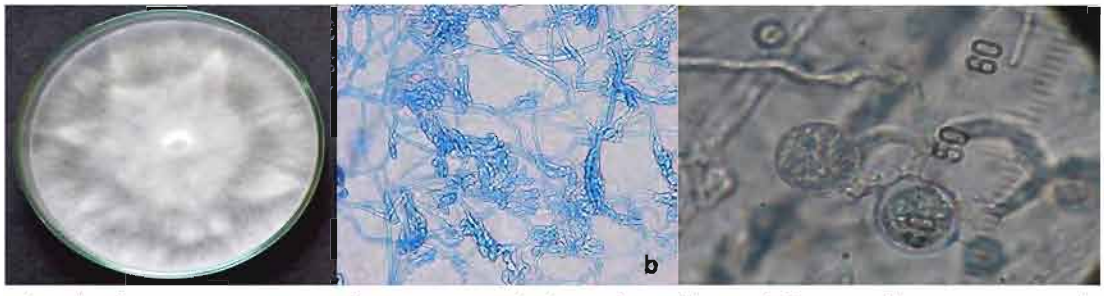


Fig. 8. Colony and mycelial characteristics of *Pythium deliense*: Growth on PDA (*Left*), Torulated sporangia (*Middle*) and Oogonia with curved oogonial stalk (*Right*)

Radopholus similis transcriptome sequencing and analysis

Total RNA was isolated using Norgen total RNA purification kit from *R. similis* adult females and sequenced using Illumina Hi-seq sequencing platform. A paired-end sequencing layout was used and an average read length of 101 bp was obtained. Total number of reads for both forward and reverse sequences were 10796325 each with a GC content of 52 %. For the *in silico* analysis of these reads, the sequences were assembled using *de-novo* assembly tool, Trinity. A total of 85253 contigs were obtained from which the longest contig was 10747 bp and the shortest contig obtained was 201 bp in size. The contig N50 of the assembly was 2420. Unigenes were then obtained using the assembled contigs using the tool CD-Hit. Total number of unigenes predicted were 62312 and were used for prediction of coding regions using the tool, Transdecoder. A total of 50685 cds were predicted which are further used for annotation using Blast2Go.

'Trichorhizosphere' of black pepper

The whole genome soil rhizosphere metagenomics was done to elucidate the microbial population and functional dynamics at the black pepper rhizosphere

by *Trichoderma harzianum* using Illumina Hiseq sequencing. The results suggested that as mycorhizosphere, another micro-ecological niche, *viz.*, 'Trichorhizosphere' also exists. The metagenomics data on black pepper rhizosphere and the Trichorhizosphere were deposited in MG-RAST (Black pepper rhizosphere metagenome Id: Project-mgp 14681; Black pepper Trichorhizospheremetagenomeld : Project-gp 14668) (Fig. 9). The rhizosphere and the Trichorhizosphere metagenomes of black pepper are the important factors in developing any IDM modules in the root ecosystem of black pepper.

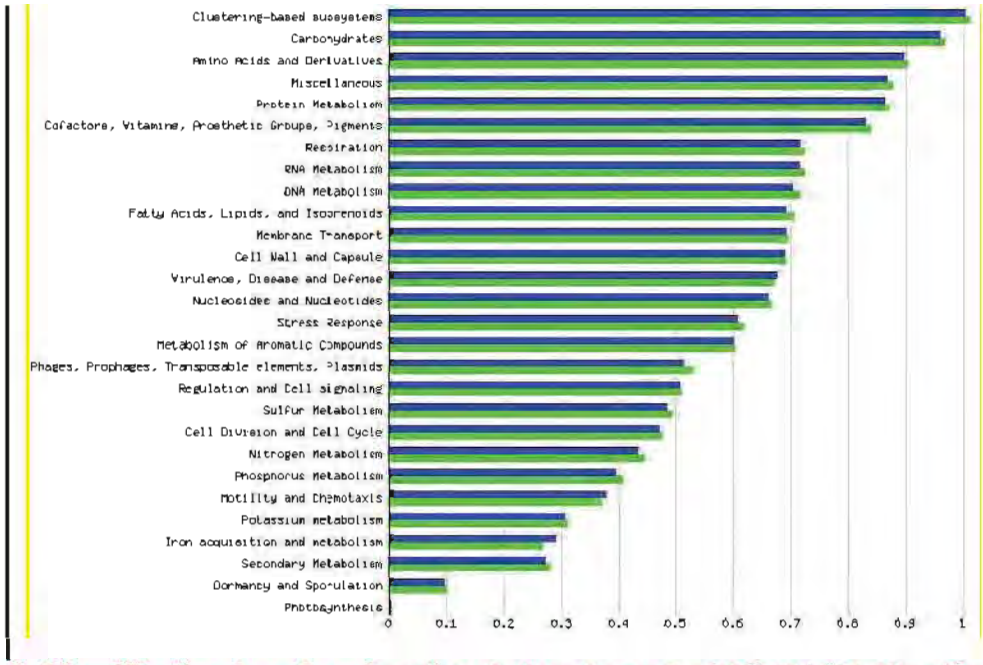


Fig. 9. Classification based on functional abundance by MG-RAST. Blue line: *T. harzianum* treatment is denoted by blue bar and control by green bar. Motility and chemotaxis, iron acquisition and virulence and disease functions are with high abundance in treatment

Trichoderma induced systemic resistance (T-ISR) in black pepper as revealed by tripartite proteomics

Expression dynamics of proteins in tripartite interaction clearly showed the *Trichoderma harzianum* induced systemic resistance (T-ISR), the systemically modulated "defense readiness" in black pepper against *Phytophthora*. The enrichment of strong ROS related activity suggests that, the ROS mediated signaling as major component in T-ISR in black pepper. The isoflavanoid pathway and lignin synthesis are also found to be important component of T-ISR in black pepper. The proteins identified in this study are considered as quantitative resistance candidates mediated by *T. harzianum* in black pepper (Fig. 10). The T-ISR proteins from the tripartite interaction are the possible candidates for studying the defense signaling mechanism, designing the new molecules as inducers of defense and using it in field condition.

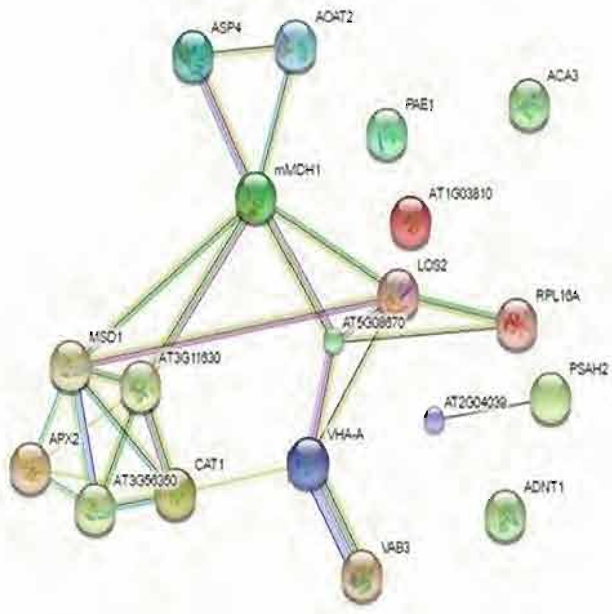


Fig.10. STRING based protein interaction network of major marker proteins from *Trichoderma* primed (72 hai) and *Phytophthora* infected (24 hai) black pepper

Host resistance

The analysis of five R gene loci from transcriptome revealed the presence of *NB-ARC* and coiled coil domains. The *PnCNBS 5* and *PnCNBS 1* were found to have high similarity to *RPM 1* type R gene. The loci *PnCNBS 4*, *PnCNBS 2* and *PnCNBS 3* were found to have similarity to *RPP1 3*. The conserved domain search showed that the *Piper* R gene locus *PnCNBS 5* and *PnCNBS 2* with *RX-CC_* like super family and *NBARC* super family domains. The *PnCNBS 3* showed LRR (LRR 8 super family) and *PLN00113* (leucine rich repeat receptor like protein kinase) domains. The *PnCNBS 4* was having *NB-ARC* super family domain. R gene loci *PnCNBS 5*, *PnCNBS 3* and *PnCNBS 2* showed higher expression in susceptible variety in the early hours of infection while resistant genotype recorded its down regulation during the infection till late hours suggesting that the selective down expression of these loci may be attributing resistance to the variety IISR Shakthi. These R genes may be the susceptibility genes (S-genes) in black pepper for *Phytophthora* in Subhakara. The R gene locus *PnCNBS 4* and *PnCNBS 1* showed their direct involvement in resistance towards *P. capsici* in IISR Shakthi.

Antimicrobial peptides

By using label-free proteomics strategy, the black pepper peptidome associated with the innate immunity against *Phytophthora* was elucidated. The occurrence of both cysteine rich, cysteine free AMPs from a complex sample and some major AMP signatures as innate immunity factors against *Phytophthora* in black pepper were identified (Table 4).

Table 4: Annotation of black pepper AMPs using CAMP R3, APD and PhytAMP database

Black pepper AMP ID	CAMP R3	APD	PhytAMP
BpAMP1	Crystal structure of the hexameric anti-microbial peptide channel dermcidin	Dermicidin	No entries
BpAMP2	Anti microbial peptide (*Aspergillus clavatus*) CAMPSQ2291	AcAMP (*Aspergillus clavatus*)	Snakin
BpAMP3	Buforin (CAMPSQ277)	Buforin (Toad)	No entries
BpAMP4	Lingual antimicrobial peptide (defensin family)(SQ1412)	Beta defensin	Ar-AMP Hevein
BpAMP5	NMR Structure of CXC chemokine CXCL11/ITAC	Chemokine	GASA-like Snakin
BpAMP6	Maximin-H7 (SQ1780)	Temporin (cationic)	
BpAMP7	Prepro-beta-defensin 1 (SQ2648)	Beta defensin	Ee-CBP leaves (Hevein)
BpAMP8	Gamma-thionin (SQ2567)	Rs-Afp 1 Plant defensin	At-AFP1 Defensin
BpAMP9	Ponericin-L2 (SQ218)	Ponericin	No entries
BpAMP10	Winter flounder 1 (pleurocidin family) (CAMPSQ861)	Winter Flounder 1	No entries
BpAMP11	Ap (antifungal) (CAMPSQ3306	Ap	No entries
BpAMP12	Chrombacin (CAMP SQ2811)	Chrombacin	No entries
BpAMP13	Pilosulin 3 (CAMPSQ495) (from insect ant)	Pilosulin 3	No entries
BpAMP14	Pp-AMP1 (defensin) (CAMP SQ3353)	Plant Pp-AMP1 (Defensin)	Plant Pp-AMP1 (Defensin)
BpAMP15	Brevinin	Brevinin	No entries
BpAMP16	Nigroain-C2 (CAMPSQ3641) from frog	Nigroain C2	No entries
BpAMP17	Defensin-1 (*Apis mellifera carnica*) (CAMPSQ4363)	Royalisin	No entries
BpAMP18	No hit	Odorranain	No entries
BpAMP19	CgUbiquitin (CAMPSQ3702)	Cg Ubiquitin	No entries
BpAMP20	LAP-like antimicrobial peptide (fragment) (defensin) (CAMPSQ 6679)	Beta defensin	No entries
BpAMP21	Ascaphin-5 (human erythrocytes) (CAMPSQ4333	Ascaphin 5	No entries
BpAMP22	Dermatoxin S1 (frog) (CAMPSQ 2946)	Dermatoxin	No entries
BpAMP23	Dahlein 4.3 (synthetic construct) (CAMPSQ2851)	Dahlein	No entries
BpAMP24	CCL 13	CCL 13 chemokine	No entries

CARDAMOM

Genetic resources

A total of 599 cardamom accessions have been maintained at National Active Germplasm Site (NAGS) which consist of 430 accessions from Appangala, 72 accessions from Pampadumpara, 41 accessions from Mudigere and 56 from Sakleshpur. One Malabar type of cardamom was collected from Biligirirangana Hills of Karnataka. Twenty nine accessions were added from Cardamom Research Station, Pampadumpara. Field screening of 230 germplasm accessions for rhizome rot showed moderately susceptible to susceptible reaction, but none of the genotype showed highly susceptible (>50 %) reaction. Leaf blight screening showed moderately susceptible to highly susceptible reaction.

Breeding

Preliminary Evaluation Trial III consisting of 23 inter-varietal F1 hybrids were evaluated for yield, reaction to pest and diseases. The hybrid, Mudigere 1 x IISR Vijetha (324.5 g plant^{-1}, dry weight) recorded highest yield followed by ICRI 4 x IISR Vijetha (236 g plant^{-1}, dry weight). Among these lines tested for *Katte* resistance, three lines *viz.*, GG x IISR Vijetha, Mudigere 1 x IISR Vijetha and Mudigere 2 x IISR Avinash were found highly susceptible. PDI for leaf blight and rhizome rot ranged from 13.33 - 40 % and 16.67 - 33.33 %, respectively.

RNA-seq based digital gene expression (DGE) analysis

Characterization of transcriptome infected with *Cardamom mosaic virus* identified many differentially expressed genes (DEGs) related to multiple biological functions. Crucial differentially up-regulated transcripts associated with viral recognition, anti-viral defense and viral resistance include NSP-Interacting Kinase 1-like gene, acidicendochitinase-like, aquaporin NIP2-1-like, ATP synthase CF1 beta subunit, CBL-interacting protein kinase, DnaJ homolog, Isoflavone reductase-like protein, NADH-plastoquinone oxidoreductase subunit K, pathogenesis-related protein, phosphoinositide phosphatase, photosystem I assembly protein and protein disulfide isomerase. Up-regulation of two transcription factors *GARP-G2*-like and trihelix and three protein kinases such as *CAMK_CAMKL-CHK1*, *RLK-Pelle_WAK* and *RLK-Pelle_LRR-II* were also found.

Crop management

Shade adaptation mechanism

The diurnal variation of net photosynthetic rate (P_n) showed a unimodal type of curve under shade (Fig. 12). The mid-day depression is mainly due to decline of leaf stomatal conductance (gs) and reversible inactivation of photosystem II under high light intensities.

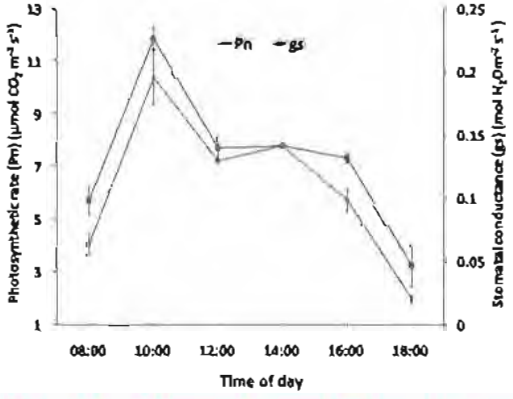


Fig. 11. Diurnal variation in net photosynthetic rate and leaf stomatal conductance

Organic farming

Under the Network Project on Organic Horticulture, trials on nutrient management of cardamom were initiated (Fig. 12). The number of shoots with panicles, number of panicles per clump and number of capsules per panicle were higher in neem cake (NC) + vermicompost (VC) and farm yard manure (FYM) + VC treatments as compared to FYM alone. The yield was significantly higher in NC + VC (445 g fresh plant^{-1}) followed by FYM + NC (350 g fresh plant^{-1}) and NC (370 g fresh plant^{-1}) combinations. Integrated management yielded significantly highest fresh capsule yield (930 g plant^{-1}) followed by fully organic management (660 g plant^{-1}) with lowest yield in conventional chemical management (Fig. 13). Enzyme activities like dehydrogenase, acid phosphatase, alkaline phosphatase and phosphodiesterase were higher under organic management as compared to chemical management. Pest management trial showed higher capsule yield in alternate application of Spinosad and *Lecanicillium* and Spinosad with *Trichoderma harzianum* and *Pochonia chlamydosporia* than control with <4 % incidence of thrips damage on capsules.

Fig. 12. Field view of cardamom under different management systems

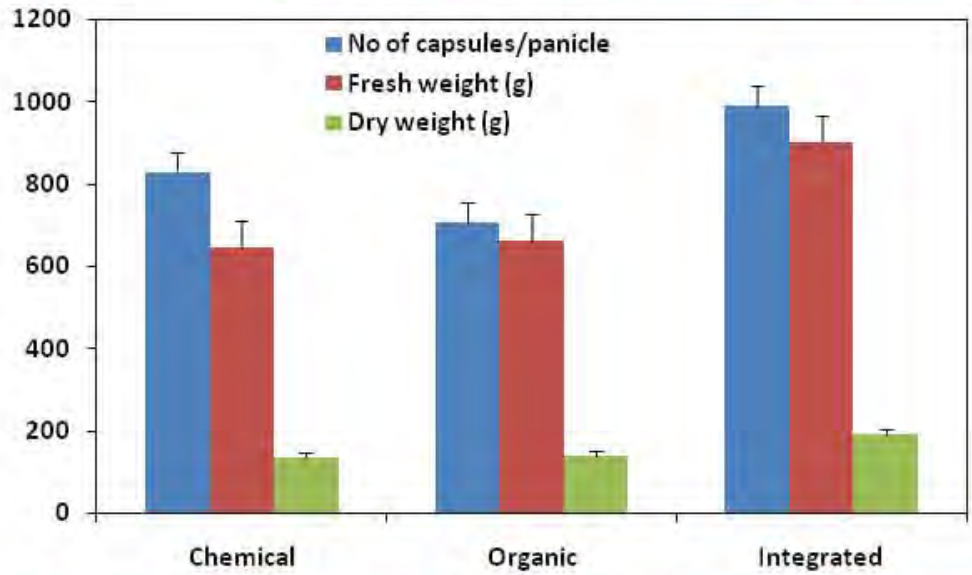


Fig. 13. Effect of different management systems on yield parameters of cardamom

Plant health management

Complete genome sequencing of *Banana bract mosaic virus* (BBrMV) causing chlorotic streak disease of cardamom

The complete genome sequence of *Banana bract mosaic virus* (BBrMV), a *Potyvirus* belonging to the family Potyviridae causing chlorotic streak disease of cardamom in India was determined for the first time from a naturally infected cardamom var. *Njallani Green Gold* through reverse transcription PCR using nine sets of primers designed to different overlapping regions of the genome (Table 5; Fig. 14). The genome consists of a single open reading frame (ORF) of 9372 nucleotide (nt) potentially coding for a large polyprotein of 3124 amino acids with a molecular weight 354.323 kDa and untranslated regions both at 5' (128 nt) and 3' (208 nt) ends (Fig. 15). The complete nt and amino acid sequence of the polyprotein of BBrMV-Cardamom shared maximum identity of 96.7 % and 97.2 %, respectively with BBrMV isolate infecting banana from India (designated as BBrMV-TRY) (GenBank accession number HM131454), followed by BBrMV isolate infecting flowering ginger (*Alpinia purpurata*) in Hawaii, USA (94.5 % and 96.4 %) (designated as BBrMV-Ginger) (GenBank accession number KT456531) and BBrMV isolate infecting banana in Philippines (94.5 % and 96.3 %) (designated as BBrMV-PHI) (GenBank accession number Dq851496). The A/T rich (60.9 %) 5' UTR of BBrMV-Cardamom isolate shared highest identity of 94.5 % with BBrMV-TRY and BBrMV-PHI while 3' UTR of BBrMV-Cardamom (with AT content of 61.5 %) shared highest identity (96.5 %) with BBrMV-PHI followed by BBrMV-Ginger (95.1 %) and BBrMV-TRY (94.1 %).

Table 5: Primers used for the amplification of *Banana bract mosaic virus* infecting cardamom (BBrMV-Cardamom) through RT-PCR

Primer (orientation)	Sequence (5'.....3')	Region amplified	Expected product size (kb)
AIB 338 (F)	AAATAACAAATCTCAGCAAGACAT	5' UTR, P1 & portion of HC-Pro	1.300
AIB 339 (R)	GCTAAATGCTCAAAACACTGC		
AIB 340 (F)	CAGTTGATGGCCCAATTATTC	HC-Pro	1.255
AIB 341 (R)	GCTTAACAGTCCCAGCCTT		
AIB 342 (F)	AAACGATGCATGTCATTGATTC	HC-Pro, P_3 & $6K_1$	1.169
AIB 343 (R)	AGTTAACAAGGTTGTATGAATGG		
AIB 344 (F)	CAAGAAGAGTTTGCTGAGTATC	P_3, $6K_1$ & CI	1.200
AIB 345 (R)	TCCACTACGACATCTATATCC		
AIB 346 (F)	AAGCATTTTGTAGTTGCCACG	CI, $6K_2$ & VPg	1.200
AIB 347(R)	TTCTTGTCCCTCGCATCG		
AIB 348 (F)	GCAACGATTGACAACTATGTC	VPg & NIa	1.144
AIB 349 (R)	AGTGGGACCGCTGAGAAAT		
AIB 350 (F)	GGTTTCAACAAAAGATGGCTTC	NIa & NIb	1.253
AIB 351 (R)	CATAGCAAGAACAACCATTAATG		
AIB 352 (F)	CAGTGGTCAAGAAATTTAAGGG	NIb & CP	1.242
AIB 353 (R)	GCCATAATTTGCCGAAAAGTAG		
AIB 354 (F)	TGCATAGAGAATGGGACATC	CP & 3' UTR	0.654
AIB 355 (R)	AAGGTGTGCACGCCAGC		

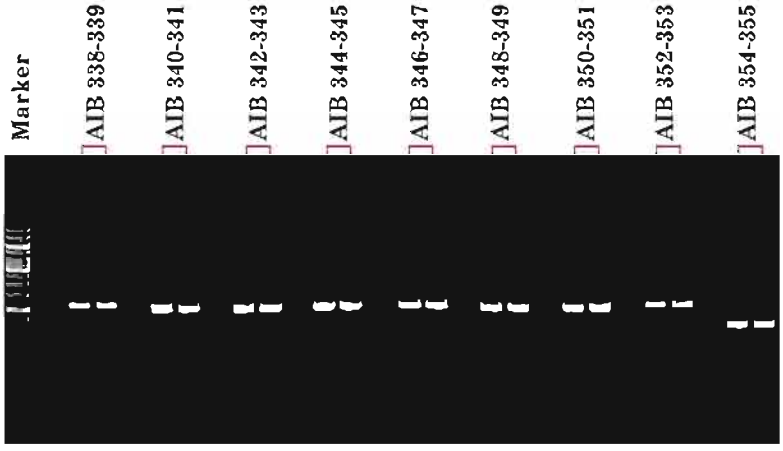


Fig. 14. Agarose gel electrophoresis of RT-PCR products obtained with different primer pairs (as shown in Table 5) of BBrMV-Cardamom

The ORF encodes a polypeptide consisting of a viral P1 protein (328 amino acids) (from 129 to 1112 nt), helper component protein (*HC-Pro*) (457amino acids) (from 1113 to 2483 nt), *P3* protein (347 amino acids) (from 2484 to 3524 nt), *6K1* protein (52 amino acids) (from 3525 to 3680 nt), cylindrical inclusion protein (*CI*) (634 amino acids) (from 3681 to 5582 nt), *6K2* protein (53 amino acids) (from 5583 to 5741 nt), *VPg* protein (190 amino acids) (from 5742 to 6311nt), nuclear inclusion protein a (*NIa*) (243 amino acids) (from 6312 to 7040 nt), nuclear inclusion protein b (*NIb*) (520 amino acids) (from 7041 to 8600 nt) and coat protein (*CP*) (300 amino acids) (from 8601 to 9500 nt) (Fig. 15). The +2 ORF coding for PIPO (Pretty Interesting Potyviridae ORF) is located at nt position from 2948 to 3194 in the BBrMV-Cardamom. All the nine cleavage sites of the putative polyprotein of BBrMV-Cardamom (Y/S, G/G, Q/S, Q/N, Q/N, E/N, E/G, Q/ H and Q/S) were similar to other three BBrMV isolates (Fig. 15). The length and arrangements of different proteins in BBrMV-Cardamom was similar to other BBrMV isolates except for the P1 protein that showed a single amino acid deletion. Analysis of polyprotein and their individual proteins also showed close identity of BBrMV-Cardamom and BBrMV-TRY (Table 6). The phylogenetic analysis also suggested that BBrMV-Cardamom isolate is closely related to other BBrMV isolates.

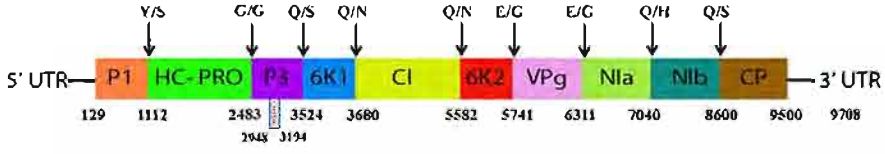


Fig. 15. Genome map and analysis of *Banana bract mosaic virus* infecting cardamom (BBrMV-Cardamom). The position and dipeptide motif of the cleavage sites are indicated. Expression of Pretty Interesting Potyviridae ORF (PIPO) in the +2 frame is also shown. The number shows the start position of each of the proteins

Table 6: Pair wise percent identities in the amino acid sequences of the polyprotein and each of the individual proteins of BBrMV-Cardamom and other BBrMV isolates

BBrMV isolates	Polyprotein	P1	HC-Pro	P3	6K1	CI	6K2	VPg	NIa	NIb	CP	PIPO
Cardamom-TRY	97.2	93.0	98.9	97.6	100	98.7	96.2	96.3	98.7	97.1	96.3	98.7
Cardamom-Ginger	96.4	88.1	98.4	97.6	100	98.2	100	95.7	98.3	96.3	94.4	97.5
Cardamom-PHI	96.3	87.5	98.2	97.1	98.0	97.9	100	96.8	97.9	96.3	94.6	96.2
Ginger -PHI	97.5	90.8	98.0	96.5	98.0	99.0	100	98.9	98.7	98	97.5	98.7
TRY-PHI	96.4	88.1	98.0	95.3	98.0	98.2	96.2	97.3	98.3	96.5	95.4	95.0
Ginger-TRY	96.5	88.1	98.2	95.3	100	98.5	96.2	96.3	98.7	96.5	95.2	96.2

Etiology of *Kokke kandu* disease

Kokke kandu (vein clearing) disease is a serious disease of cardamom reported from Hassan and Uttara Kannada districts of Karnataka. The characteristic symptoms of the disease include continuous or discontinuous clearing of the veins. In advanced stages rosetting, loosening of leaf sheath and severe stunting of plants are observed. The complete degeneration of the affected plants takes place in 2 - 3 years. Though the disease is reported to occur since 1984, the etiology remained unknown. Electron microscopy, serology and PCR failed to give any results on the identification of causal virus associated with the disease. Next generation sequencing (NGS) is known to provide unbiased approach to plant disease diagnosis without prior knowledge of the host or virus. Sequencing of small interfering RNA (siRNA), which is also referred as small RNA sequencing (sRNA) isolated from diseased plant is one such approach. In response to infection by RNA/DNA viruses, the host plant generates specific RNA molecules of 21-24 nucleotide length, called short interfering RNAs (siRNAs). RNA silencing (RNAi) is a cytoplasmic cell surveillance system to recognize dsRNA and specifically destroy single and double-stranded RNA molecules homologous to the inducer, using small interfering RNAs as a guide. NGS of siRNAs offers good opportunities to identify viruses infecting plants, even at extremely low titers, as in symptomless infections, including previously unknown viruses. NGS can provide thousands to millions of siRNA sequences from virus infected plant material that can be assembled to and blasted against NCBI's virus database to identify the virus. In view of this, small RNA sequencing through next generation sequencing approach was used to identify the virus associated with *Kokke kandu* infected cardamom plant. The sRNA population separated from total RNA isolated from diseased plants were added with adapters and subjected to cDNA synthesis. The amplified cDNA library was sequenced through Illumina Hiseq2500 platform. Sequencing resulted 68.6 Mb sized selected reads of 16 - 20 bases. The analyses of the sRNA reads by all three approaches clearly indicated the occurrence of a virus belonging to the genus, *Nucleorhabdovirus* in cardamom.

Insect pests

Plant growth promoting traits of *Lecanicillium psalliotae*

In vitro studies on direct as well as indirect plant growth promoting traits of *L. psalliotae* showed that, the

entomopathogen has both direct and indirect plant growth promoting traits. The direct plant growth promoting traits included the productions of IAA and NH3, and solubilzation of phosphate and zinc. The indirect plant growth promoting traits included production of siderophores and cell wall degrading enzymes. The fungus produced 6.9 ± 0.01 µg ml^{-1} of IAA, 3 DAI. The ability of the fungus to solubilize insoluble phosphate was proved by the formation of clear halo zone around the fungal colony in Pikovskaya's agar medium 96 h post inoculation (SE = 1.3 ± 0.05). The fungus was able to solubilize Zn (SE = 2.0 ± 0.02) as indicated by the formation of halo zone 15 DAI. The fungus showed positive results for NH3 and siderophore production, in the YPD medium. Extracellular protease activity of the fungus was indicated by clearing zones on skim milk agar. The ability of the fungus to produce α-amylase was evident by the production of clearing zone on starch media. Cellulase production by the fungus was revealed by the formation of clear zone on the surface of SDAY/4 amended with 1 % CMC 10 DAI (Fig. 16).

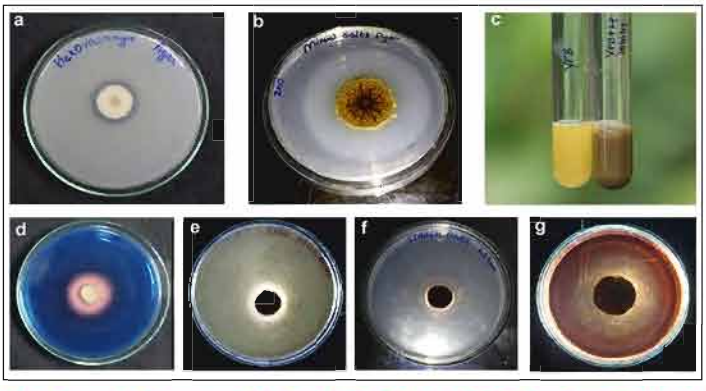


Fig. 16. *In vitro* plant growth promoting traits of *Lecanicillium psalliotae* strain IISR-EPF-02: (a) phosphate-solubilizing activity on Pikovskaya's agar medium (b) Zinc solubilizing activity on mineral salts agar medium (c) production of NH3 in YPD broth (d) Siderophore production on CAS-blue agar (e) protease activity skimmed milk agar (f) α-amylase activity on starch agar (g) cellulase activity on quarter strength Sabouraud's dextrose agar with yeast (SDAY/4) extract amended with 1 % carboxymethyl cellulose (CMC)

Application of *L. psalliotae* significantly influenced the growth of cardamom plants (Fig. 17). The average shoot, root length, terminal leaf length and width in treated plants were 9.6±0.27, 10.9±0.48, 8.4±0.29 and 2.8±0.09 cm, respectively, whereas it was 5.8±0.20, 5.1±0.26, 5.9±0.20 and 2.1±0.08 cm, respectively for untreated plants 40 DAI. The average number of leaves and roots in treated plants (6.1±0.12, 6.6±0.17) was also more. The fungal application significantly increased shoot and root biomass of cardamom plants (average: 132.8±8.48, 26.8±2.44 mg) when compared to untreated plants (average: 66.4±3.89, 10.3±0.90 mg). The treated plants showed a significant increase in chlorophyll a (87 %), b (64 %) and total chlorophyll (82 %).

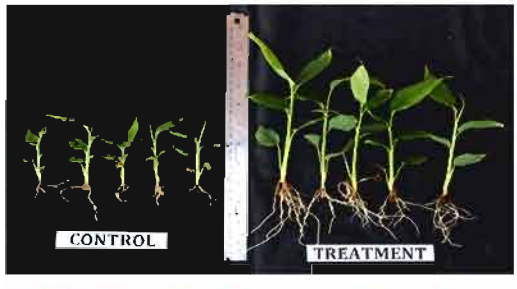


Fig. 17. Growth enhancement of cardamom seedlings applied with *Lecanicillium psalliotae* strain IISR-EPF-02 (40 DAI)

Antagonistic activity of *L. psalliotate to other phytopathogens*

Antagonistic activity of the fungus against major plant disease causing pathogens, *Phytophthora* spp. was studied. The fungus was antagonistic to *P. capsci* and *P. meadii* under laboratory conditions indicating *L. psalliotae*'s potential as biocontrol agent with broad spectrum of disease suppression.

Evaluation of IPM module against cardamom thrips

Evaluation of IPM strategies against cardamom thrips was continued at Wayanad, Kerala for the second year. The results showed that, soil application of *L. psalliotae* was very effective in controlling thrips and the level of control was on par with chemical treatment like spraying with quinalphos. Two sprays of Spinosad (0.0135 %) and soil application of *L. psalliotae* twice alternatively during March, April, May and August were also effective in managing the pest.

GINGER

Genetic resources

Six hundred and sixty eight ginger accessions have been maintained in the field gene bank. The ginger germplasm conservatory was enriched with 20 ginger accessions and six *Zingiber* spp. collected from Meghalaya and Assam.

Yield evaluation

Eight accessions were evaluated to find out the promising elite genotype in terms of high yield and low fibre content. Among the accessions, Acc. 278 was found to be promising.

Mutation breeding

Ten M1V5 and 102 M1V10 mutants have been maintained. Three potential mutants identified against *Pythium* sp. (V 0.5/2, R 0.8/1 and R 1.25/4) and three potential mutants against *Ralstonia solanacearum* (HP 0.5/2, HP 0.5/15 and M 0.5/1) were multiplied for further evaluation. The irradiated M1V1 and M1V2 ginger mutants were subjected to first round screening against soft rot using *P. myriotylum*. The shortlisted 29 mutants were subjected to second round of screening and five mutants survived.

Induction of polyploidy

The rhizome buds of IISR Rejatha were submerged in different concentrations of colchicine (0.025, 0.050, 0.075 and 0.1 %) solution for 24 h and 48 h to induce polyploidy. The chromosome number analysis of rhizomes harvested from the plants derived from colchicine treated buds confirmed tetraploidy (2n = 44) in two of them. Both were derived from buds treated with 0.1 % colchicine for 48 h (0.1/48/3 and 0.1/48/5). These two promising tetraploids (Fig. 18) are being multiplied and characterized.

Fig. 18. Normal (a) and induced polyploids(b&c) in ginger

Crop management

Optimizing fertigation dose

The objective of the experiment was to standardize a soil less mixture and also fertigation schedule for ginger production. Two years data indicated that, 75 % of recommended dose of fertilizers (RDF) is optimum for maximizing the rhizome yield through fertigation. Accordingly, 75 % recommended dose of fertilizers alone was used in fertigation and it was compared with 100 % recommended dose as solid fertilizers under field condition. In fertigation treatment with 75 % RDF, both soil less mixture as well as potting mixture containing soil, sand and farm yard manure in 2:1:1 proportion were used.

Partitioning, nutrient levels, yield and quality under fertigation treatments

Results revealed that, 75 % of recommended dose of fertilizers supplied through fertigation produced significantly higher rhizome yield compared to 100 % and 50 % RDF supplied through fertigation or 100 % RDF applied as solid fertilizers at monthly intervals. But partitioning to rhizomes was significantly reduced under fertigation treatments compared with that supplied with 100 % recommended dose as solid fertilizers under field condition (Fig. 19). Leaf nutrient analysis indicated higher N, P and K contents in fertigation treatment compared to field grown plants supplied with solid fertilizers while, micronutrient contents were on par. Rhizomes from fertigation treatment had lower starch and fibre content compared to that from the field grown plants supplied with solid fertilizers. Hence, fertigation may be more suitable for vegetable ginger production where low fibre and starch are preferred.

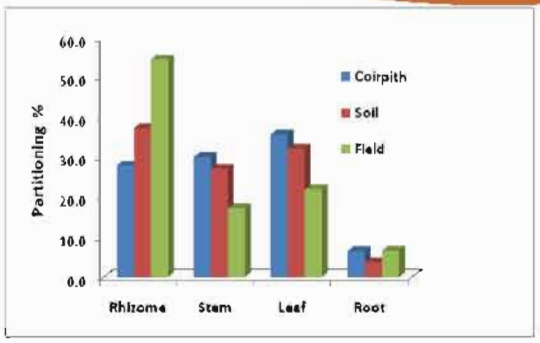


Fig. 19. Dry matter partitioning to different plant parts at 120 days after planting as influenced by treatments

Micronutrient management

A field experiment was conducted to study the effect of micronutrient application (one spray on 60th day and two sprays on 60th and 90th day using IISR Ginger Special) on two varieties of ginger (IISR Varada and IISR Rejatha). The treatments also included the promising Zn solubilizing bacteria (ZnSB2 - *Bacillus megaterium*). The yield data revealed that, irrespective of the treatments, two sprays of micronutrients registered the maximum rhizome yield in both IISR Varada and IISR Rejatha (21.9 and 14.6 kg/3m^2, respectively), which was on par with application of ZnSB2 (21.52 and 12.10 kg/3m^2, respectively) (Fig. 20).

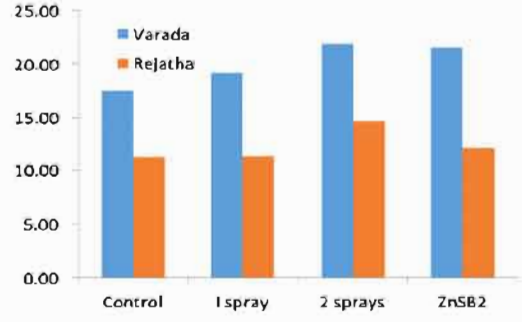


Fig. 20. Effect of micronutrient sprays (one spray on 60th DAP, two sprays on 60th and 90th DAP) and zinc solubilizing bacteria (ZnSB2 - *Bacillus megaterium*) on rhizome yield (kg/ 3m^2) of ginger (LSD P<0.05 - 1.99)

Plant health management

Bacterial wilt
Integrated disease management

The IDM technology developed for management of bacterial wilt was demonstrated in two farmer's plots at Wayanad with the support of Directorate of Arecanut and Spices Development, Kozhikode (Fig. 21).

Fig.21. Ginger fields treated with *Bacillus licheniformis* (a) and calcium chloride (b) in farmer's plot at Wayanad, Kerala

Before planting, the soil was indexed for the pathogen and solarized for 50 days which is a key component of the technology. Under the organic system, a biocontrol agent, *Bacillus licheniformis* (GAP107, MTCC 12725), was deployed for control of the disease while, in the inorganic system calcium chloride was used. These treatments were imposed at the time of planting and at 30, 45, 60 and 90 days interval. No wilt or soft rot incidence was noticed in both the plots, whereas the control and adjacent plots showed >30 % disease incidence. Absolutely disease-free rhizomes were obtained at the time of harvest from both the plots. The average yield in calcium chloride treated plots ranged from 13.90 - 15.19 kg (fresh) bed^{-1} while it was 8.26 - 10.37 kg (fresh) bed^{-1} in *B.* licheniformis treated plots. The technology is being further demonstrated through KVK at five FLDs.

Leaf blight disease
Bipolaris rostrata, a new report

Based on morphological characterization and molecular studies, leaf blight causing fungal isolate was identified as *Bipolaris rostrata* (Drechs.) Shoemaker [synonym - *Exerohilum rostratum*]. This is a new report on ginger and the disease is found to be an emerging disease in most of the ginger growing areas. The fungus, *B. rostrata*, produced brown to dark brown coloured conidia with cylindrical shape and round at both ends, 2 - 11 septate with bipolar germination (Fig. 22). Total genomic DNA was extracted from 3 days-old pure culture of the fungus grown in potato dextrose broth. *ITS* region was amplified with the universal primers (*ITS-4* and *ITS-5*) and β-tubulin gene was amplified with specific primers (*BTUB-F* and *BTUB-R*) and sequenced (Fig. 24). The nucleotide sequences shared 99 - 100 percent maximal identity with Genbank derived sequences of *B. rostrata*. Pathogenicity trials conducted with *B.* rostrata, *Colletotrichum gloeosporioides*, *Colletotrichum capsici* and *Fusarium oxysporum* on ginger varieties IISR Rejatha and Rio-de-Janeiro confirmed their pathogenicity.

Fig. 22. *Bipolaris rostrata*, a new report on ginger (*from left*) Culture, Conidium, Germinating conidia and Bipolar germination

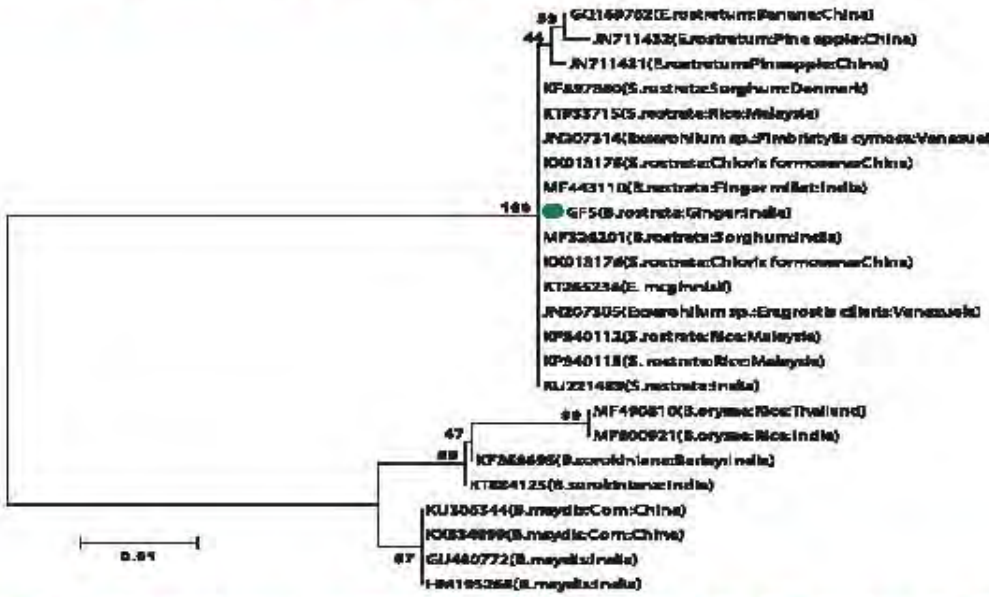


Fig.23. Phylogenetic tree constructed with sequences of the ITS region of rDNA of *Bipolaris rostrata* infecting ginger and sequences from GenBank (indicated by database code), using the neighbor-joining method. The numbers above or underneath each knot indicate the frequency (in percentage) of each branch in bootstrap analyses of 1000 replicates

Screening of fungicides against foliar pathogens

Ten fungicides were evaluated under *in vitro* conditions against *B. rostrata* and *C. gloeosporioides*. The fungicides tebuconazole (0.1 %), carbendazim - mancozeb, cymoxanil - mancozeb and hexaconazole were found to be effective under *in vitro* conditions against both the pathogens. The most effective chemicals [tebuconazole (0.1 %) and carbendazim - mancozeb (0.2 %)], along with biocontrol agents (*Trichoderma harzianum*, *Bacillus amyloliquefaciens* and apoplastic bacteria) were tested against ginger foliar diseases under pot culture conditions. Pot culture studies indicated that, seed treatment and spraying of 0.1 % tebuconazole (disease severity - 18.75 %) was found to be effective in managing foliar diseases of ginger compared to control (disease severity - 63.24 %).

Studies on pink pigmented facultative methylotrophs

Epiphytic pink pigmented facultative methylotrophs (PPFM) were isolated

from ginger leaves and stem. A total of 60 PPFMs were selected based on their colony morphology and distinct pigmentation. All the isolates tested were Gram^{-ve} and rod shaped. They were screened against major five pathogens of ginger *viz.*, *Pythium myriotylum, Colletotrichum gloeosporioides, Fusarium oxysporum, Macrophomina phaseolina* and *Sclerotium rolfsii.* Out of the 60 isolates, seven isolates were proved as efficient antagonists with the ability of chitinase and siderophore production. Additionally, these isolates solubilized zinc (Zn), phosphate (P) and potassium (K). Among the isolates one isolate was identified as *Luteibacter* sp. using 16S rRNA analysis (Fig. 24). This is the first report of *Luteibacter* as a PPFM, which was also found to be inhibitory to *P. myriotylum* (Fig. 25) under *in vitro* conditions. Some methanol utilizing endophytic fungi were also isolated and are being evaluated against the pathogens.

Fig. 24. *Luteibacter* sp. isolated from leaves of ginger

Fig. 25. Inhibition of *Pythium myriotylum* by *Luteibacter* sp.

Viral disease

The viruses associated with chlorotic streak disease of ginger are unknown though its occurrence is known since 1974. The prominent symptoms of the disease are the appearance of either light green or bright yellow flecks intravenously on the foliage. Electron microscopy of leaf dip preparation of diseased leaves showed presence of isometric particles of about 28 - 30 nm diameter and flexuous rod shaped particles. Our efforts to identify viruses through PCR using primers specific to viruses reported on ginger elsewhere such as *Cucumber mosaic virus, Tobacco mosaic virus* and *Sobemovirus* did not give results. Hence, we attempted small RNA (sRNA) sequencing approach to identify viruses. sRNA population separated from total RNA isolated from diseased plants were added with adapters and subjected to cDNA synthesis. The amplified cDNA library was sequenced through Illumina Hiseq2500 platform. Sequencing resulted 61.3 Mb sized selected reads of 16 - 20 bases. Sequence reads were submitted to the automated VirusDetect pipeline for analysis and were assembled into contigs using Velvet and CLC genomics work bench and contigs were then blasted against BLAST N and BLAST X database from NCBI GenBank. The results clearly indicated the occurrence of a virus belonging to the genus, *Panicovirus* and an *Ampelovirus* in ginger. Confirmation of sRNA results through RT-PCR using total RNA from diseased ginger and primers designed from contigs that mapped to viruses and their sequencing through Sanger method is underway.

TURMERIC

Genetic resources

One thousand four hundred and four *Curcuma* accessions are being maintained in the field gene bank. The germplasm conservatory was enriched with 32 *Curcuma longa* accessions and 13 *Curcuma* spp. collected from Meghalaya and Assam. As part of National Active Germplasm Site (NAGS) on spices and germplasm exchange programme, 51 accessions were shared with other turmeric research centers for research purpose.

Characterization

Fifty turmeric accessions were characterized based on morphological traits according to DUS guidelines. A total of 12 quantitative and 10 qualitative characters were recorded for each turmeric accession.

Curcumin biosynthetic pathway

Curcuma transcriptome was mined for the key rate limiting enzyme of the curcumin biosynthetic pathway *viz.*, phenylalanine ammonia lyase (*pal*). Gene expression profiling was done to validate transcripts showing highest fold expression. Maximum relative expression was seen in case of *pal* and *clpks11*. Expression of the identified phenylalanine ammonia lyase correlated well with high curcumin content and was on par with the novel gene *clpks 11* indicating that, the identified transcript is a part of the *pal* gene putatively involved in curcumin biosynthesis. Transcriptomes developed (based on the Illumina sequencing) from rhizomes of *Curcuma longa* (IISR Prathibha) under normal as well as under nutrient stress conditions were used as the resource for mining the putative MYBs. TblastN analysis was carried on the transcriptome data to Plant MYB transcription factors which are already reported in Plant Transcription Factor Database with an e value cut off of 10^{-15}. About 156 putative contigs showing similarity to MYBs were identified and chosen for further analysis. The contigs selected based on fold change value were shortlisted by confirming the presence of MYB DNA binding domain. The protein and nucleotide sequence of important MYB Transcription factors which are already reported in phenylpropanoid pathway were downloaded. Contigs having motifs common to the already reported activators and repressors of phenylpropanoid pathway were short listed. The phylogenetic tree was constructed using MEGA 6 where putative *Curcuma longa* MYBs (ClMYBs) and the already reported MYBs from other plants were used for the tree construction. Twenty sequences possessed complete opening reading frames (ORF) in ORF Finder.

Genetic improvement

Maintenance of seedling progenies, inbreds and hybrids

First generation seedlings (224 nos), mother genotypes (23 nos), second generation seedlings (462 nos), third generation seedlings (40 nos), first generation inbreds (52 nos), second generation inbreds (6 nos) and inter-varietal hybrids (4 nos) were maintained. One hundred and sixty five F_2 hybrid progenies of H1 (49), H2 (115), H3 (1) and eight open-pollinated progenies of high curcumin line SLP 389/1 were also maintained. Additionally, intercross hybrids (38), back cross hybrids (8), OP progenies of two inter-varietal hybrids

(31) and 75 somaclones were also maintained.

Self-pollination studies

Self-pollination of first and second generation inbreds of 138/11/1, first generation inbreds of 138/7/1, 359/4, 359/2, 65/12, 69/5/22 and a triploid Acc. 65 were performed. Fruit set was obtained in a first generation inbred of 13/7/1, three second generation inbreds of 138/11/1, five second generation inbreds of 69/5/22 and the triploid accession, Acc. 65. Seeds obtained from selfing of first generation inbreds of 69/5/22. I_1 4, second generation inbreds of 138/11/1/I_1-12 and Acc. 65 were started germinating. Two hundred and ninety three third generation inbreds of 138/11/1 and two first generation inbreds of Acc. No. 65 were established as on date.

Chromosome number analysis

Chromosome number analysis was completed in 10 seedlings, 10 hybrids and 10 inbreds. All the second generation OP seedlings analyzed showed 2n = 84. One F_2 hybrid analyzed showed 2n = 81 while, all the other F_2 hybrids analysed showed 2n = 80. Of the ten third generation inbreds of 138/11/1/I_1-12 analyzed, three showed 2n = 84 while, seven showed 2n = 86 (Table 7).

Table 7: Chromosome number in seedlings, inbreds and hybrids of turmeric

Identity	Chromosome Number (2n)
Second generation OP seedlings	
18/7/3	84
18/7/9	84
18/7/13	84
18/12/2	84
18/22/3	84
18/22/5	84
18/22/15	84
20/7/3	84
20/7/9	84
138/39/1	84
F_2 hybrid progenies of hybrid -1 (2n = 82) and hybrid-2 (2n = 80)	
H1F2-5	81
H2F2-5	80
H2F2-33	80
H2F2-35	80
H2F2-36	80
H2F2-39	80
H2F2-41	80
H2F2-42	80
H2F2-50	80
H2F2-61	80
Third generation inbreds of 138/11/1/I_1-12 (2n = 84)	
138/11/1/I_1-12/I_2-2/I_3-9	86
138/11/1/I_1-12/I_2-2/I_3.10	86
138/11/1/I_1-12/I_2-2/I_3.12	84
138/11/1/I_1-12/I_2-2/I_3.14	84
138/11/1/I_1-12/I_2-2/I_3.18	86
138/11/1/I_1-12/I_2-2/I_3.28	84
138/11/1/I_1-12/I_2-2/I_3.31	86
138/11/1/I_1-12/I_2-2/I_3.34	86
138/11/1/I_1-12/I_2-2/I_3.38	86
138/11/1/I_1-12/I_2-2/I_3.41	86

Pollen fertility analysis

Pollen fertility analysis was performed in one first generation inbred, three second generation inbreds and a germplasm accession which showed fruit set. Glycero-carmine staining showed that pollen fertility ranged from 86.23 % to 91.37 % among inbreds and 14.20 % in germplasm accession (Table 8). Second generation inbred 138/11/1/I_1-12/I_2-2 also showed high *in vitro* pollen germination (74.63 %) in Brewbaker and Kwack medium containing 5 % sucrose.

Table 8: Pollen fertility in inbreds and germplasm accession which showed fruit set

Genotype	Pollen fertility by staining (%)
138/7/1/I_1-2	88.18
138/11/1/I_1-12/I_2-1	91.37
138/11/1/I_1-12/I_2-2	86.23
138/11/1/I_1-12/I_2-3	86.75
Acc. No. 65	14.20

Multiplication of promising seedlings and hybrids in the field

Inter-varietal hybrids; H1, H2, H3, seedling progenies; SLP-359/2, SLP-65/12 and 389/1-OP-1 were multiplied in the field. Seedling progeny; SLP 359/2 showed the highest yield of 29.5 kg/3m^2.

Quality analysis in seedlings and hybrids

Quality analysis of two seedlings and two hybrids showed high curcumin content in seedling, SLP 359/2 (5.57 %) followed by SLP 65/12 (4.43 %). In hybrids, Hybrid-1 and Hybrid-2, curcumin content was less than 3 %.

Crop management

Quality evaluation of turmeric cured in concentrated solar thermal turmeric curing unit

In the present study, turmeric (variety Alleppey Supreme) was cured in solar thermal turmeric-curing unit using six different time intervals (15, 30, 45, 60, 75 and 90 min). Curing of turmeric in TNAU turmeric boiler and traditional curing by water boiling method (60 min) served as controls. After curing, the rhizomes were dried under sun on cemented concrete floor. The results revealed that, the time required for drying turmeric cured for 15 min in concentrated solar thermal turmeric curing unit was 21 days (504 h), while a minimum of 9 days (216 h) was required when it was cured for 90 min. Turmeric cured by traditional water boiling method for 60 min took 10 days (240 h) and that cured by TNAU turmeric boiler took 12 days (288 h) for complete drying. Maximum retention of quality was obtained when turmeric was cured for 15 min in concentrated solar thermal turmeric curing unit. On curing, turmeric cured 15 min, the concentration (%) of primary metabolites like carbohydrate, fat, protein and starch content were 46.69, 2.45, 3.10 and 41.69, respectively and the concentration (%) of secondary metabolites like essential oil, oleoresin and curcumin content were 5.51, 10.35

and 3.15, respectively. GCMS profiling of essential oil revealed five important constituents and they were ar-turmerone (45.53 %) followed by β-sesquiphellandrene (2.68 %), α-phellandrene (2.46 %), ar-curcumene (1.34 %) and turmerone (0.25 %). The study revealed that, curing of turmeric in concentrated solar thermal turmeric curing unit fitted with cooking vessel for 60 min was optimum.

Organic farming

Under Network Project on Organic Farming, 11 varieties of turmeric were tested under five treatments *viz*., organic 100 %, organic 75 %, INM (75 % organic + 25 % chemical), INM (50 % organic + 50 % chemical) and 100 % chemical for yield and quality. The soil pH, available P, K, Ca, Mg, Fe, Zn and Cu were significantly higher in 100 % organic, which was on par with 75 % organic followed by 75 + 25 % and 50 + 50 % integrated nutrient treatments. Activities of acid and alkaline phosphatase were higher under organic (both 100 % and 75 %) as compared to integrated management systems (50:50). Significantly higher fresh rhizome yield was recorded in 100 % organic nutrient management and integrated (75:25 and 50:50) (17 kg bed^{-1}) nutrient managements as compared to integrated (50:50) (16.9 kg bed^{-1}) and inorganic (14.5 kg bed^{-1}). Among the varieties, IISR Pragati, recorded significantly highest yield (26.8 kg bed^{-1}) under integrated nutrient management (75:25) followed by Suguna and Sudharsana under organic (100 %) and integrated (75:25) managements. The rhizome yield was lowest under organic (75 %) and fully inorganic nutrient management systems for IISR Prathibha and IISR Alleppey Supreme (8 kg bed^{-1}). Highest curcumin content was observed in IISR Alleppey Supreme (6.2 %) under organic (100 %) with a mean of 5.9 % followed by Suguna (5.9 %). Lowest curcumin contents were recorded by varities; Sobha, Kanthi, Varna and Suvarna under all management systems.

Micronutrient management in turmeric

Field experiments were conducted to study the effect of micronutrient application (one spray on 60th day and two sprays on 60th and 90th day using IISR Turmeric Special) on three varieties of turmeric (IISR Pragati, IISR Alleppey Supreme and IISR Prathibha). The treatments also included the promising Zn solubilizing bacteria (ZnSB2 - *Bacillus megaterium*). The yield data revealed that, irrespective of the treatments, the rhizome yield was markedly higher with IISR Pragati (24.2 - 25.3 kg/3m^2) and maximum yield of 25.3 kg/3m^2 was recorded with ZnSB2. In contrast, the yield of IISR Alleppey Supreme was highest with one spray of IISR Special (15.8 kg/3m^2), while in case of IISR Prathibha, the yield was highest with two

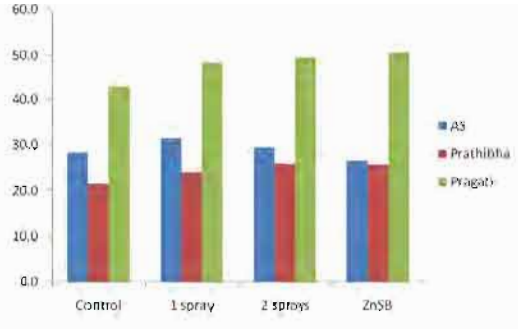


Fig. 26. Effect of micronutrient sprays (one spray on 60thDAP, two sprays on 60 and 90thDAP) and Zinc solubilizing bacteria (ZnSB2 - *Bacillus megaterium*) on rhizome yield (kg/3m^{2}of three varieties of turmeric (IISR Pragati, IISR Alleppey Supreme and IISR Prathibha) (LSD P<0.05 - 1.1).

Promising soil Zn solubilizing bacteria

Out of the six promising Zn solubilizing bacteria (ZnSB), ZnSB2 (*B. megaterium*, KY687496) was found to be the most potential strain owing to its enhanced Zn solubilization *in vitro*, in liquid culture and in soil *per se* (Fig. 27). Such enhanced rates of Zn release by ZnSB2 were attributed to marked decrease in pH owing to enhanced gluconic acid production. In fact, gluconic acid production by ZnSB2 was 1884.7 ± 413.4 µg mL^{-1}, which was 35.3 - 69.7 % greater than the other shortlisted ZnSB isolates (Fig. 29). Further evaluation of ZnSB2 was done in the green house using turmeric as the test crop. The results revealed that, rhizome yield, was at par in the treatments with ZnSB2 + 75 % of Zn (154.2 g ± 36.0 pot^{-1}) and 100 % Zn applied as $ZnSO_4$ (177.2 ± 36.7 g pot^{-1}). The study indicated that, ZnSB2 strain was a potential candidate for enhanced Zn dissolution in soil, which would allow reduced inorganic Zn application rates.

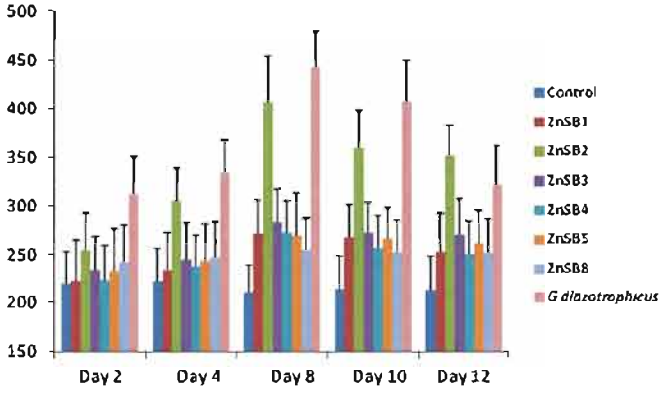


Fig. 27. Zn release rate (mg kg^{-1}) in soils inoculated with Zn solubilizing bacteria (ZnSB1 - *Burkholderia lata*; ZnSB2 - *Bacillus megaterium*; ZnSB3 - *Lysinibacillus* sp; ZnSB4 - *Bacillus* sp.; ZnSB5 - *Burkholderia latens*, ZnSB8-Unidentified) and reference Zn solubilizer (*G. diazotrophicus*) at different days of incubation [Vertical bars indicate standard deviation; LSD (P<0.05) at Day 2- 64.12; Day 4- 45.75; Day 8- 50.77; Day 10- 83.0; Day 12- 62.5]

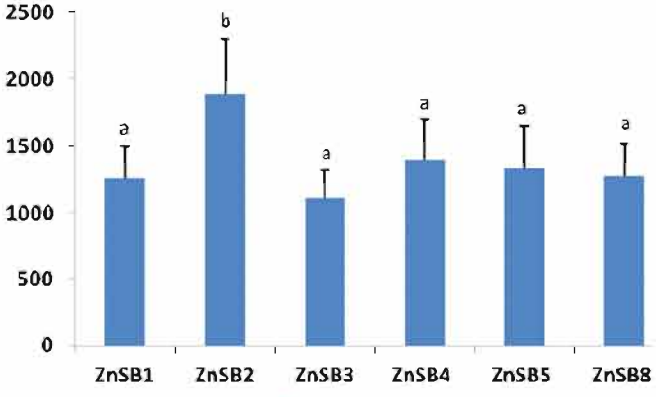


Fig. 28. Gluconic acid production (µg mL^{-1}) by promising Zn solubilizing bacteria (ZnSB1- *Burkholderia lata*; ZnSB2- *Bacillus megaterium*; ZnSB3- *Lysinibacillus* sp; ZnSB4- *Bacillus* sp.; ZnSB5- *Burkholderia latens*, ZnSB8- Unidentified) [Vertical bars indicate standard deviation; different letters indicate significant difference at P<0.05].

Plant health management

Foliar Diseases

Screening of germplasm accessions

Germplasm accessions (100 nos) of turmeric were screened for foliar diseases and leaf blotch caused by *Taphrina maculans* was found to be severe in accessions Narendra Haldi, BSR 1 and 2, Co-2, Rajendra Haldi etc. and the percent disease intensity ranged from 0 - 59.49 %. Accessions BSR 2, SC 61, Acc 219 were found to be infected with leaf spot caused by *Colletotrichum* spp. with percent disease intensity ranging from 0 - 27.5 %.

Insect pests

Incidence of shoot borer in relation to crop phenology and date of planting

Incidence of *Conogethes punctiferalis* infesting turmeric in relation to crop phenology was studied by recording incidence of the pest at fortnightly intervals. Influence of date of sowing on the incidence of the pest was also studied. In the early planted crop, the pest attack started in the first week of July and in normal planting the incidence occurred in the last week of August. The peak incidence was in the last week of August in the case of early planting and it was in the last week of October in the case of normal planting.

Spray schedule optimization of insecticides against shoot borer

Three insecticides (Spinosad, flubendiamide, chlorantraniliprole), which were found to be effective earlier and also a treatment with spraying of chlorantraniliprole (0.5 ml litre^{-1}) and Spinosad (0.5 ml litre^{-1}) alternatively were screened under field conditions at Peruvannamuzhi farm for dose optimization against the shoot borer. The insecticides were tested at three doses: 0.3, 0.5 and 1.0 ml per litre. All the tested insecticides were highly effective against the pest even at lower concentrations against the borer.

TREE SPICES

Genetic resources

Clove

One accession of little leaf clove, one accession of Pechi Parai Clove (PPCL) (1) and six seedlings of Madagascar clove from Tamil Nadu were added to the germplasm.

Garcinia

In an exploration trip to North East India, seven accessions of *Garcinia* were collected and established. The collection includes *G. lancifolia, G. pedunculata* and three unidentified species. Three high yielding accessions of *G. gummi-gutta* were collected from NBPGR Regional Station, Thrissur. Among this, one of the accessions has an added advantage of early fruit maturity. Two exotic species collected from the farmer's field were also added to the germplasm.

Cinnamon

Six accessions of *Cinnamomum* were collected from Karbi Anglong and Dima Hasao districts of Assam.

Allspice

An all spice accession which bear twice a year with bold berries was collected from farmer's field at Wayanad, Kerala.

Conservation and evaluation of monoecious nutmeg

Monoecious nutmeg plants collected from various parts of the country are being evaluated at Chelavoor campus. Few of the seedling progenies of monoecious trees planted at Chelavoor campus are early bearing and has flowered and fruited.

Crop management

Layering in nutmeg

Air layering was successfully carried out and reported for the first time, in orthotropic and plagiotropic shoots of nutmeg with 100 % success. The root initiation was found to be slow in nutmeg and it takes about 75 - 90 days.

Pruning studies in nutmeg

An experiment was conducted for three years to study the effect of pruning in 12 year old yielding nutmeg. The four treatments selected for the study consisted of cutting all the side plagiotropic branches at varying length of 1 m, 2 m and alternative side branches cut at 1 m and 2 m length and control (without pruning). All the trees under study (including control) were detopped at a height of 17 ft. The treatments were replicated eight times. The observations on number of fruits, weight of nuts (fresh and dry) and weight of mace (fresh and dry) were recorded. No significant difference in yield parameters were observed in the first two years of pruning however, in third year, an increase in yield was recorded in moderately pruned trees (all side branches cut at 2 m and alternative side branches cut at 1m and 2 m length) as compared to control (unpruned) and severely pruned trees (all side branches cut at 1 m length). In third year of pruning, the side branches pruned at 2 m length produced more fresh (3136 g) and dry (1286 g) nuts, fresh (536 g) and dry (548.50 g) mace and number of fruits (205.37) over control. Hence, detopping combined with pruning all the side branches at 2 m length resulted in enhanced yield in nutmeg.

Synchronous fruit splitting in nutmeg using plant growth regulators:

An experiment was conducted to study the possibility of synchronized splitting of nutmeg fruit for reducing the harvesting difficulty. In this study, a simple technique of hormone treatment was developed for synchronous splitting (ripening) of nutmeg fruits. The methodology involved harvesting physiologically mature fruits and dipping in 500 ppm ethrel (2-chloroethylphosphonic acid) solution for 10 min and then storing under shade. By this method, 90 – 100 % of fruits got split in 18 - 20 h. Width of the split which helps in easy separation of nut and mace from fruit pericarp was on par with that of naturally split fruits. The dry recovery of nut and mace, nut to mace ratio and fresh and dry weights of the nut and mace of the treated fruits were comparable with that of naturally split fruits. The intrinsic quality i.e., oil, oleoresin and also moisture content of nut and mace of treated fruits were on par with that of nut and mace of naturally split fruits. The great advantage of the method is that it is very effective in preventing aflatoxin contamination (mycotoxin contamination of nut and mace due to soil contact of naturally split fruits on the tree which then fall on the ground). The method is very simple and can be easily practiced by farmers which save time, labour and money both for harvesting and processing of nutmeg. The cost of ethrel treatment works out to be around Rs. 800 per ton of fruits (USD 12.3) which is negligible.

Antioxidants from nutmeg leaf

Among methanol extracts of leaf, nut, mace and pericarp of *Myristica fragrans,* leaf extract showed superior antioxidant activity (DPPH-IC $_{50}$ = 6.3 µg ml^{-1}). To isolate antioxidant principles, methanol extract of leaf was partitioned with ethyl acetate and the ethyl acetate fraction was tested for phenolic constituents. The phenolic constituents were isolated and subjected to HPLC analysis. The antioxidants identified were synapic acid, ferulic acid and quercetin which exhibited excellent DPPH scavenging activity with IC_{50} values 8.36 µg ml^{-1}, 11.36 µg ml^{-1} and 3.74 µg ml^{-1}, respectively.

Nutmeg accessions with superior quality

Twelve accessions of nutmeg collected from Appangala were analyzed for essential oil content and essential oil constituents. The essential oil content in nut and mace varied between 4.7 - 10.3 % and 7.0 - 23.0 %, respectively. CRCN - 26 had highest oil content in nut and mace. By GC-MS analysis, 26 constituents contributing to more than 90 % of the mace oil were characterized. Major constituents were α-pinene (1.97 - 17.41 %), sabinene (9.92 - 51.24 %), β-pinene (0.91 - 14.93 %), limonene (5.09 - 9.29 %), safrole (0 - 20.22 %), myristicin (1.85 - 26.69 %) and elemicin (0 - 26.6 %). Mace oil with high myristicin (CRCN - 26) and high safrole (CRCN - 15, 24, 27, 28 and 36) were identified. Nut oil contained α-pinene (7.97 - 21.82 %), sabinene (26.6 - 50.2 %), β-pinene (1.05 - 22.38 %), limonene (4.35 - 8.64 %), safrole (1.0 - 20.44 %), myristicin (1.43 - 20.37 %) and elemicin (0.25 - 7.66 %). Accessions with high myristicin (CRCN - 15, 21 and 28) and high safrole (CRCN - 24, 27)in nut oil were identified. The fatty acid profile of the nutmeg butter indicated mainly six fatty acids, of which 60 - 86 % was contributed by myristic acid; other constituents were lauric, palmitic, stearic, oleic and linoleic acids. Accessions with >80 % myristic acid in nutmeg butter were identified as CRCN - 18, 20, 24 and 26, with highest in CRCN - 18. CRCN - 26 with high myristicin and high essential oil content in nut and mace was identified as a promising line for pharmaceutical industry and CRCN - 18 with high butter and high myristic acid contents for cosmetics.

Enhancing the economic viability of coconut-based land use systems

The objective was to test and demonstrate the productivity of coconut-based mixed farming systems (black pepper and nutmeg) through site-specific soil management. The treatments for correcting the subsoil acidity (combination of gypsum + liming materials) were imposed for nutmeg in AEU 9 (in Ernakulam district) and for pepper in AEU 11 (Kozhikode district). Soil and leaf test based amendment and fertilizer (including micronutrient) application was imposed at one experimental plot each of black pepper and nutmeg and 4 demonstration plots each of pepper (in Naduvannur and Arikulam panchayats of Kozhikode) and nutmeg (at Mookanur panchayat of Ernakulam). Foliar supplementation of the micronutrients for black pepper and nutmeg was done twice in a year. Application of bioagents and plant protection operations were carried out as per recommended package of practices. The surface soil recorded significantly higher available nutrient status as compared to deeper layer. Similar increase in soil pH was observed in

nutmeg system with the application of lime + gypsum, even if it is not significant. The adoption of site-specific soil fertility management has helped in increasing the yield of black pepper by 76 - 97 % over control (farmer's practice). Similar increase in yield was observed in demonstration plots are various farmer's plots (15 - 30 %). Even though the quality of the produce did not show any significant increase, the BMP treatments showed higher values of oil, oleoresin, piperine contents and bulk density as compared to farmer's practice.

In nutmeg, application of amendments (lime and lime + dolomite) along with site-specific nutrients and micronutrients as BMP has increased the yield significantly over the farmer's practice. The yield increase was upto 50 % in the treated plots in the experimental condition and from 10 - 25 % in farmer's demonstration plots as compared to farmer's practice (Fig. 29). The farmers have registered an increase in income of Rs. 30000 - 40000 by the adoption of BMP on homestead cultivation of nutmeg in one year. Three trainings including scientist-farmer interaction meetings benefitting farmers and extension officials (Fig. 30) were also conducted.

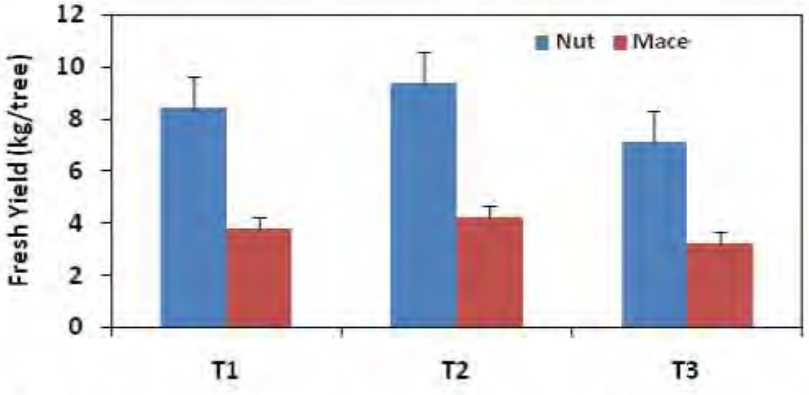


Fig. 29. Effect of treatments on the nut and mace yield of nutmeg: T1 - Best management practice (BMP); T2 - BMP + (Lime + Gypsum); T3 - Farmer's Practice (FP)

Fig. 30. Scientists-Farmers interaction at Naduvannur

Integrated farming system model

Farming system model plot was established at Chelavoor, Kozhikode with spices (black pepper, turmeric), fodder (hybrid Napier, CO-3, CO-6, Congo signal grass, DHN-6), tuber crops (tapioca), fruit crops (banana, pineapple) and cowpea and harvested 700 kg of fodder grass, 12 kg vegetable cowpea, 70 kg tapioca and 70 kg banana. A diary unit with three cows was established and produced 3970 liters milk and about 12 tonnes of fresh cow dung for making composts/manures. During 2017-18, a profit of 0.90 lakhs was realized from the components of integrated farming system. Organic production packages were also released in English and Hindi for major spice crops (black pepper, ginger and turmeric) (Fig. 31).

Fig. 31. Organic production package released in English and Hindi for major spice crops (black pepper, ginger and turmeric)

Agro-processing centre for processing and value addition of spices

An 'Agro-processing Centre' for primary processing of cardamom and black pepper was established at ICAR-IISR Regional Station, Appangala, Karnataka. The primary processing facility for cardamom has equipments like cardamom washer, cardamom drier, cardamom polisher, cardamom grader and a sealing unit. The primary processing facility for black pepper has equipments like pepper thresher, cleaning cum grading unit for black pepper and a spiral separator for cleaning black pepper.

Hypoglycemic potential of cinnamon and turmeric

Methanol extract of cinnamon and cinnamon-turmeric combination showed

anti-diabetic potential in the *in vitro* study. A detailed study on all extracts was taken up under controlled conditions using male Wistar rats at Care Keralam animal house facility at Koratty, Thrissur. The dosage

Table 9: Details of dosage of extracts

Group No.	Group	Treatment for 28 days
I	Vehicle control	Normal rats (6 nos) (Vehicle – 1 ml 100 g^{-1} body weight, per oral)
II	Diabetic control	STZ induced diabetic rats (5 nos) (Vehicle – 1 ml 100g^{-1} body weight, per oral)
III	Low dose	STZ induced diabetic rats (2 nos) received single extract I - 50 mg kg^{-1} body weight, per oral
		STZ induced diabetic rats (5 nos) received combination extract - 50 mg kg^{-1} body weight, per oral
		STZ induced diabetic rats (2 nos) received single extract II - 50 mg kg^{-1} body weight, per oral
IV	High dose	STZ induced diabetic rats (5 nos) received combination extract – 150 mg kg^{-1} body weight, per oral
V	Standard	STZ induced diabetic rats (5 nos) received glibenclamide - 5 mg kg^{-1} body weight, per oral

Diabetes was induced in male rats by administering streptozotocinan, an internationally accepted drug. Group III consists of single extract of cinnamon, cinnamon-turmeric combination and single extract of turmeric at lower dose and group IV is a high dose of cinnamon-turmeric combination. There was significant elevation in blood glucose levels of diabetic control group compared to normal control animals (Table 10) throughout the treatment period. Significant reduction ($p<0.05$) in blood glucose levels were noted in the animal treated with single extract. I and combination extract (150 mg kg^{-1} body weight). It is evident from table 10 that, single extract of cinnamon 50 mg kg^{-1} body weight had reversed blood glucose level from 605 mg dl^{-1} to 95.0 mg dl^{-1} in 28 days time. Similarly, single extract of turmeric @50 mg kg^{-1} body weight reduced blood glucose level to 134 mg dl^{-1} followed by high dose of cinnamon-turmeric combination to 152 mg dl^{-1}.

Table 10: Summary of blood glucose levels during treatment period

Group		Blood glucose (mg dl^{-1})		
		1st day	2nd week	4th week
Group 1 (Normal control)		103.67 ± 4.19	104.67 ± 6.86	88.50 ± 1.67
Group II (Diabetic control)		605.00 ± 1.70	340.60 ± 49.37	335.40 ± 67.30
Group III (Low dose)	Single extract I	438.00 ± 85.00	162.50 ± 13.50	95.00 ± 5.00
	Combination extract	604.80 ± 0.97	245.60 ± 48.44	200.80 ± 60.49
	Single extract	497.50 ± 107.50	171.50 ± 14.50	134.50 ± 2.50
Group IV (High dose)	Combination extract	491.80 ± 62.58	274.00 ± 100.77	152.60 ± 40.17
Group V (Standard)	Glibenclamide	499.40 ± 47.95	168.40 ± 47.17	138.80 ± 33.78

Serum lipid profile increased markedly in diabetic control group compared to the normal animals and statistically significant elevation was noted in Total Cholesterol (TC) and Low Density Lipoprotein (LDL) levels of diabetic control group ($p<0.05$ and $p<0.01$, respectively (Table 11). Animals which received combination of cinnamon turmeric (150 mg kg^{-1} body weight) showed significant reduction in TC levels ($p<0.01$). Single extract of cinnamon, cinnamom-turmeric combination (50 mg kg^{-1} body weight) and higher dose of 150 mg kg^{-1} body weight could reduce LDL levels significantly.

Table 11: Summary of serum lipid profile

Group		TC (mg dl^{-1})	TG (mg dl^{-1})	HDL (mg dl^{-1})	LDL (mg dl^{-1})
Group I (Control)		83.47 ± 7.72*	71.28 ± 7.77	68.57 ± 7.67	0.64 ± 4.10**
Group II (Diabetic control)		130.48 ± 7.37	115.70 ± 25.44	76.68 ± 9.33	30.66 ± 7.56
Group III (Low dose)	Single Extract I	99.15 ± 8.25	90.10 ± 8.50	82.20 ± 8.00	-1.07 ± 1.45*
	Combination Extract	100.7 ± 10.25	76.787 ± 8.75	84.82 ± 11.04	-0.14 ± 4.47**
	Single Extract II	79.61 ± 1.30	52.70± 4.30	67.86 ± 7.05	1.24 ± 9.21
Group IV (High dose)		74.48 ± 14.76 **	67.08 ± 21.41	68.42 ± 10.55	-7.36 ± 6.56 ***
Group V (Standard)		89.56 ± 10.01*	59.78 ± 7.38	76.20 ± 7.78	1.40 ± 6.16**

Vanilla

Wilt diseases

Screening of biocontrol agents against *Fusarium oxysporum* f.sp. *vanillae*

Forty bacterial species isolated from roots, leaves and stem of healthy vanilla were evaluated under *in vitro* conditions against *Fusarium oxysporum* f.sp. *vanillae*. Among the isolates evaluated, seven isolates showed >50 % inhibition and the maximum inhibition of 53.33 % was recorded in VREN1 (root endophyte collected from Kodagu). Thirty one bacterial isolates were tentatively identified as *Bacillus* species using biochemical and phenotypic characterization. PCR amplification with *Bacillus* genus-specific primers BCF1 (CGGGAGGCAGCAGTAGGGAAT) andBCR2 (CTCCCCAGGCGG AGTGCTTAAT) yielded a fragment of approximately 546 bp corresponding to the 16S-23S rRNA intervening region for *Bacillus* sp. (Fig. 32).They were further sequenced and nine of them showed a nucleotide sequence identity of 99 percent with the *Bacillus amyloliquefaciens*.

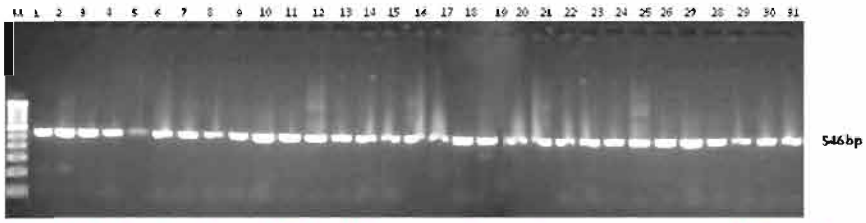


Fig. 27. Detection of *Bacillus* species using genus specific primers

Thirteen fungal microbes were isolated from leaves, stem and roots of healthy vanilla plants. Most of them were non-sporulating except FVREP1 and FVLEP2. Based on the morphological characters of asci and ascospores, they were tentatively identified as *Chaetomium* spp. (Fig. 33).

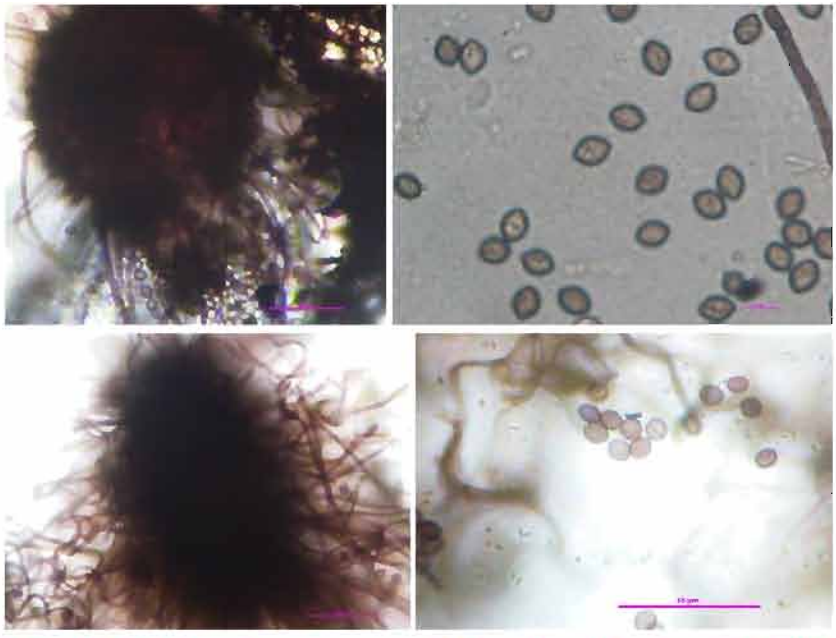


Fig. 33. Asci and ascospores of fungal epiphytes: FVREP1 (*Top*) and FVREP2 (*Bottom*)

***In vitro* screening of volatile antibiotics**

Volatiles of four best isolates of bacterial endophytes *viz.*, VSEn2, VSEn8, VLEp2 and VREn1 which showed maximum inhibition of pathogen under dual culture were assayed for their antifungal properties. These *Bacillus* isolates differed in their capacity to inhibit *F. oxysporum f.sp. vanillae,* the maximum inhibition being recorded in VREn1 (54.11 %) followed by 48.55 %, 26 % and 23 % inhibition by VLEp2, VSEn2 and VSEn8, respectively.

Growth promotion by bacterial endophytes

Growth promotion properties of the bacterial endophytes were studied by analyzing their ability to produce Indole-3-Acetic Acid (IAA), salicylic acid (SA) and siderophores. Out of the 32 strains of endophytic *Bacillus* strains studied, VREn1, VREp4, VLEp2 and VREn5 were found to produce significantly higher amounts of IAA compared to control, the maximum being 12.44 µg ml^{-1} by VREn1. SA production ability was found to be significantly higher in VREn1, VLEp2, VSEp2 and VSEp1 with VREn1 producing the maximum amount of SA (11.21 µg ml^{-1}). Bacterial endophytes producing siderophores exhibited a yellow coloured halo around the bacterial streak on dark blue coloured agar plates. The siderophores produced by *Bacillus* spp. chelated the iron from the dye, chromazurol/ Fe^{3+}/hexadecyltrimethylammonium bromide and turned

dark blue to yellowish fluorescent colour. In order to characterize the type of siderophores produced by these bacterial isolates, $FeCl_3$ test, Tetrazolium test, Arnow's test and Shenker's test were conducted. Most of the isolates were positive to Shenker's test indicating that, the siderophores produced belong to carboxylate group.

Amending liquid media for enhancing shelf life of endophytes

For enhancing survival of *Bacillus* cells in liquid media (nutrient broth), the following chemical amendments were attempted: mannitol 10 mM, galactose 10 mmN, sorbitol 10mM, glycerol 10 mM, glycine 10 mM, trehalose 10 mM, glucose 10 mM, maltose 10 mM and polyvinylpyrrolidone (PVP) at 2 %. Among the different amendments that were tested, glycerol 10 mM showed maximum survival of *Bacillus* cells under the formulated freezed cell formulation. On 60th day observation, the cells were 2.1 x 10^8 cfu ml^{-1} in starch as carrier material and glycerol 10 mM as chemical amendment. Hence, starch and glycerol 10 mM can be considered as the best carrier material and amendments, respectively.

Surveillance and documentation of pests and diseases of spices

Black pepper and cardamom

As part of survey programme, one cardamom and nine black pepper plantations were surveyed for the incidence of pests and diseases in Kodagu district, Karnataka. Three cardamom plots (Hassan district) and one black pepper plot (Chikkamagaluru district) of Karnataka were also surveyed for the incidence of diseases. Leaf spot incidence in ginger was recorded in two locations of Kerala (Kozhikode and Wayanad). In Kodagu, the incidence of black pepper anthracnose ranged from 15 - 25 %. DNA from two leaf blight (in black pepper) inciting isolates of *Colletotrichum* was isolated, internal transcribed spacer (*ITS*) and β-tubulin (*TUB*) gene regions were amplified and sequenced. Sequence comparison with other *Colletotrichum* species indicated that, the fungus is closely related to *Colletotrichum fructicola* and *C. gloeosporioides*.

Ginger and turmeric

Surveys were carried out in 53 locations of ginger and turmeric growing areas of Wayanad district of Kerala, Chamarajanagar and Mysuru districts of Karnataka, Guntur and Krishna districts of Andhra Pradesh, Nizamabad and Jagtiyal districts of Telangana. The incidence of foliar diseases in turmeric grown in Andhra Pradesh and Telangana was found to be very high (60 - 80 %) with the severity ranging from 10 - 40 % (Fig. 34). Circular areas were observed in turmeric fields where the plants were found to be infected with rhizome rot and nematodes. Incidence of rhizome rot disease was found to be very high (37.5 %) with the severity ranging from 5 – 25 %. Root knot nematode (*Meloidogyne incognita*) infestation in turmeric was found to be high (42.4 %) and was generally observed where rhizome and root rot incidences were severe. Leaf blight of ginger characterized by reddish brown lesions was found to be severe in repeated surveys carried out in the ginger growing tracts of Mysuru and Chamarajanagar districts of Karnataka. Different fungi *viz.*, *Bipolaris rostrata*, *Fusarium oxysporum*, *Fusarium* spp., *Colletotrichum gloeosporioides*, *Colletotrichum capsici* etc. were isolated from infected samples of ginger and turmeric collected from various locations.

Fig. 34. Symptoms of turmeric leaf spot (a) and blight disease (b) observed in Andhra Pradesh and Telangana

African snails damaging black pepper and ginger

During surveys in Somwarpet, Kodagu, occurrence of giant African snail causing damage to ginger and black pepper was noticed. Severe damage was noticed at Shanivarsanthe, Kodagu (N 12°25.112' E 075°44.676'). The nature of damage on ginger and black pepper was also studied in and around the infested area. On an average, 2 - 3 snails aggressively feed at the base of the clumps and suppressed young shoots. Different stages of snails weighed between 6.67 to 76 g and their eggs are 5.19 ± 0.09 mm long and 4.16 ± 0.11 mm wide. Length of their shells varied between 10.1 to 125.4 mm and width between 6.4 to 55.9 mm.

Survey of entomopathogens and other natural enemies

Surveys for natural enemies of insect pests of spice crops (black pepper, cardamom, ginger, turmeric and nutmeg) in 16 locations (Wayanad and Kozhikode districts of Kerala and Kodagu, Chamarajanagar and Mysuru districts of Karnataka) resulted in the documentation of three entomopathogenic fungi, one each from *Protopulvinaria longivalvata* (IISR-EPF-16), an unknown caterpillar infesting ginger (IISR-EPF-17) and *Mimegralla coeruleifrons* (IISR-EPF-18). A nucleopolyhedrovirus was isolated from *Spodoptera* sp. (IISR-NPV-05), a highly polyphagous pest of economic importance. An isolate of SpobNPV - Ambalavayal isolate (IISR-NPV-04) was found to be cross infective to *Olepa ricini*. An ichneumonid larval parasitoid attacking ginger shoot borer was recorded from Wayanad district. Incidence of an anthocorid predator (3 - 5 nymphs observed per 25 marginal gall infected leaves) was recorded on *Liothrips karnyi* during January 2018 in black pepper. The nymphs and adults pierce the body of thrips through neck membrane or ventral apex and suck the body fluid. It could feed 3 - 4 thrips day^{-1} and the adult thrips are not preferred by nymphs.

Microbial dynamics in ginger and turmeric rhizosphere soils

Representative soil samples collected from ginger and turmeric survey locations were analyzed to understand the basic and functional microbial dynamics. Total count of fungi and bacteria, nitrogen fixing bacteria, phosphate solubilizing bacteria, *Trichoderma* and actinomycetes populations were recorded. The basic microbial count (total fungi, bacteria and actinomycetes) and functional microbial count (nitrogen fixing bacteria, phosphate

solubilizing bacteria and *Trichoderma*) was found to be highest in soil samples collected from Karnataka. Representative soil samples from surveyed locations indicated higher fluorescein aiacetate (FDA) hydrolysis rate, an indicator of total microbial activity in aerobic soils, in soil samples from Andhra Pradesh and Karnataka. FDA was found to be positively correlated with basic and functional flora in Karnataka soils and high microbial activity 27.4 µg fluorescein g^{-1} h^{-1} was found in soil sample collected from location 9 (Chamarajanagar, Mysuru). Same trend in FDA hydrolysis rate was observed in soil samples collected from turmeric growing regions of Andhra Pradesh. Highest FDA hydrolysis rate was observed in soils collected from turmeric growing areas of Kollipara Mandal, Guntur district. In general, Kerala soil samples were very low in soil enzyme activity as compared with Karnataka and Andhra samples indicating a low overall activity of microbes (Fig. 35).

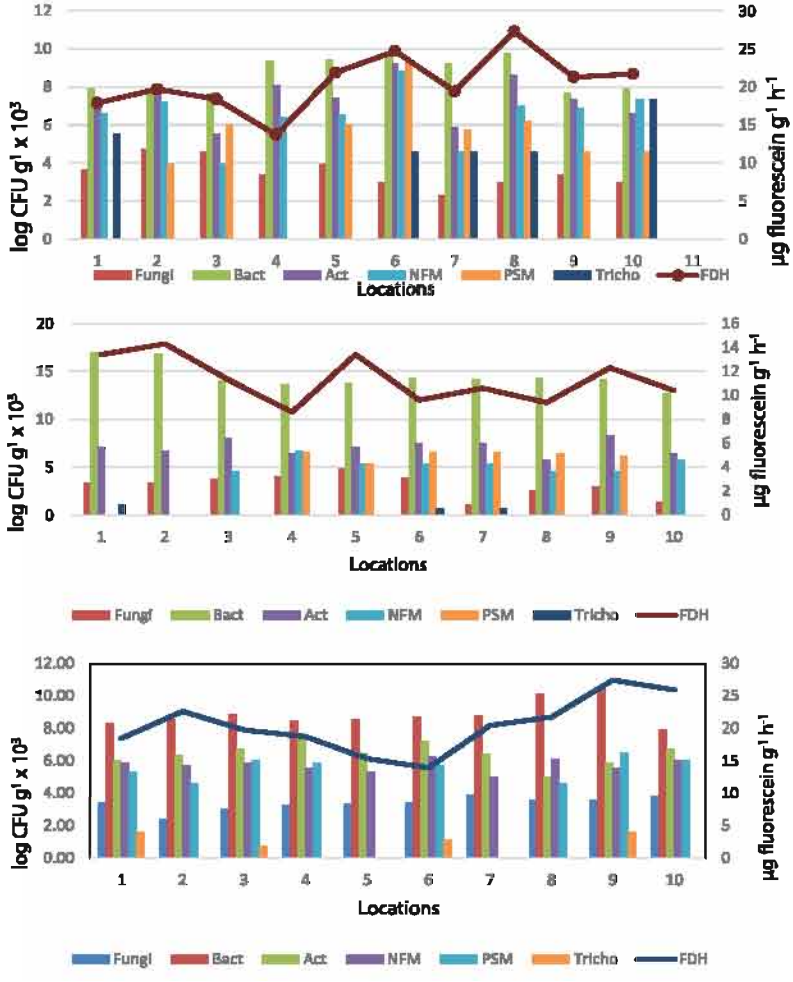


Fig. 35. Microflora v/s enzyme activity of rhizosphere soils from different ginger and turmeric growing areas: Karnataka (*Top*), Andhra Pradesh (*Middle*) and Kerala (*Bottom*)

ECONOMICS, EXTENSION AND IMPACT ASSESSMENT

The sphere of influence of spice technologies

Estimates indicate that the technologies developed and deployed in spices can benefit more than seven million agricultural holdings across the country. The share of marginal and small holdings in the total holdings tends to be more than 90 per cent in most of the spice crops reflecting the potential of technology interventions in benefitting small holder production systems. The focus on spice crops cultivating holdings and their up-liftment in terms of farm income promotes equitable development and social justice.

Yield advantage of spices varieties

The yield relative which measures the advantage of improved varieties from ICAR IISR with respect to the farmer yield levels attained over the XII plan period clearly indicates the potential benefits from varietal technology adoption (Table 12). The yield relative was calculated using attainable yields in farmer plots which reflects a practically attainable yield with average management.

Table 12: Yield advantage of released varieties during 12 FYP

Crop	Average Yield (kg/ha)	Average attainable farmer yield of improved varieties from ICAR IISR	Yield relative (ratio)
Black pepper	237	1203	5.08
Ginger	4068	4757	1.17
Turmeric	4776	5996	1.26
Cardamom(S)	161	791	4.90
Nutmeg	696	1521	2.19

Economic benefit from varietal improvement in nutmeg

The impact of spread of elite varieties in nutmeg (estimated during XII Plan period) can be visualized as the impact on productivity of the crop. Though the entire productivity improvement cannot be attributed to the varietal technology from ICAR IISR, a significant share of the increased productivity can be attributed to the genetic improvement engineered through varietal improvement. A conservative estimate of impact of nutmeg varietal improvement in terms of output (by selecting appropriate base period) shows that an annual additional production of 1000 tonnes could be attributed to the improvement in varietal profile of the crop.

Impact of micronutrient technology in spices

Crop specific designer micronutrient mixture for spice crops was developed at ICAR IISR during the XII Plan period and the technology was released during 2013-14. The technology gives an enhanced yield of 10-15 per cent over control plots and the results were validated across several agro-climatic locations in the country. The technology, still in its infancy with respect to technology diffusion and spread, has been licensed to 16

entrepreneurs in various crops to enhance the reach and impact of the technology. The incremental production resulting from adoption of micronutrient technology in spices by the farmers is estimated to be about 366 tonnes in black pepper, 1755 tonnes in dry ginger, 1995 tonnes in dry turmeric and 15 tonnes in cardamom (Table 13).

Table 13 : Production impact of micronutrient technology in spices

Crop	Technology Spread (ha)	Share in area with MN deficiency (%)	Incremental Yield (kg/ha)	Additional Production (tonnes)
Black pepper	21333	41.72	34	366.2
Ginger	8000	12.90	439	1755.3
Turmeric	10667	14.74	374	1995.1
Cardamom(S)	1333	4.76	22	14.9

Turmeric survey in Andhra Pradesh and Telangana

A field survey of turmeric growers was conducted in Andhra Pradesh and Telangana, which together account for a significant share in area (38.64%) and production (58.98%) of turmeric in India. The study flagged several issues like low level of varietal awareness, the need to offer better cropping choices complementing the specific turmeric varieties, the high cost of plant protection arising from wrong time, wrong chemical and wrong method of pesticide use, need for rationalizing water use, *etc*. The study also highlighted the need for a sensitization drive on integrated plant protection strategies among field functionaries and farmers to address the indiscriminate use of pesticides.

Capacity building and front line interventions programmes for spice sector development in NE states and tribal empowerment.

The project is implemented under Tribal Sub Plan (XII Plan) aiming at livelihood improvement of tribal communities. The selection of the target areas/ institutions and feasible areas/ themes of technology interventions were carried out though collection and analysis of secondary data and participatory rural need assessment and appraisal methods. The major domains of interventions were demonstration of black pepper community nurseries, interventions on irrigation for spices, food crops and vegetables in tribal hamlets, demonstrations of improved varieties of yams and tubers and their popularization as alternative food crops in tribal hamlets, promotion of house hold vegetable farming in hamlets and capacity building programmes on improved cultivation practices of various crops. Programmes were implemented in Vishakapattanam tribal agency area in Andhra Pradesh and Wayanad District, Kerala.

Table 14 : Activities undertaken in different locations

Location	Partner Institutions involved	Activities
Madamkunnu Tribal Colony, Wayanad District, Kerala.	MSSRF, Kalpetta, Wayanad	Two joint meetings and three field visits were carried out to identify the interventions (August 2017)
Vishakapattanam, Andhra Pradesh, Tribal Agency Area	AICRPS centre, Chintappalle and Guntur	Four field surveys conducted in Chintappalle, Paderu, Arku valley and Pedabayalu to identify interventions for black pepper, training and capacity building of FPOs and demonstrations of primary processing of spices Four turmeric boilers (TNAU model and turmeric polishers of capacity 160 kg/hour were installed under the supervision of 4 FPOs.
Priyadarshini Estate, Wayanad District	Mananthavady Tribal Cooperative society.	Estate survey and establishment of black pepper nursery with improved varieties released from ICAR-IISR.
Chiyambam Tribal Colony, Wayanad	MSSRF, Kalpetta, Wayanad	Establishment of irrigation facility with 8 HP diesel pump from two farm ponds

KRISHI VIGYAN KENDRA

Training programmes

The Kendra conducted total one hundred and twenty two training programmes in various disciplines during the year, benefitting 4761 participants. It included five trainings for extension functionaries on ornamental fish culture, aquaponics, freshwater fish culture, Indigenous medicine for animals, spice production for 140 persons, a series of training programmes and demonstrations on jack fruit, nutmeg and ginger processing in different parts of the district. On value addition alone 18 training programmes were organised and 557 farmers were benefitted. KVK also organised two day training on Fresh water ornamental fish culture for youth of age group ranging from 15 to 25 years. A district level one day training on 'Spices propagation and integrated management' was also organized for the field and extension staff of Agriculture Technology Management Agency (ATMA), Kozhikode as a part of Coconut improvement project. KVK celebrated World Fisheries day, III International Yoga day, National Science day, World Environment day and World Honey day. During the period KVK implemented seven FLDs and nine OFTs in 136 farmer fields. World Soil Day was organized at KVK on 5 December 2017. KVK distributed 436 soil health cards to the people of 25 villages.

Sankalp Se Siddi Programme

KVK organized the programme on Sankalp Se Siddhi, at ICAR-IISR Kozhikode, Chelavoor on 25 August 2017 for popularizing the vision, efforts and strategies adopted by Government institutions for doubling farmers income. The programme was inaugurated by Shri M K Raghavan, Hon. MP Kozhikode. Shri. Babu Parasseri, Zilla Panchayat President and Shri. Pradeep Kumar MLA, Kozhikode also witnessed the event. Dr. T.E. Sheeja, Principal Scientist, ICAR-IISR delivered a special lecture on "Doubling farmers' income – Strategies and success stories" during the occassion. An exhibition on technological inputs developed by ICAR-IISR and value added products of self help groups were also held. The programme was attended by about 500 people.

KVK Silver Jubilee Celebration

Hon'ble Member of Parliament Shri Mullappally Ramachandran inaugurated IISR-KVK Silver Jubilee celebrations which was organized on 12 February 2018 to observe the completion of 25 years of IISR-KVK establishment. The MP applauded the KVK activities and congratulated staff for their tireless service to farmers. The programme was presided by Dr. K. Nirmal Babu, Director, ICAR-IISR, Kozhikode. The event was arranged to honour the previous Directors of IISR and previous Programme Coordinators of KVK also. Previous Directors Viz. Drs K.V. Peter, P.N. d.

Ravindran, V.A. Parthasarathy, S. Devasahayam and T. John Zachariah were present and were felicitated.

Technology Week

KVK observed Technology Week during 12 to 17 February 2018 for the benefit of farmers, students and visitors to learn and experience the demonstration of farm machineries, bush pepper production, bee keeping, aquaphonics, hydoponic fodder production, hatchery, *etc*. during which sale of various KVK products was also arranged. DASD sponsored seminar on cultivation and value addition of turmeric, workshop on ginger cultivation, seminars on scientific and traditional dairy management, poultry rearing, trainings on aquaponics, pest and disease management in vegetables, spices, plant propagation, mushroom cultivation and processing were also conducted during the week. A total of about 1500 farmers and 600 students visited and participated in the events.

Fig. 36. a) Silver jubilee celebrations; b) Distribution of soil health card during World Soil Day celebration; c) Inauguration of Sankalp Se Siddi programme

MAJOR EVENTS

Parliamentary Standing Committee on Agriculture visits ICAR-IISR

The Parliamentary Standing Committee on Agriculture visited IISR Regional Station at Appangala, Madikeri on 28 April 2017. Shri. Hukamdeo Narayan Yadav, Chairman of the Standing Committee was accompanied by three members each from Rajya Sabha and Lok Sabha. At Appangala, the Chairman and members were received by Director and staff of the Institute. Dr. T. Janakiram, ADG (HS II) welcomed the dignitaries in the official meeting that ensued. Dr. K. Nirmal Babu, Director, ICAR-IISR made a detailed presentation on the programmes and progress of the on-going research activities carried out by the Institute. The Committee appreciated and congratulated the Institute for its excellent research work in the field of spices. A field visit was also organized for the benefit of the visiting delegation.

Ten important points covering various aspects of spices such as price fluctuation, import duty imposition, spreading of improved varieties and technologies to North East, focusing research activities on food safety, medicinal and nutraceutical properties, value addition, enhancement of budget allocation and manpower to strengthen research programmes etc. emanated out of the deliberations.

Shri. Hukamdeo Narayan Yadav, chairing the meeting held at IISR Regional Station.

Additional Secretary (DARE) & Secretary (ICAR) visits IISR Regional Station

Shri. Chhabilendra Roul, Additional Secretary (DARE) & Secretary (ICAR) visited IISR Regional Station, Appangala, Madikeri on 4 July 2017. Ceremonial planting of the nutmeg variety 'IISR Keralashree' developed by the institute was done by Sh. C. Roul. A field visit and an exhibition depicting the achievements and success stories of technologies developed by the Institute was also arranged. Shri. Roul appreciated the work done by the staff of the station and he emphasized the need to maintain the record of success stories in the farmer's field and also to maintain the record on the farmers benefitted by the station.

Shri C. Roul and staff of ICAR-IISR after ceremonial planting.

SAARC Regional Expert Consultation Meeting

The Regional Expert Consultation Meeting on Technology Sharing of Spice Crops in SAARC Countries, jointly organized by ICAR- IISR and SAARC Agriculture Centre, Dhaka was held at ICAR-IISR during 11-13 September, 2017. The three day meeting was attended by scientists and policy makers from Afghanistan, Bangladesh, Sri Lanka, Bhutan, Nepal and India which also included country-wise presentations and brainstorming session on policy and

technological interventions for spices value chain development in South Asia.

Representatives of SAARC member countries

Symposium on Spices, Medicinal and Aromatic Crops (SYMSAC IX)

The National Symposium on Spices, Medicinal and Aromatic Crops (SYMSAC IX) jointly organized by Indian Society for Spices, Kozhikode and School of Agricultural Sciences & Rural Development, Nagaland University, Medziphema with the theme "*Spices for doubling farmer's income*" was held during 15-17 March 2018 at School of Agricultural Sciences & Rural Development, Nagaland University, Medziphema Campus, Nagaland.

Hon'ble Governor of Nagaland Shri P.B. Acharya inaugurating the Symposium

The symposium was inaugurated by Shri. Padmanabha Balakrishna Acharya, Hon'ble Governor of Nagaland. The most notable feature of the symposium was the B2B meeting between buyers and sellers and also interactive meeting between farmers and scientists. During the symposium a clear cut road map for improvement of spices production and marketing in North Eastern region was suggested.

Turmeric festival and awareness programme on PPV&FRA held at IISR

A two day District level seminar and field day on turmeric titled "Turmeric fest" was organized by ICAR-IISR during 19-20 January 2018. Adv. Shri. V. S. Sunil Kumar, Hon'ble Minister for Agriculture Development and Farmers Welfare, Government of Kerala, inaugurated the Turmeric fest. A turmeric themed exhibition was the highlight of the fest where more than 100 types of turmeric from across the country, several value added products from turmeric, lab equipments used in turmeric research, traded grades of turmeric and farmer varieties were on display. The awareness programme on provisions of the Protection of Plant Varieties and Farmers' Right Act (PPV&FRA) was inaugurated by Dr. B.N.S. Murthy, Horticulture Commissioner, Government of India on 19 January 2018. The farmer participants and other stakeholders were provided an opportunity to experience the varietal diversity of major spices through focused showcasing of varietal wealth in turmeric, black pepper, cardamom, ginger and nutmeg. More than 250 farmers from across the state attended the event.

Adv. Shri V S Sunil Kumar, Hon'ble Minister inaugurating the turmeric fest

A view of spices varietal exhibition

Swachhta programmes

As per the guidelines of ICAR, Swachhta Pakhwara was observed during 16-31 May 2017 and Swachhta Hi Seva fortnight was observed at ICAR-IISR, Kozhikode during 15 September to 2 October, 2017. In order to spread the message of clean and green environment, programmes including planting of spices, avenue trees etc. were organized. Awareness programmes for farmers as well as students and session on organic waste management and literary competitions on swachhta were organized in different languages for the institute staff. Institute undertook cleanliness programmes at Government Mental Health Centre, Kuthiravattam, cleaning of Kozhikode beach, Sarwatra Swachhta (cleaning of public place) etc. Various housekeeping activities were organized to maintain cleanliness in the office buildings, rooms, laboratories, canteen, campus, planting material production units and residential area in which all the staff members actively participated. Emphasis was also given for speedy disposal and weeding out of files.

Snapshots of swcchta pakhwara activities

INSTITUTE TECHNOLOGY MANAGEMENT - BUSINESS PLANNING AND DEVELOPMENT UNIT

Recognition for ICAR-IISR startups

ICAR-IISR was selected for participation in the Festival of Innovation and Entrepreneurship (FINE), a week-long annual event hosted at the Rashtrapathi Bhavan during 19-21 March 2018. Two startups from ICAR-IISR *viz.*, Dr. Chaitra Narayanan, Kodagu Agritech, Karnataka and Mrs. Thabeera K, Natura Nursery, Kozhikode were selected for presenting their technologies. Hon'ble President of India accompanied by Dr. Trilochan Mohapatra visited the startup stall of ICAR-IISR. Dr. Chaitra Narayanan, presented a brief summary about her initiative on biocapsules. The technology comprising encapsulating delivery of agriculturally important microorganisms (biocaspules), a patented technology developed by ICAR-IISR is expected to herald a revolution in biofertilizer industry. The ITM-BPD unit signed thirteen license agreements for technology commercialization/services during 2017-18.

Participation in various events

ICAR-IISR participated in the Agricultural technology show and event organized by ICAR-CTCRI, Thiruvananthapuram during 27-28 October 2017. ICAR-IISR was invited to attend SAFARI 2, an international conference organized by ICAR-CMFRI, Kochi during 15-17 January 2018. IISR also participated in the XI Indian Fisheries and acquaculture forum held during 21-24 November 2017 at Kochi organized by ICAR-CIFT. IISR was an invited participant for the Kisan Mela cum Agribusiness Expo organized by ICAR-CPCRI, Kasaragod during 5-10 January 2018.

Dr. Chaitra Narayanan presenting about her initiative to Hon'ble President of India during FINE 2018 held at Rashtrapathi Bhavan, New Delhi

Table 15: Details of Licenses issued and agreements signed during 2017-18

No	Company/Licensee Name	Technology/Service availed
1	Nirasamruddhi Micronutrients, Kerala	A micronutrient composition for cardamom and a process for its preparation
2	Natura Nursery & Agro Products, Kerala	Commercial production of planting material of black pepper variety IISR Thevam and ginger variety IISR Varada
3	M/s Linga Chemicals, TamilNadu	A micronutrient composition for black pepper and cardamom and a process for its preparation
4	M/s Raja Entreprises, TamilNadu	A micronutrient composition for black pepper and a process for its preparation
5	SRT Agro Sciences, Chattisgarh	Biocapsule technology for PGPR for cereals, vegetables, fruits, plantation and ornamental crops
6	Kodagu Agritech, Karnataka	*Pochonia chlamydosporia*
7	Nature Resorts and Organic Farms India Pvt Ltd, Chattisgarh	IISR Prathibha (turmeric) and IISR Pragati (turmeric)
8	Gene Win Biotech, Hosur, TamilNadu	IISR Varada (Ginger) for conventional and tissue culture production
9	Lean Crop Technology Solutions Pvt. Ltd. Madhyapradesh	IISR Pragati (turmeric)
10	Unique Associates, Chattisgarh	IISR Prathibha (turmeric), IISR Pragati (turmeric), IISR Varada (Ginger)
11	Mannil Spices, Kerala	Spice processing facility for spice/curry powder production
12	The Central Arecanut and Cocoa Marketing and Processing Cooperative, Karnataka	Spice processing facility for graded black pepper
13	Innofarm Agriculture Producer Company, Kozhikode, Kerala	Spice processing facility for spice/ curry powder production

ICAR-ALL INDIA COORDINATED RESEARCH PROJECT ON SPICES

XXVIII Workshop of ICAR-AICRP on Spices

The XXVIII Workshop of ICAR-All India Coordinated Research Project on Spices was held during 10-12 October 2017 at Horticultural Research Station, Dr. Y. S. R. Horticultural University, Lam, Guntur, Andhra Pradesh. The workshop was inaugurated by Dr T. Janakiram, ADG, HS-II, ICAR, New Delhi. The "Best AICRPS Centre Award 2016-17" was presented to three AICRPS centres *viz.*, Rajendra Prasad Central Agricultural University, Dholi, Dr. Y. S. R. Horticultural University centres at Guntur and Chintapalle during the occassion. 'Brain Storming Session on Turmeric" was also held during workshop. Two turmeric varieties *Narendra Saryu*, high yielding and high curcumin variety and *CL-34* -tolerant to leaf spot and leaf blotch; two coriander varieties, *Gujarat Coriander 3*- high yielding, high volatile oil and high linalool contents and *Ajmer Coriander 2*- resistant to stem gall, high linalool and early maturing and one fenugreek variety *Ajmer Fenugreek 5* - high seed yield, high antioxidant content and suitable for green leaf production were recommended for release during the workshop.

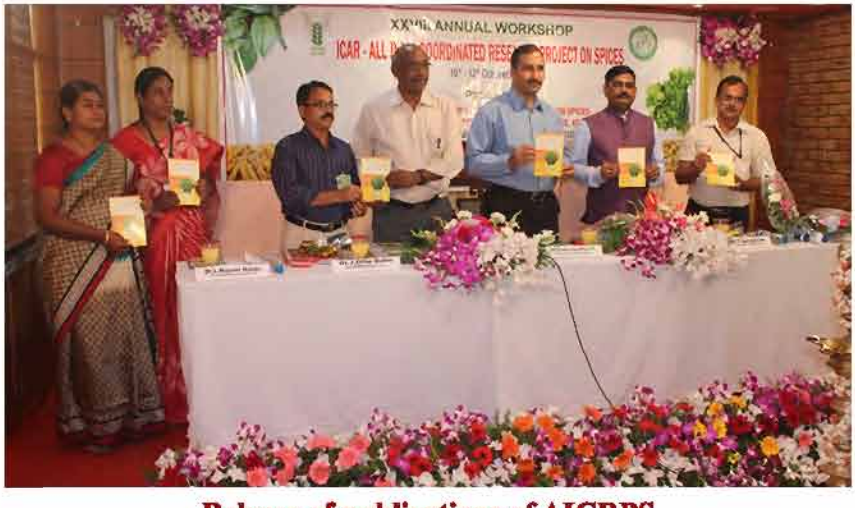
Location specific technologies developed by AICRPS centres

1. Standardization of drip fertigation in black pepper under Kerala conditions
2. Liming in cardamom for Kerala
3. Utilization of herbicides for effective control of weeds in ginger for Andhra Pradesh
4. Micro nutrient management in fennel in Gujarat
5. Management of blight and powdery mildew by spacing and potash application in cumin in Gujarat
6. Organics for yield enhancement in small cardamom in Karnataka
7. Standardization of fertigation in cardamom for Karnataka

Inauguration of AICRPS Workshop

Details of the varieties recommended for release

Crop	Variety	Organization	Salient features of the variety	Recommended for
Turmeric	NDH-8 (Narendra Saryu)	Narendra Dev University of Agriculture & Technology, Kumarganj, Faizabad, Uttar Pradesh	High curcumin content of 5-6%, more number of primaries with yield advantage of 10% over the national check	All the turmeric growing regions of the country
Turmeric	IISR Cassia (D1)	Horticultural Research Station (TNAU), Pechiparai	Less coumarin content	All the cassia growing regions of the country
Coriander	Gujarat Coriander -3	Centre for Research on Seed Spices (CRSS), (SDAU), JAGUDAN	High yield (16.94 q/ha), high volatile oil (0.52 %) and high linalool (72.16%)	Gujarat
Coriander	Ajmer Coriander 2	ICAR-NRC on Seed Spices, Ajmer	stem gall resistance, high linalool content (71.7%) and early maturing type	All coriander growing regions of the country
Fenugreek	Ajmer Fenugreek 5	ICAR-NRC on Seed Spices, Ajmer	High seed yield (17.21 q/ha), high antioxidant content (66.428 mg/ BHTE/ ppm) and suitable for green leaf production under shade net condition in summer season	All fenugreek growing regions of the country



Release of publications of AICRPS

HUMAN RESOURCE DEVELOPMENT

MoU for academic interaction

ICAR-IISR signed Memorandum of Understanding (MoU) on 4 October 2017 with Kerala Agricultural University, Thrissur and on 14 October 2017 with Providence Women's College, Malaparamba, Kozhikode for academic interaction for facilitating collaborative training and post graduate research/doctoral studies.

Training programmes

HRD cell organized training programme on implementation of PFMS in Central Sector Schemes to the officials of Kerala Veterinary and Animal Sciences University on 23 January 2018. HRD cell conducted In-Plant training programmes for 65 B. Tech. (Agrl. Engg.) students from Kelappaji College of Agrl. Engg. & Technology, KAU, Tavanur at ICAR-IISR Experimental Farm, Peruvannamuzhi. HRD cell also facilitated the study visit of final year B.Sc. (Hort.) students from College of Horticulture, Mudigere to IISR Regional Station, Appangala during 22 May to 17 June 2017. One month Summer internship programme for M.Sc. students was organised by HRD cell from 8 May 2017 to 6 June 2017.

Participation of staff members in training programmes

Sl No	Name	Training particulars	Duration	Institute
		Scientific Staff		
1	Dr. A. Ishwara Bhat, Principal Scientist	Training on Priority setting, Monitoring and Evaluation	06-11 October 2017	ICAR-NAARM, Hyderabad
2	Dr. R. Praveena, Scientist	Nanotechnological approaches in pest and disease management	15-24 November 2017	ICAR- NBAII, Bangalore
3	Dr. S.J. Ankegowda, Head, Regional Station, Appangala	Training programme 'MDP on Leadership Development (a pre-RMP programme)'	12-23 December 2017	ICAR-NAARM, Hyderabad
4	Dr. M. Alagupalamuthir solai, Scientist	Recent Developments in Statistical Modeling and Forecasting in Agriculture	28.12.2017 to 17.01.2018	ICAR-IASRI, New Delhi
5	Dr. C. Sarathambal, Scientist	Microbiological analysis of spices/spice products	29.01.2018 to 02.02.2018	Spices Board, Cochin
6	Ms. R. Sivaranjani, Scientist	Training on Purification of natural products and their characterization using QTOF-LCMS/MS	15-01-2018 to 02-02-2018	CSIR-CDRI, Lucknow
7	Mrs. S. Aarthi, Scientist	Writing and Publishing Skills for Scientists	7- 9 March 2018	ICAR-CPCRI, Kasargod
8	Mrs. H. J. Akshitha, Scientist	Writing and Publishing Skills for Scientists	7- 9 March 2018	ICAR-CPCRI, Kasargod
9	Ms. R. Sivaranjani, Scientist	Writing and Publishing Skills for Scientists	7- 9 March 2018	ICAR-CPCRI, Kasargod

Technical Staff				
1	Mr. B.T. Hareesh, Technician (T1)	Good Agricultural Practices	24-28 April 2017	NIPHM, Hyderabad
2	Mr. A. R. Rasmish, Technician (T1)	Good Agricultural Practices	24-28 April 2017	NIPHM, Hyderabad
3	Dr. B. Pradeep, SMS, KVK	Aquaponics	13-15 June 2017	Hi Tech Research & Training Unit, KAU, Thrissur
4	Mr. P. Prakash, Driver (T3)	Automobile Maintenance, Road Safety and Behavioural Skills	27.11.2017 to 01.12.2017	ICAR-CIAE, Bhopal
5	Mr. E. S. Sujeesh, Sr. Technical Officer	Training course on `Irrigation Water Management'	05-08 December 2017	CWRDM, Kozhikode
6	Mr. E. S. Sujeesh, Sr. Technical Officer	Training course on `Irrigation Water Management'	05-08 December 2017	CWRDM, Kozhikode
Administrative Staff				
1	Mr. P. Muraleedharan, AAO	Training on `Government e-Marketing place (GeM)'	21 - 22 August 2017	NIFM, Faridabad
2	Mr. V. V. Sayed Muhammed, Assistant	Training on `Government e-Marketing place (GeM)'	21 - 22 August 2017	NIFM, Faridabad
3	Mr. R.N. Subramanian, AAO	Training on `Government e-Marketing place (GeM)'	18-19 September 2017	NIFM, Faridabad
4	Mr. V.C. Sunil, Assistant	Training on `Government e-Marketing place (GeM)'	18-19 September 2017	NIFM, Faridabad
5	Mrs. C.K. Beena, Personal Assistant	ICAR nominated training for PS/PA & Stenographers	25-31 October 2017	ICAR-NAARM, Hyderabad
6	Mr. R.N. Subramanian, AAO	Refresher course on 'Administration and Finance Management for Section Officers, AAOs, AFAOs & Assistants'	18-23 January 2018	ICAR-NAARM, Hyderabad
7	Mr. P. Muraleedharan, AAO	Refresher course on 'Administration and Finance Management for Section Officers, AAOs, AFAOs & Assistants'	18-23 January, 2018	ICAR-NAARM, Hyderabad
8	Mr. T.D.S. Prakash, FAO	Administration and Finance Management for Under Secretaries, Sr. Admn Officers, SFAOs, AOs, FAOs	1-7 February 2018	ICAR-NAARM, Hyderabad

PhD Awarded

Name	Subject	Title	University	Guide
Ms. Anu Cyriac	Applied Botany	Development of microsatellite markers for small cardamom (*Elettaria Cardamomum* Maton)	Mangalore University	Dr. K. Nirmal Babu
Ms. Suraby E J	Applied Botany	Isolation and cloning of disease resistance gene candidates using degenerate primers from NBS region in black pepper and related Piper species	Mangalore University	Dr. K. Nirmal Babu
Ms. Prameela TP	Applied Botany	Studies on biovar specific diagnostics for *Ralstonia solanacearum* Yabuuchi (Smith) infecting ginger (*Zingiber officinale* Rosc.) and evaluation of apoplastic microbes for biocontrol	Mangalore University	Dr. R Suseela Bhai
Ms. Deeshma K P	Life Science	Studies on seed transmission and genome sequencing of *Piper yellow mottle virus* infecting black pepper (*Piper nigrum* L.)	Kannur University	Dr. A. Ishwara Bhat
Ms. Shina Sasi	Botany	Elimination of *Piper yellow mottle virus* through somatic embryogenesis in black pepper (*Piper nigrum* L.)	Mangalore University	Dr. A. Ishwara Bhat
Ms. Parvathy Viswanath A	Biotechnology	Detection of plant based adulterants in selected market samples of spices using DNA barcoding	University of Calicut	Dr. B. Sasikumar

HINDI CELL

Official Language Implementation Committee Meeting

The Official Language Implementation Committee meeting was held once in every quarter (29.06.2017, 25.07.2017, 11.12.2017 and 20.02.2018) during the year. The committee reviewed the OL implementation and suggested solutions to improve the OL Implementation.

Hindi Workshop

During the year four Hindi workshops were conducted for the benefit of the staff members. In these workshops various experts handled sessions on Hindi noting and drafting, Hindi typing and usage of Hindi language. A Workshop on Hindi typing was organized on 15 September 2017. Dr. V. Balakrishnan, Deputy Director (Implementation), Dr. Herman P.J., Assistant Professor (Hindi), Calicut University and Smt. Mridula C., Assistant Director, (OL), BSNL, Kozhikode delivered a lecture on Hindi noting and drafting on 14 June 2017, 06 December 2017 and 7 February 2018 respectively.

Hindi Week 2017

Hindi Week was celebrated from 14 - 20 September 2017. During this week various Hindi competitions like caption writing, quiz programme on Official Language, word making, Hindi noting and drafting, dictation, paragraph writing, Hindi song, recitation, essay writing, pick and speak, mock press *etc.* were conducted for the staff members. The staff members actively participated in these competitions and cash prizes were distributed to the winners. In the valedictory function of Hindi Week Celebration, sixth edition of Institute's Official Language Magazine "*Masaloon Ki Mehak*" was released by the chief guest Dr. R. Surendran on 20 September 2017. Noting and drafting award was also presented to the staff members who had written maximum Hindi words during the year.

TOLIC Activities

- Ms. N. Prasannakumari, Senior Technical Officer attended TOLIC Sub committee meeting on 24 May 2017, 24 August 2017 and 18 January 2018.
- Dr. K. Nirmal Babu, Director and Ms. N. Prasannakumari, Senior Technical Officer attended TOLIC meeting at Indian Institute of Management, Kunnamangalam, Kozhikode on 28 June 2017.
- Dr. K. Nirmal Babu, Director and Ms. N. Prasannakumari, Senior Technical Officer attended TOLIC half yearly meeting and prize distribution function held at Hotel Malabar Palace on 14 November 2017.
- Ms. Seema M., Senior Clerk attended the Hindi Workshop conducted by TOLIC, Kozhikode on 23 February 2018.

Hindi Award

Ms. N. Prasannakumari, Senior Technical Officer has been awarded "*Rajbhasha Sevi Samman*" by *Bhasha Samanvaya Vedi* on 21 September 2017.

RESEARCH PUBLICATIONS

1.	Aarthi S, Suresh J & Prasath D 2018 Variability and association analysis of curcumin content with yield components in turmeric (*Curcuma longa* L.). Electronic Journal of Plant Breeding 9(1): 295-303.
2.	Agisha V N, Eapen S J, Monica V, Sheoran N, Munjal V, Suseela Bhai R & Kumar A 2017 Plant endophytic *Pseudomonas putida* BP25 induces expression of defense genes in black pepper roots: Deciphering through suppression subtractive hybridization analysis. Physiological and Molecular Plant Pathology 100: 106-116.
3.	Agisha V N, Eapen S J, Suseela Bhai R & Kumar A 2017 Detecting and monitoring endophytic colonization by *Pseudomonas putida* BP25 in black pepper (*Piper nigrum* L.) using quantitative real-time PCR. Journal of Spices and Aromatic Crops 26(1): 1-7.
4.	Alagupalamuthirsolai M, Ankegowda S J, Mohammed Faisal Peeran, Hosahalli Jagannath Gowda Akshitha, Balaji Rajkumar & Narendra Chaudhary 2018 Effect of natural growth enhancer on growth, physiological and biochemical attributes in black pepper (*Piper nigrum* L.). International Journal of Current Microbiology and Applied Sciences 6: 2857-2866.
5.	Alagupalamuthirsolai M, Ankegowda S J & Sharon Aravind 2018 Factors determining the midday depression of photosynthesis in small cardamom (*Elettaria cardamomum* Maton.) under summer climate. Multilogic in Science (7): 525-528.
6.	Anusree Thampi & Suseela Bhai R 2017. Distribution, diversity and antagonistic ability of actinobacteria from black pepper (*Piper nigrum* L.) rhizosphere. Journal of Global Biosciences 6(10): 5260-5288.
7.	Bhai R S, Eapen S J, Kumar A, Aravind R, Pervez R, Varghese E M, Krishna P B & Sreeja K 2017 Mitigating Phytophthora foot rot and slow decline diseases of black pepper through the deployment of bacterial antagonists. Journal of Spices and Aromatic Crops 26(2): 69-82.
8.	Bhat A I, Martin A, John A, Isaac N & Eapen S J 2017 Indian Plant Virus Database – a platform for showcasing research on plant viruses in India. Current Science 113: 27-29.
9.	Bhat A I, Pamitha N S, Gopika A & Biju C N 2018 Complete genome sequencing of *Banana bract mosaic virus* isolate infecting cardamom revealed its closeness to banana infecting isolate from India. Virus Disease DOI.org/10.1007/s13337-018-0443-7.

10.	Blessy M. Baby, Eapen, S.J., Agath Martin and Rosana, O.B. 2017. Radobase –A database on burrowing nematodes infesting tropical and sub-tropical crops. *Indian Journal of Nematology* 47: 197-200.
11.	Deeshma K P & Bhat A I 2017 Occurrence of endogenous *Piper yellow mottle virus* in black pepper. Virus Disease 28:213-217.
12.	Dinesh R, Srinivasan V, Hamza S, Sarathambal C et al. 2018 Isolation and characterization of potential Zn solubilizing bacteria from soil and its effects on soil Zn release rates, soil available Zn and plant Zn content. Geoderma, 321: 173-186.
13.	Karthika R, Prasath D & Anandaraj M 2017 Comparative gene expression studies of candidate genes associated with defense response in ginger and mango ginger post inoculation with *Ralstonia solanacearum*. Physiological and Molecular Plant Pathology. (https://www.sciencedirect.com/science/article/pii/S0885576518300493)
14.	Karthika R, Prasath D, Leela N K, Suseela Bhai R & Anandaraj M 2017 Evaluation of antibacterial activity of mango ginger rhizome extracts against bacterial wilt pathogen *Ralstonia solanacearum*. Journal of Spices and Aromatic Crops 26(2): 95-100.
15.	Krishnamurthy K S, Rema J & Anandaraj M 2017 Synchronous fruit splitting in nutmeg using plant growth regulators. Journal of Plantation Crops 45(3): 190-196.
16.	Leela N K, Muneeb A M, Mukherjee S, Ghosh D & Bhattacharya N 2017 Essential oil content of cardamom (*Elettaria cardamomum* Maton) by Hand-held Electronic nose. Journal of Spices and aromatic crops 26 (2) :125-129.
17.	Mohammed Faisal P, Deeba K & Lakshman P 2017 Extracellular myco-synthesis of silver nanoparticles from *Trichoderma virens* and *Metarhizzium anisopliae*. Journal of Mycology and Plant Pathology *47(4): 424-429.*
18.	Mohammed Faisal P, Lakshman P & Deeba K 2018 Characterization of secondary metabolites from *Rhizopus oryzae* and its effect on plant pathogens. International Journal of Current Microbiology and Applied Sciences 7(3): 705-710.
19.	Neema Malik & Johnson George K 2017 Resistance genes in *Piper colubrinum*: *In silico* survey from leaf transcriptome and expression studies upon challenge inoculation with *Phytophthora capsici*. Applied Biochemistry and Biotechnology DOI.10.1007/s12010-017-2600-7.

20.	Pervez R, Eapen S J & Rajkumar 2017 Screening native entomopathogenic nematodes against semi-looper (*Synegia* sp.) infesting black pepper (*Piper nigrum* L.). Journal of Plantation Crops 45(3): 180-189.
21.	Prameela T P, Suseela Bhai R, Anandaraj M & Kumar A 2017 Development of real-time loop-mediated isothermal amplification for detection of *Ralstonia pseudosolanacearum* race 4 in rhizomes and soil. Australasian Plant Pathology 46:547-549.
22.	Prasath D, Santhosh J Eapen, Sasikumar B, Akshitha H J, Leela N K, Chitra R, Mahender B, Chandrasekhara Rao C, Swargaonkar S L & Nirmal Babu K 2017 A new short duration turmeric variety, IISR Pragati – a boon to Indian farmers. International Journal of Innovative Horticulture 6(1): 89-92.
23.	Renganathan P, Ruíz-Alvarado C, Hernández-Montiel L G, Duraisamy Prasath & Rueda-Puente E O 2017 Evaluation of genetic diversity in germplasm of paprika (*Capsicum* spp.) using random amplified polymorphic DNA (RAPD) markers. Journal of Plant Science and Phytopathology 1: 080-086.
24.	Raghavan Dinesh, Veerarahavan Srinivasan, Sheeja T E, Muthuswami Anandaraj & Srambikkal Hamza 2017 Endophytic actinobacteria: Diversity, secondary metabolism and mechanisms to unsilence biosynthetic gene clusters. Critical Reviews in Microbiology. 45:546-566.
25.	Revathy K A & Bhat A I 2017 Complete genome sequencing of *Cucumber mosaic virus* from black pepper revealed rare deletion in the methyltransferase domain of 1a gene. Virus Disease 28: 309-314.
26.	Sasikumar B, Rema J & Saji K V 2017 A note on a seed sterile nutmeg from the secondary centre of origin. Journal of Spices and Aromatic Crops 26:44-46.
27.	Sasi, S. and Bhat, A.I. 2018. *In vitro* elimination of *Piper yellow mottle virus* from infected black pepper through somatic embryogenesis and meristem-tip culture. *Crop Protection* 103: 39-45.https://doi.org/10.1016/j.cropro.2017.09.004.
28.	Senthil Kumar R, Prasath D, Sharon Aravind, Leela N K, Venugopal M N, Ankegowda S J, Biju C N & Anandaraj M 2017 Evaluation of elite cardamom (*Elettaria cardamomum*) genotypes for yield, quality and resistance to *Cardamom mosaic virus*. Journal of Plantation Crops 45(2): 129-134.

29.	Senthil Kumar, C.M., Jacob, T.K., Devasahayam, S., Stephy Thomas and Geethu, C. 2018. Multifarious plant growth promotion by an entomopathogenic fungus *Lecanicillium psalliotae*. Microbiological Research 207: 153-160.
30.	Senthil Kumar, C.M., Jacob, T.K. and Devasahayam, S. 2017. Evaluation of insecticides and natural product for their efficacy against shoot borer (*Conogethes punctiferalis* Guen.) (Lepidoptera: Crambidae) infesting ginger (*Zingiber officinale* Rosc.). Journal of Spices and Aromatic Crops 26: 86-90.
31.	Shimna K, Krishnamurthy K S & Shamina A 2017 Coumarin, essential oil and total phenol levels in bark and leaves of *Cinnamomum species*. Journal of Plantation Crops 45(3): 200-205.
32.	Sruthi D & John Zachariah T 2017 *In vitro* antioxidant activity and cytotoxicity of sequential extracts from selected black pepper (*Piper nigrum* L.) varieties and *Piper* species. International Food Research Journal 24(1):75-85.
33.	Suseela Bhai, R. and Eapen, S.J. 2017. Disease free planting material-The key stone for successful cultivation of black pepper. Indian Journal of Arecanut Spices and Medicinal Plants 19(4): 3-12.
34.	Thankamani C K, Muthamil Selvan M, Annamalai S J K & Jayashree E 2017 Influence of machine generated potting mixture in the growth of black pepper (*Piper nigrum* L.) cuttings and nutmeg (*Myristica fragrans* Houtt.) seedlings in nursery. Journal of Plantation Crops 45(3): 206-209.
35.	Umadevi P & Anandaraj M 2017 Genotype specific host resistance for *Phytophthora* in black pepper (*Piper nigrum* L.). Physiological and Molecular Plant Pathology 100: 237-241.
36.	Umadevi P, Anandaraj M, Vivek Srivastav & Benjamin S 2017 *Trichoderma harzianum* MTCC 5179 impacts the population and functional dynamics of microbial community in the rhizosphere of black pepper (*Piper nigrum* L.). Brazilian Journal of Microbiology DOI.org/10.1016/j.bjm.2017.05.011.
37.	Umadevi P, Soumya M, Johnson K George & Anandaraj M 2018 Proteomics assisted profiling of antimicrobial peptide signatures from black pepper (*Piper nigrum* L.). Physiology and Molecular Biology of Plants 24:379-387.
38.	Umadevi P, Anandaraj M & Benjamin S 2017 Endophytic interactions of *Trichoderma harzianum* in a tropical perennial rhizo-ecosystem. Research Journal of Biotechnology 2(3): 22-30.
39.	Vandana V V & Suseela Bhai R 2018 Differential expression of PR genes in response to *Phytophthora capsici* inoculation in resistant and susceptible black pepper (*Piper nigrum* L.) lines. European Journal of Plant Pathology 50:713–724.

AGRICULTURAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

AKMU facilitates the IT and ICT related activities of the institute and ensures uninterrupted internet connectivity to all divisions/sections and VPN connectivity to IISR Regional station, IISR Experimental Farm and Krishi Vigyan Kendra. AKMU is also taking care of network security aspects, regular updation of websites of the institute, AICRP on spices, SpicE-Library, BPD and developed websites for SYMSAC IX. Displaying circulars and other materials in the website and intranet portal, maintenance of SpicE-mail, webserver, etc., were also done. The Personnel Management Information System Network of ICAR (PERMISnet II) and Project Information & Management System of ICAR (PIMS-ICAR) were updated. The repair and maintenance of computers and its accessories, audio visual support to various activities were also facilitated through AKMU. Apart from this AKMU assists in analyze and interpret geographical data using ArcGIS & DIVA GIS and statistical analysis of scientific data using SAS and other statistical software and developing mobile Applications

Mobile Application

Developed a Mobile App. (Android) ICAR-IISR Turmeric. This mobile app is to help farmers by getting relevant information quickly. With click of a button, they can get the information on cultivation, management, varieties, plant protection etc. It is a bilingual (English & Hindi) application and freely downloaded from Google play store.

Mobile App. : ICAR-IISR Turmeric

LIBRARY

IISR library subscribed thirty Indian Journals and seven foreign journals / databases. Web-scale discovery services (WDS) was continued using Summon Discovery service up to September 2017. Library purchased eleven books. Two hundred seventy nine other publications were received on gratis basis. As part of exchange programme two hundred and twenty publications were collected from various organizations. Library continued to be a part of CeRA, e-journal consortium of ICAR and catered thirty five document delivery requests from CeRA partners. The scope of digital institutional repository, 'DSpice', was widened by adding seven hundred seventy five institute full text publications. Cataloguing and Classification data updated in Library automation software 'KOHA' and all newly added publications were brought in to the database. Twelve issues of the 'Agrititbits', an agricultural news service, were brought out during the period. An online demonstration on CeRA was arranged to improve the utilization of CeRA. Regular user awareness was done for the benefit of new patrons of library.

LIST OF PROJECTS 2017-18

DIVISION OF CROP IMPROVEMENT AND BIOTECHNOLOGY

Project I: Conservation, characterization and sustainable utilization of genetic resources of spices [Project leader: Dr. K.V. Saji]

1. Gen. XXVIII 813: Conservation and characterization of *Piper* germplasm (2008-2020) [Dr. K.V. Saji, Dr. B. Sasikumar & Dr. Sharon Aravind]

2. Gen. XIX (813): Conservation, characterisation, evaluation and improvement of *Zingiber* and *Curcuma* sp. (2007-2020) [Dr. D. Prasath, Dr. B. Sasikumar, Dr. K.V. Saji & Ms. H.J. Akshitha]

3. Gen. XXXIII (813): Identification of core collection, characterization and maintenance of cardamom germplasm (2012-2017) [Dr. Sharon Aravind, Dr. S.J. Ankegowda & Dr. Mohammed Faisal Peeran]

Project II: Development of trait specific and improved varieties of spices through conventional breeding and biotechnological approaches [Project Leader: Dr. B. Sasikumar]

4. Gen. XXXI (813): Breeding black pepper for high yield, quality and resistance to stresses (2012-2017) [Dr. B. Sasikumar, Dr. Johnson K. George, Dr. K. V. Saji, Dr. T.E. Sheeja, Dr. T. John Zachariah, Dr. R. Suseela Bhai, Dr. K.S. Krishnamurthy, Dr.S.Devasahayam & Ms. . Aarthi]

5. Gen. X (813): Breeding cardamom for high yield and disease resistance (2007-2018) [Dr. Sharon Aravind, Dr. Mohammed Faisal Peeran, Dr. C. M. Senthil Kumar and Mr.Narendra Chaudhary]

6. Gen. XXVI (813): Evolving high yielding and high quality nutmeg clones by selection (2007-2021) [Dr. J. Rema, Dr. K.V. Saji, Dr. B. Sasikumar & Ms. . Aarthi]

7. Gen. XXXIV (813): Induction of variability in ginger through induced mutation for yield and disease resistance (2012-2017) [Dr. D. Prasath, Dr. R. Ramakrishnan Nair & Dr. R. Suseela Bhai]

8. Gen. XXXV (813): Genetic improvement in turmeric through seedling selection and hybridization (2013-2020) [Dr. R. Ramakrishnan Nair & Ms. . Aarthi]

9. Biotech. XIII (813): Development and deployment of Antimicrobial peptides against *Phytophthora capsici* from tree spices (2016-2018) [Ms. P. Umadevi, Dr. Johnson K George, Dr. R. Suseela Bhai & Dr. C. Sarathambal]

Externally funded

10. ICAR-CIB 1. Mining and validation of candidate gene markers and screening on antimicrobial peptides of black pepper and small cardamom (2015-2017) [Dr. Johnson K. George, Ms. P. Umadevi, Dr. K.V. Saji, Dr. Sharon Aravind, Dr. Dinesh Kumar, Dr. Sarika, Dr. M.A. Iquebal & Dr. U.B. Angadi (IASRI)]

DIVISION OF CROP PRODUCTION AND POST HARVEST TECHNOLOGY

Project III: Development of resource conservation and management technologies for improving productivity of spices [Project leader: Dr.K. Kandiannan]

11. Phy. X (813): Evaluation of black pepper and cardamom elite lines for

yield and quality under moisture stress (2010–2020) [Dr. S.J. Ankegowda, Dr. K.S. Krishnamurthy & Ms. H.J. Akshitha]

12. Phy. XI (813): Source sink relationship, endogenous hormone levels and their relationship with rhizome development in ginger and turmeric (2011-2017) [Dr. K.S. Krishnamurthy, Dr. K. Kandiannan, Dr. V. Srinivasan & Dr. C.K. Thankamani]

13. Phy. XII (813): Physiological interventions for yield improvement in small cardamom (*Elettaria cardamomum* Maton) under weather extremities (2016-2021) [Dr.M.Alagu Palamuthir Solai, Dr. S.J. Ankegowda, Dr. Sharon Aravind]

14. SSC VI (813): Nutrient cycling and soil C sequestering potential of spice crops under different management systems (2011-2017) [Dr. V. Srinivasan, Dr. R. Dinesh, Dr. S.J. Ankegowda & Dr. . Hamza]

15. AGR. XXXI (813): Development of fertigation schedule for better productivity in black pepper (2015-2018) [Dr. CK Thankamani, Dr. R. Dinesh, Dr. K Kandiannan and Dr.Alagupalamuthirsolai]

16. AGR. XXXII (813): Delineation of spices zone beyond boundaries using climate analogue tools in changing climate (2016-19) [Dr. K. Kandiannan, Dr. M. Alagupalamuthirsolai and Mr. K. Jayarajan]

Externally funded

17. ICAR Mega Seed Project: Production of nucleus planting materials of improved varieties of spice crops (2006-2017) [Dr. K. Kandiannan, Dr. S.J. Ankegowda, Dr. J. Rema, Dr. K.V. Saji, Dr. D. Prasath & Dr. P. Rajeev]

18. ICAR-CPPHT-4: Network project on micronutrient management in horticultural crops for enhancing yield and quality (2014-2017) [Dr. R. Dinesh, Dr. V. Srinivasan, Dr. S.J. Ankegowda & Dr. S. Hamza]

Project IV: Development, refinement and demonstration of integrated cropping system for improved total factor productivity in spices [Project Leader: Dr. V. Srinivasan]

19. Hort. VII (813): Evaluation of nutmeg for its suitability for high density planting (2011-2021) [Dr. J. Rema & Dr. Sharon Aravind] **Externally funded**

20. Kerala State – CPPHT-3: Integrated pepper research and development Project for North Kerala districts (2013-2017) [Dr. V. Srinivasan, Dr. P.S. Manoj, Dr. K.M. Prakash, Dr. K.K. Aiswariya, Dr. P. Rajeev, Dr. S. Hamza, Dr. R. Suseela Bhai, Dr. T.K. Jacob, Dr. A. Ishwara Bhat, Dr. Santhosh J. Eapen, Dr. Rashid Pervez, Dr. R. Dinesh, Dr.C.K. Thankamani, Dr. K. Kandiannan, Dr. K.S. Krishnamurthy and Dr. K.V. Saji]

Project V: Development, refinement and demonstration of organic production technology of spices for improved productivity, quality and soil health [Project leader: Dr. C.K. Thankamani]

Externally funded

21. ICAR-CPPHT-1: Network project on organic farming (2007-2017) [Dr. C.K. Thankamani, Dr. V. Srinivasan, Dr. T. John Zachariah, Dr. R. Praveena & Dr. . Shanmughavel]

22. ICAR-CPPHT-2: Network project on organic horticulture (2014-2017) [Dr. J. Rema, Dr. V. Srinivasan, Dr. K. Kandiannan, Dr. R. Dinesh, Dr. S.J. Ankegowda, Dr. C.N. Biju, Dr. C.M.

Senthil Kumar & Mr. Narendra Chaudhary]

Project VI: Development and refinement of post harvest handling, processing and value addition technologies for minimization of post harvest losses and diversified use of spices (Project leader: Dr. N.K. Leela)

23. PHT VII (813): Developing energy efficient processing technologies for spices (2013-2017) [Dr. E. Jayashree, Dr. N.K. Leela & Dr. Ankur Nagori (CIFT, Cochin)]

24. Org. Chem. IV (813): Chemoprofiling of *Myristica* species for nutraceutical and medicinal properties (2013-2018) [Dr. N.K. Leela & Dr. T. John Zachariah]

25. PHT VIII (813): Consortium Research Project on Secondary Agriculture (2016-2017) [Dr. E. Jayashree, Dr. T. John Zachariah & Dr. S. J. Ankegowda]

Externally funded

26. ICAR-CPPHT-3: Network project on high value compounds and phyto-chemicals (2014-2017) (Dr. T. John Zachariah, Dr. N.K. Leela, Dr. Santhosh J. Eapen & Ms. R. Sivaranjani)

DIVISION OF CROP PROTECTION
Project VII. Bio-Intensive management of pests in spices (Project leader: Dr. T.K. Jacob)

27. Ent. XIV (813): Survey and documentation of naturally occurring entomopathogens in spice cropping systems (2012-2018) [Dr. C.M. Senthil Kumar, Dr. T.K. Jacob & Dr. . Devasahayam]

28. Nema. VI (813): Mass production and field evaluation of promising entomopathogenic nematodes against insect pests infesting major spices (2012-2017) [Dr. Rashid Pervez, Dr. Santhosh J. Eapen & Dr. . Devasahayam]

Externally funded

29. ICAR-ORP 3: Outreach programme on management of sucking pests in horticultural crops: (2009-2017) [Dr. T.K. Jacob, Dr. S. Devasahayam & Dr. C.M. Senthil Kumar]

30. ICAR-CP 1. ICAR-Consortium research project on borers in network mode (2014-2017) [Dr. C.M. Senthil Kumar, Dr. T.K. Jacob & Dr. . Devasahayam]

Project VIII. Integrated management of fungal and bacterial diseases of spices (Project leader: Dr. R. Suseela Bhai)

31. Crop. Prot. 1.5 (813): Integrated management of *Phytophthora* foot rot and slow decline diseases of black pepper (2008-2018) [Dr. R. Suseela Bhai, Dr. Santhosh J. Eapen, Dr. Rashid Pervez & Dr. T.P. Ahammed Shabeer, NRCG, Pune]

32. Path XXII (813): Investigations on the endophytic and rhizospheric microflora associated with cardamom and allied genera (2012-2017) [Dr. C.N. Biju, Dr. R. Praveena & Dr. Mohammed Faisal Peeran]

33. Path. XXIV (813): Surveillance, documentation and development of decision support system for pests and diseases of major spice crops (2016-2020) [Dr CN Biju, Dr. S. Devasahayam, Dr. Santhosh J. Eapen, Dr. T. K. Jacob, Dr. R. Suseela Bhai, Dr. A. Ishwara Bhat, Dr. Rashid Pervez, Dr. C. M. Senthil Kumar, Dr. R. Praveena, Dr. Mohammed Faisal Peeran, Dr. C. Sarathambal, Dr. Lijo Thomas & Mr. K. Jayarajan]

34. Path. XXV (813): Spatiotemporal dynamics in relation to ecology and epidemiology of fungal foliar diseases in ginger and turmeric and management (2016-2019) [Dr. R.Praveena, Dr. R. Suseela Bhai, Dr. A. Ishwara Bhat, Dr. K S. Krishnamurthy & Dr. C. Sarathambal)

35. Path. XXVI (813): Revisiting wilt diseases of vanilla and exploitation of associated microbiome for its management (2016-2019) [Dr. Mohammed Faisal Peeran, Dr. C. Sarathambal & Dr. M. Alagupalamuthirsolai]

Externally funded

36. ICAR-ORP 1: Outreach Programme on *Phytophthora, Fusarium & Ralstonia* Diseases of Horticultural and Field Crops (2008-2017) [Dr. Santhosh J. Eapen, Dr. R. Suseela Bhai, Dr. K. Nirmal Babu, Dr. Johnson K. George, Dr. D. Prasath, Dr. R. Praveena & Ms. P. Umadevi]

37. ICAR-ORP 2: Outreach Programme on Fungal Foliar Diseases (2009-2017) [Dr. C.N. Biju, Dr. R. Praveena & Dr. Mohammed Faisal Peeran]

Project IX. Development of diagnostic kits and integrated management of viral diseases (Project leader: Dr. A. Ishwara Bhat)

38. Path XX (813): Screening of *Piper* germplasm accessions against *Piper Yellow Mottle Virus* (PYMoV) (2008-2017) [Dr. A. Ishwara Bhat, Dr. T.K. Jacob, Dr. K.V. Saji, Dr. K.S. Krishnamurthy & Ms. P. Umadevi]

39. Path XXIII (813): Identification and development of diagnostics for unknown viruses associated with cardamom and ginger (2016-2019) [Dr. A. Ishwara Bhat & Dr. C. N. Biju]

SOCIAL SCIENCES SECTION

Project X. Improving knowledge and skill of stakeholders for increasing production of spices (Project leader: Dr. P. Rajeev)

40. Ext. VI (813). Capacity building and front-line intervention programmes for spice sector development in NE states and tribal empowerment (2014-17) (Dr. P. Rajeev & Dr. Lijo Thomas)

41. Eco. III (813): Economic analysis technology, market dynamics and policy scenario in major spice crops (2014-2019) (Dr. Lijo Thomas & Dr. P. Rajeev)

Externally funded

42. DBT-SS1: Distributed Information Sub-Centre (2000-2017) [Dr. Santhosh J. Eapen]

43. ICAR-SC1: Network project on Economic Impact studies on crop diversification and technology adoption in Horticulture (2014-2017) [Dr. P. Rajeev & Dr. Lijo Thomas]

44. Kerala State – CPPHT-4: Enhancing the economic viability of Coconut based land use systems for Land Use Planning in Kerala State. (2014-2017) [Dr. V. Srinivasan, Dr. R. Dinesh, Dr. R. Praveena, Dr. Lijo Thomas, Dr. S. Hamza, Ms. Mariya Dainy, Dr. K.M. Prakash, Dr. P.S. Manoj & KVK, Ernakulam]

45. Kerala State –CP-1. Area wide integrated pest management for wilt diseases in black pepper (2014-2017) [Dr. R. Suseela Bhai, Dr. Santhosh J. Eapen, Dr. Rashid Pervez & Dr. K.K. Aiswariya]

46. DBT-SS2: Empowerment of rural women and youth in Kozhikode district through ornamental fish culture applying biotechnologies (2015-2017) (Dr. B. Pradeep and Dr. P. S. Manoj)

RECOMMENDATIONS OF RAC & ACTION TAKEN REPORT

No.	Recommendation	Director's comments	Council's comment	Action taken
1.	Database on area and production under organic cultivation for each spice may be attempted	Collection of area and production of spices under organic cultivation (state wise) will be attempted with the help of state Departments and DAC database, whenever available	Agreed	Area and production of spices in India under organic cultivation (state wise) was collected and compiled. Cultivated area of black pepper under organic cultivation is 16,510 ha and approximate production is 8040 tons. Regarding ginger organically cultivated area and production is 61,960 ha and 3.2L tons respectively and major contributor is Assam. Organic turmeric is being cultivated in an area of 30,170 ha and approx. production is 1.5 lakh tons. Large cardamom is being cultivated in an area of 20,710 ha and production is 5520 tons and major producer is Sikkim
2.	Possibility of collaborative research project may be explored for research on medicinal properties of spices. Since ICAR and ICMR has an MOU, a programme may be worked out with ICMR in consultation with ICAR head quarters. Combination of spice extracts may be tried for studying the medicinal properties. However, IPR issues may be taken care.	A project on medicinal property of spices will be taken up in collaboration with NIN, Hyderabad. This work will be taken up.	Agreed	Letter sent to Director, NIN, Hyderabad requesting collaborative study on anti-diabetic formulation from cinnamon bark and curcumin extracted in virgin coconut oil and olive oil to enhance bioavailability and manage Alzhimer's disease. A reminder is also dispatched. Based on the reply scientists will visit NIN to discuss on future course of action. Already study is in progress on two spices namely, cinnamon and turmeric combination. The anti-diabetic effect of combination is not as effective as individual extracts as shown in the animal study conducted at Care Keralam, Thrissur and KVASU Mannuthy. An M. Sc project is initiated with combination of black pepper, cinnamon and turmeric in different proportions to study the bioefficacy. The turmeric used will be normal oven dried powder as well as second year harvested Chintappally turmeric which possess high oil, oleoresin, curcumin and turmerone in oil.

3.	Efforts may be intensified to profile and identify the natural enemies on pests and diseases of spice crops. More focus shall be made to identify promising Bacillus species with broad spectrum antagonistic traits against major pathogens of spices.	Four *Bacillus* species viz., *Bacillus subtilis*, *B. amyloliquefaciens*, *B. licheniformis* and *B. megaterium* have already been isolated and found promising against major pathogens of spices like foot rot of black pepper, soft rot and bacterial wilt diseases of ginger. They are under different stages of evaluation. Identification of promising natural enemies of spice crop pests will be intensified.	Agreed	Four *Bacillus* species viz., *Bacillus subtilis*, *B. amyloliquefaciens*, *B. licheniformis* and *B. megaterium* have already been isolated and found promising against major pathogens of spices like foot rot of black pepper, soft rot and bacterial wilt diseases of ginger. The potential of B. *licheniformis*, the apoplastic bacterium found effective against *R. pseudosolanacearum*, was demonstrated in farmers' plots in Wayanad and Kozhikode in association with KVK. Efforts are on to demonstrate this technology in other ginger growing areas in collaboration with AICRP centres. Endophytic *Bacillus* strains were isolated from *Vanilla planifolia* which showed multiple growth promoting traits such as mineral solubilization IAA, GA, and siderophore production. The isolates were found antagonistic to vanilla wilt pathogen, *F. oxysporum* f.sp. *vanillae* and in planta experiments are in progress. Surveys for natural enemies were conducted. Several natural enemies of pests have been identified. Studies are in progress to evaluate the biocontrol potential of these natural enemies.
4.	Possibilities of the existence of mating types in the natural populations of Phytophthora species infecting black pepper may be explored.	A project has been formulated and initiated to explore the possible existence of mating types in natural populations of *Phytophthora* species infecting black pepper.	Agreed	A project has been formulated and initiated to explore the possible existence of mating types in natural populations of *Phytophthora* species infecting black pepper. For mating type detection, we crossed more than 50 *Phytophthora capsici* isolates from black pepper, but no sexual stages were observed in any of the crossings indicating the existence of a single mating type. Since the two mating types for *P. capsici* are not yet located from black pepper, the possibility of developing markers from mating types available with other *Phytophthora* species is being explored.

5.	A model village has to be developed with all sustainable techno logies in a system mode and in a participatory mode with farmers.	The Kattipara village in Kozhikode district has been identified for technology demonstration and development as a model village	Agreed	Mera Gaon Mera Gourav progarmme is in operation in Kattippara village which has been adopted and the following activities were conducted. Primary pilot survey, Household socio economic survey, Completion of household survey and data entry, Experience sharing & participatory need assessment meeting, Scientists field visit for monitoring vegetable cultivation in Kattippara, Farmers meeting and assessment of key issues, Field visit by multi disciplinary scientists team, elite farmer identification programme, Supply of planting material of improved varieties and Demonstrations in various crops,
6.	Action plan for targeted multi plication and distribution of varieties for targeted industrial needs should be attempted.	Improved varieties with specific traits are being multiplied and distributed. In black pepper, breeder seed foot-rot tolerant varieties like IISR Thevam, IISR Shakti are multiplied from Main Campus, Regional Station, Appangala besides in AICRPS Centres. In turmeric low curcumin variety is replaced by improved varieties to meet the industrial need. IISR Prathibha already spread in many turmeric growing tracts of important turmeric producing states like Andhra Pradesh, Tamil Nadu and Maharashtra. A new short duration turmeric variety IISR Pragati with curcumin > 5.0% is being multiplied with participatory seed production system in Andhra Pradesh and Tamil Nadu to meet demand. An action plan was prepared for distribution of varieties in the target states in collaboration with the DASD	Agreed	Improved varieties with specific traits are being multiplied and distributed. In black pepper, breeder seed foot-rot tolerant varieties like IISR Thevam, IISR Shakti are multiplied from Main Campus, Regional Station, Appangala besides in AICRPS Centres. In turmeric low curcumin variety is replaced by improved varieties to meet the industrial need. IISR Prathibha already spread in many turmeric growing tracts of important turmeric producing states like Andhra Pradesh, Tamil Nadu and Maharashtra. A new short duration turmeric variety IISR Pragati with curcumin > 5.0% is being multiplied with participatory seed production system in Andhra Pradesh and Tamil Nadu to meet demand. An action plan was prepared for distribution of varieties in the target states in collaboration with the DASD. In order to meet the planting material demand, IISR has issued the license for further multiplication and distribution of targeted varieties. In turmeric, six licenses were issued in IISR Paratibha variety (355 tonnes) to agencies from Kerala, Gujarat, Maharashtra, Chattisgarh; license for IISR Alleppey Supreme (6 tones) issued to two from Kerala and Gujarat; IISR Pragati (600 Tonnes) to five from Andhra Pradesh, Chattisgarh and Madhya Pradesh.

				Ginger variety IISR Varada (25 tonnes) issued to four from Kerala, Tamil Nadu and Chattisgarh; IISR Mahima and IISR Rejatha issued to one each in Telanagana and Gujarat, respectively. Black pepper variety IISR Thevam license was issued to three farmers. By june about 1700 rooted cuttings of Thevam will be available.For IISR Girimunda by june 13000 rooted cuttings will be available for distribution to various stake holders. Tree spice nutmeg IISR Viswashree and IISR Keralashree issued to one each from Kerala. The AICRPS centres in collaboration with DASD have multiplied and distributed 4 lakhs rooted cuttings of black pepper, 9600 suckers of cardamom, 70 t of turmeric, 16 t of ginger and 3000 grafts of cinnamon.
7.	Products which enhance bioavailability, stability and efficacy has to be developed from spices.	The programme is in progress under the Network project on High value compounds and Phytochemicals which will be further strengthened	Agreed	The programme is in progress under the Network project on High value compounds and Phytochemicals. An M.Sc project on 'Extractability of curcumin in vegetable oils' is initiated to study the extractability and bioavailability enhancement of curcumin with virgin coconut oil and olive oil. Preliminary observation indicate extractability is superior in oilive oil compared to virgin coconut oil. However, there is a saturation limit in extractability of curcumin based on time, quantity and temperature.
8.	The vacant posts in all categories at Institute may be filled for improving the functioning.	We have communicated the vacancies of all categories to the Council and awaiting their instructions.	Since this is not a researchable issue hence may be taken care of separately.	Noted

INSTITUTE MANAGEMENT COMMITTEE

1.	Dr. K. Nirmal Babu	Director, ICAR- Indian Institute of Spices Research, Marikunnu PO, Kozhikode	Chairman
2.	Sri. Asok Kumar Thekkan	Director, Directorate of Agricultural, Vikas Bhavan, Thiruvananthapuram	Member
3	Thiru L.Sitherasenan	Director (Hort.) Directorate of Horticulture & Plantation Crops , Chennai	Member
4	Dr. M.C. Narayanan Kutty	Associate Director, Regional Agricultural Research Station, Pattambi	Member
5.	Shri. T. P. Suresh	Srigovindam (H), MLA Raod Kunnamangalam PO, Kozhikode	Non-Official Member
6.	Shri. K.K. Rajeevan	Karuvangadiyil(H), Kadameri P O	Non –Official Member
7.	Dr. R. Viswanathan	Head, Plant Protection , ICAR – Sugarcane Breeding Institute, Coimbatore	Member
8.	Dr. V. Niral	Principal Scientist, ICAR - Central Plantation Crops Research Institute, Kasaragod	Member
9.	Dr. K. Kandiannan	Principal Scientist, ICAR – Indian Institute of Spices Research , Kozhikode	Member
10.	Dr. P. K. Ashokan	Principal Scientist & Scientist in-charge, Calicut Research Centre of CMFRI, Kozhikode	Member
11.	Dr. T. Janakiram	Assistant Director General (H.S)-II, Indian Council of Agricultural Research, New Delhi	Member
12.	Smt. Saribai R	Finance & Accounts Officer, Central Tuber Crops Research Institute, Thiruvananthapuram	Member
13.	Mr. K. V. Pillai	Administrative Officer, ICAR- Indian Institute of Spices Research, Kozhikode	Member

PERSONNEL

Sl. No	Name	Designation
SCIENTIFIC STAFF – KOZHIKODE		
1.	Dr. K Nirmal Babu	Director & Project Coordinator (Spices)
2.	Dr. B. Sasikumar	Head, Division of Crop Improvement & Biotechnology *(till 31-01-2018)*
3.	Dr. Santhosh J Eapen	Head, Division of Crop Protection
4.	Dr. C K Thankamani	Head in charge, Div. of Crop Production & PHT
5.	Dr. T John Zachariah	Principal Scientist (Biochemistry)
6.	Dr. T K Jacob	Principal Scientist (Entomology)
7.	Dr. J Rema	Principal Scientist (Horticulture)
8.	Dr. Johnson George K	Principal Scientist (Genetics & Cytogenetics)
9.	Dr. R Dinesh	Principal Scientist(Soil Science)
10.	Dr. R Suseela Bhai	Principal Scientist (Plant Pathology)
11.	Dr. A Ishwara Bhat	Principal Scientist (Plant Pathology)
12.	Dr. R Ramakrishnan Nair	Principal Scientist (Genetics & Cytogenetics)
13.	Dr. K S Krishnamurthy	Principal Scientist (Plant Physiology)
14.	Dr. K Kandiannan	Principal Scientist (Agronomy)
15.	Dr. N K Leela	Principal Scientist (Org. Chemistry)
16.	Dr. K V Saji	Principal Scientist (Economic Botany)
17.	Dr. P Rajeev	Principal Scientist (Agril. Extension)
18.	Dr. V Srinivasan	Principal Scientist (Soil Science)
19.	Dr. T E Sheeja	Principal Scientist (Biotechnology)
20.	Dr. D Prasath	Principal Scientist (Horticulture)
21.	Dr. E Jayashree	Principal Scientist (Agril. Engineering)
22.	Dr. C M Senthil Kumar	Senior Scientist (Agricultural Entomology)
23.	Dr. C N Biju	Scientist (Plant Pathology)
24.	Dr. R Praveena	Scientist (Plant Pathology)
25.	Ms. P Umadevi	Scientist (Biotechnology)
26.	Dr. Lijo Thomas	Scientist (Agri. Economics)
27.	Ms. S Aarthi	Scientist (Spices Plantation Medicinal & Aromatic Plants)
28.	Ms. R Sivaranjani	Scientist (Plant Biochemistry)
29.	Dr. C Sarathambal	Scientist (Agril. Microbiology)
30.	Mr. V A Muhammed Nissar	Scientist (Spices Plantation Medicinal & Aromatic Plants)
31.	Dr. M S Shivakumar	Scientist (Genetics & Plant Breeding)
32.	Dr. A Jeevalatha	Scientist (Crop Protection) *(w.e.f. 03-07-2017)*
33.	Dr. C Sellaperumal	Scientist (Nematology) *(w.e.f. 10-07-2017)*

34.	Dr. Anees K	Scientist (Plant Biochemistry) *(w.e.f. 10-07-2017)*
35.	Dr. Sharon Aravind	Scientist (Spices Plantation Medicinal & Aromatic Plants)

ADMINISTRATIVE STAFF, KOZHIKODE

1.	Sri. K V Pillai	Administrative Officer *(till 30/11/2017)*
2.	Sri. K Nataraj	Administrative Officer *(w.e.f. 19-1-2018)*
3.	Sri. T D S Prakash	Finance & Accounts Officer *(w.e.f. 28-04-2017)*
4.	Ms. P V Sali	Private Secretary
5.	Sri. R N Subramanian	Assistant Administrative Officer
6.	Sri. K G Jegadeesan	Asst. Finance & Accounts Officer
7.	Sri. P Sundaran	Assistant Administrative Officer
8.	Sri. V C Sunil	Assistant
9.	Sri. V V Sayed Mohammed	Assistant
10.	Ms. C K Beena	Personal Assistant
11.	Ms. M Seema	Upper Division Clerk
12.	Mr. P Rajeev	Upper Division Clerk
13.	Ms. Rebeena N	Lower Division Clerk
14.	Mr. P T Jayaprakash	Lower Division Clerk
15.	Mr. P K Rahul	Lower Division Clerk
16.	Mr. A Z Anas	Lower Division Clerk

TECHNICAL STAFF, KOZHIKODE

1.	Dr. Hamza Srambikkal	Chief Technical Officer
2.	Mr. M P Ramesh Kumar	Chief Technical Officer
3.	Dr. E Radha	Asst. Chief Technical Officer
4.	Mr. K Jayarajan	Asst. Chief Technical Officer
5.	Ms. N Prasannakumari	Senior Technical Officer
6.	Mr. N A Madhavan	Technical Officer *(till 02/10/2017)*
7.	Mr. A Sudhakaran	Technical Officer
8.	Mr. K Krishnadas	Technical Officer
9.	Ms. P K Chandravally	Technical Officer
10.	Mr. M K Raveendran	Senior Technical Assistant
11.	Mr. K B Prasannakumar	Senior Technical Assistant
12.	Ms. N Karthika	Senior Technician (Lab. Tech.)
13.	Mr. I P Vijesh Kumar	Technical Assistant (T3) *(w.e.f. 4-1-2018)*
14.	Ms. Asha K Chandran	Technical Assistant (T3) *(w.e.f. 11-1-2018)*
15.	Mr. O G Sivadas	Technician
16.	Mr. V S Binoy	Technician

SUPPORTING STAFF, KOZHIKODE

1.	Mr. M K Purushu	Skilled Support Staff
2.	Ms. C M Kamalam	Skilled Support Staff

IISR EXPERIMENTAL FARM, PERUVANNAMUZHI - TECHNICAL STAFF

1.	Mr. E Sujeesh	Senior Technical Officer
2.	Mr. K P Premachandran	Senior Technical Assistant
3.	Mr. N A Madhavan	Technical Officer *(w.e.f. 03/10/2017)*
4.	Mr. T R Sadasivan	Technical Assistant
5.	Ms. Rejina P Govind	Technician
6.	Mr. Hareesh B T	Technician
7.	Mr. Rasmish A R	Technician

SUPPORTING STAFF, PERUVANNAMUZHI

1.	Mrs. N K Girija	Skilled Support Staff
2.	Mrs. P N Kausalya	Skilled Support Staff
3.	Mrs. V P Sarada	Skilled Support Staff (till *30-09-2017)*

KVK, PERUVANNAMUZHI - SCIENTIFIC STAFF

1.	Dr. P Ratha Krishnan	Programme Coordinator

KVK, PERUVANNAMUZHI - TECHNICAL STAFF

1.	Dr. P S Manoj	Subject Matter Specialist (T9) (Hort.)
2.	Dr. S Shanmugavel	Subject Matter Specialist (T 9) (Vet. Sc.)
3.	Mr. K M Prakash	Subject Matter Specialist (T 9) (Agro.)
4.	Dr. B Pradeep	Subject Matter Specialist (T-7-8) (Fisheries)
5.	Ms. A Deepthi	Subject Matter Specialist (T-7-8) (H. Sc.)
6.	Dr. K K Aiswariya	Subject Matter Specialist (T-7-8) (Pl. Prot.)
7.	Dr. Maria Dainy M	Programme Assistant (T4) (Lab Tech.)
8.	Mr. T C Prasad	Driver-cum-Mechanic (T4)
9.	Mr. C K Jayakumar	Programme Assistant (T4) (Computer)
10.	Mr. P Prakash	Technical Assistant (Driver)

KVK, PERUVANNAMUZHI - ADMINISTRATIVE STAFF

1.	Mr. K Faisal	Stenographer Gr. III

KVK, PERUVANNAMUZHI – SUPPORTING STAFF

1.	Mr. C V Ravindran	Skilled Support Staff
2.	Mr. C Ravindran	Skilled Support Staff

IISR–REGIONAL STATION, APPANGALA

SCIENTIFIC STAFF

1.	Dr. S J Ankegowda	Head and Principal Scientist
2.	Mr. Narendra Choudhary	Scientist (Spices Plantation & Medicinal Aromatic Plants)
3.	Dr. Muhammed Faisal Peeran	Scientist (Plant Pathology)
4.	Dr. P Alagupalamuthirsolai	Scientist (Plant Physiology)
5.	Ms. H J Akshitha	Scientist (Spices Plantation Medicinal & Aromatic Plants)
6.	Dr. Balaji Rajkumar	Scientist (Agri. Entomology) *(w.e.f. 01-07-2017)*

ADMINISTRATIVE STAFF

1.	Mr. P Muraleedharan	Assistant Administrative Officer
2.	Mr. D Chethan	Lower Division Clerk

TECHNICAL STAFF

1.	Sri. H C Rathish	Senior Technical Assistant
2.	Sri. H D Praveena	Technical Assistant
3.	Sri. N Cholurappa	Technician

SUPPORTING STAFF

1.	Smt. H B Lakshmi	Skilled Support Staff
2.	Sri. B N Seshappa	Skilled Support Staff
3.	Smt. B L. Chennamma	Skilled Support Staff
4.	Smt. B M Lalitha	Skilled Support Staff
5.	Smt. K M Puttasiddamma	Skilled Support Staff
6.	Sri. B K Poovappa	Skilled Support Staff
7.	Sri. Marigowda	Skilled Support Staff
8.	Sri. K.K. Thimmaiah	Skilled Support Staff *(till 30-04-2017)*

WEATHER DATA 2017

IISR Experimental Farm, Peruvannamuzhi, Kerala

Months	Rainfall		Temperature (°C)		Relative Humidity (%)	
	Total Rainfall (mm)	Rainy days	Max. (Mean)	Min. (Mean)	Max. (Mean)	Min. (Mean)
January	53.0	2	34.6	20.1	89.4	32.5
February	53.0	1	35.5	21.8	88.2	35.0
March	104.6	4	35.2	23.4	88.2	44.0
April	64.0	6	35.1	25.3	90.4	56.4
May	321.0	14	34.2	24.6	94.0	62.8
June	764.0	29	29.3	24.7	95.6	81.9
July	755.8	27	29.9	24.2	95.3	78.0
August	837.6	26	29.9	24.2	95.8	80.2
September	650.4	21	31.3	24.3	94.7	76.8
October	309.6	16	32.2	24.1	95.3	69.5
November	21.0	4	34.6	23.8	93.1	59.5
December	15.2	2	35.0	22.0	89.4	50.0
Total/Mean	**3949.2**	**152**	**33.1**	**23.5**	**92.4**	**60.6**

ICAR - IISR Regional Station, Appangala, Madikeri

	Raifall		Temperature (°C)		Relative Humidity (%)	
Months	**Total Rainfall (mm)**	**Rainy days**	**Max. (Mean)**	**Min. (Mean)**	**Max. (Mean)**	**Min. (Mean)**
January	37.0	2	30.7	10.2	94.2	93.6
February	0.00	0	30.6	14.1	93.7	91.5
March	17.9	1	32.0	13.2	89.4	86.4
April	69.9	5	33.5	13.9	77.2	69.3
May	113.4	9	30.7	14.9	80.4	66.7
June	424.3	26	26.8	15.8	87.5	73.0
July	520.3	27	22.4	16.3	90.0	83.0
August	661.7	25	22.2	16.1	91.0	90.0
September	265.0	15	23.6	16.0	92.0	77.0
October	88.9	8	24.8	15.1	88.0	75.0
November	32.0	2	25.4	14.1	93.0	75.0
December	14.6	3	25.8	13.0	93.0	75.0
Total/Mean	**2245**	**123**	**27.4**	**14.4**	**89.1**	**79.6**

AWARDS & RECOGNITIONS

- Two startups from ICAR-IISR *viz.*, Kodagu Agritech, Karnataka and Natura Nursery, Kozhikode were selected for presenting their technologies to Hon'ble President of India during the Festival of Innovation and Entrepreneurship (FINE), hosted at the Rashtrapathi Bhavan, New Delhi during 19-21 March 2018.
- Dr B. Sasikumar, Former Principal Scientist and Head won the National Award for Outstanding Efforts in Science & Technology Communication through Print Media including Books and Magazines (Category-B) instituted by DST, Govt of India. He also bagged *Karshaka Bharathi* Award for farm journalism instituted by Govt of Kerala.
- Dr R. Dinesh, Principal Scientist was awarded the Fellow of National Academy of Agricultural Sciences
- Dr D. Prasath, Principal Scientist was selected for Endeavour Fellowship instituted by Australian Govt. He also won Dr D.P. Ghosh Young Scientist award instituted by Horticultural Society of India.
- Dr E. Jayashree, Principal Scientist received National Academy of Sciences India - ICAR award for Innovation and Research in farm machinery.
- Dr S. Shanmugavel, SMS, IISR-KVK won *Ksheera Bandhu award.*
- Ms. N. Prasannakumari, Senior Technical Officer was awarded *Rajbhasha Sevi Samman* by Bhasha Samanvaya Vedi.
- Dr R. Ramakrishnan Nair, Dr R. Suseela Bhai, Dr V. Srinivasan, Dr Faisal, M.P., Dr M. Alagupalamuthirsolai, Dr M.S. Shivakumar won best paper (oral/poster) awards in various national and international seminars.

1. President of India interacting with ICAR-IISR startup
2. *Piper beteloides*
3. Conidium of *Bipolaris rostrata*
4. Germinating conidia of *Bipolaris rostrata*
5. Oogonia of *Pythium deliense*

ICAR-Indian Institute of Spices Research
Marikunnu P. O., Kozhikode - 673012, Kerala, India
Phone: 0495-2731410, Fax: 0495-2731187
E-mail: mail@spices.res.in, Web site: www.spices.res.in