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Annual Report
2016-17

भाकृअनुप
ICAR

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

The research achievements of the institute during 2016-17 are presented here. During the year, 33 Piper accessions including 31 cultivars and two wild types were collected. The alternate field gene banks for black pepper are maintained at CHES, Chettalli, Karnataka and IISR, Chelavoor campus, Kerala. The significant achievement during the year was development and release of a high yielding, short duration and stable curcumin turmeric variety, IISR Pragati. This variety paves the way for curcumin upgradation in major turmeric growing states. Three new accessions of nutmeg with bold nut and thick mace were added to the germplasm.

Large scale demonstrations on site specific nutrient management in black pepper showed significant increase in yield as compared to farmers practice. Studies on the *in vitro* cytotoxic effect of spice extracts on the cell lines SKBR-3 and HCT-116 indicated highest cytotoxic effect in hexane extract of cinnamon.

Th institute developed IPM strategies for the control of cardamom thrips i.e., two sprays of spinosad 0.0135% and soil application of the entomopathogenic fungus, *Lecanicillium psalliotae.* In ginger, soil solarization followed by application of 3% calcium chloride was found to be effective in bacterial wilt management.

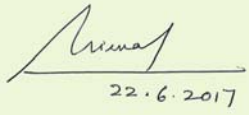
The advisory services of the Agricultural Technology Information Center were delivered to more than 2700 clients. Thirteen training programmes were conducted by the institute targeting diverse stakeholder groups like farmers, youth, tribal beneficiaries and students. A total of 48 exhibitions were organized by the institute during the last year. In KVK, about 112 training programmes for practicing farmers and farm women, rural youth and extension functionaries were conducted. Eight front line demonstrations and seven on farm trials on technology assessment and refinement were carried out.

During the year, the ITM-BPD Unit facilitated seven non exclusive licensing of black pepper, turmeric and ginger varieties. License agreement for cleaning, grading, packing and powdering of black pepper and white pepper was signed with CAMPCO Pvt India Ltd.

Overall, the efforts of the scientists, staff, research associates, farmers, planters and entrepreneurs have been unprecedented, overwhelming and encouraging. Your relentless support and fair appraisal gives me the verve to strive for betterment and strengthening of our research and extension programmes to trigger the change we want to witness in the spices sector.

I consider it a privilege to place on record the encouragement given by Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR and Dr. S. Ayyappan, former Secretary, DARE and Director General, ICAR. I am also grateful for the strong support and necessary guidance received from Dr. A. K. Singh, Deputy Director General (Hort. Science), Dr. N.K. Krishna Kumar, former Deputy Director General (Hort. Science) and Dr. T. Janakiram, ADG (Hort. Science). I appreciate the efforts and zeal shown by all the project investigators in executing various programmes. The financial support for the projects received from ICAR is gratefully acknowledged. I also appreciate the editors for having compiled and brought out this publication in time.

Kozhikode,
22.06.2017



(K. Nirmal Babu)

EXECUTIVE SUMMARY

BLACK PEPPER

Genetic Resources

Thirty one cultivated accessions and two wild accessions from Arunachal Pradesh were collected. The unique accessions collected from Kodagu district, Karnataka are

- An accession with very long spike (about 30 cm long)
- An accession having male, female and bisexual flowers in the same vine
- An accession with very less pungent ('sweet') berries
- A variant resembling the triploid "Vadakkan" but with elongated leaves.

A total of 3395 black pepper accessions are now maintained at *ex situ* conservatory. A field gene bank of 200 accessions at Peruvannamuzhi, 223 at Chelavoor and 627 accessions at the alternate field gene bank at CHES, Chettalli are also being maintained. The alternate field genebank at CHES, Chettalli was enriched with 100 accessions. Eighty five accessions were characterized based on IPGRI descriptors for 27 traits.

Breeding

In a trial involving 10 improved genotypes, maximum fresh yield vine^{-1} was recorded in Hp 117 x Thommankodi (3.46 kg vine^{-1}, 30.2% dry recovery) followed by OPKM (2.679 kg vine^{-1} with 33.2% dry recovery) and Thevam (2.49 kg vine^{-1} with 31.3% dry recovery). Quality wise, Sreekara (control) and Hp 728 had 3.6% oil each followed by Hp 1411 and Coll. 820 with 3.5 and 3.4% oil, respectively. However Coll. 820 recorded highest oleoresin (10.2%) followed by Hp 1411 (9.1%) and Hp 728 (9.0%).

Transcriptome analysis

Transcriptome sequencing was performed using drought tolerant Acc. 4226 exposed to water deficit stress. Sequencing using the PacBio protocol resulted in 53689 reads of insert (ROIs) with mean read length of 2378 bp. The transcripts were aligned against the drought responsive gene sequences in the drought stress gene database (Drought DB) and 431 transcripts were found matching to molecular adaptation regulatory (MAR) sequences, 96 were aligned to molecular adaptation functional (MAF) sequences and 331 were aligned to physical adaptation (PA) sequences.

Mining of antimicrobial peptides (AMP) from transcriptome

A cysteine rich peptide showing similarity to plant defensins with a mature peptide length of 48 amino acids was discovered from the derived transcripts.

Crop management

Scheduling fertilizer dose for fertigation

An adaptive trial was conducted at Laxmi Estate, Mudigere, Karnataka. Significantly higher yield was registered with foliar supplementation of NPK (5.42 kg std^{-1} fresh) and NPK + micronutrients (5.36 kg std^{-1} fresh). Additional investment of Rs. 15.00 per standard has yielded an additional profit of Rs. 175.00 per standard.

Management of virus affected gardens for yield sustainability

Trials on the management of virus affected black pepper gardens were taken up in three locations at Madapura, Chettalli and Pollibetta in Karnataka. The fresh yield was higher in application of FYM + NPK + PGPR + micronutrients (3.6-7.1 kg std^{-1}) which was on par with FYM + NPK + micronutrients application (3.2-6.4 kg std^{-1}) and significantly higher than control (2.4-4.4 kg std^{-1}) across locations.

Promising Zn solubilising bacteria

Six promising strains (ZSB1-*Burkholderia sp.*; ZSB2-*Bacillus megaterium;* ZSB3- *Lysinibacillus sp.*; ZSB4-*Bacillus sp.*; ZSB5-*Burkholderia sp* and ZSB8-unidentified) were further tested for their Zn solubilization efficiency in liquid medium with reference to the Zn solubilising

isolate *Gluconacetobacter diazotrophicus* (PAL-5), obtained from TNAU, Coimbatore, Tamil Nadu. Marked differences were observed in the Zn solubilization efficiency at different days after initiation (DAI) and the most promising bacteria was ZSB2 (*Bacillus megaterium;* NCBI-KY687496), registering as high as 126.8 mg L^{-1} Zn at 7th DAI.

Delineation of spices zone

Efficient cropping zones of black pepper were identified based on the criteria of relative yield index (RYI) and relative spread index (RSI). In Kerala, Kasaragod is the efficient black pepper producing zone with high RYI of 147, Idukki and Kozhikode are efficient zones with little year to year variation. In Karnataka, Chikkamagaluru is the most efficient zone, whereas, Dakshina Kannada, Hassan, Kodagu, Shivamogga, Udupi and Uttara Kannada are efficient zones with little year to year variation. In Tamil Nadu, Dindugul is the most efficient zone and The Nilgiris, Namakkal and Salem are efficient zones.

Drought management in black pepper

Among the antitranspirants tested (kaolin 1.5% and 2%, sprays, lime 1.5% with 0.5% SOP), black pepper vines sprayed with 2% kaolin showed higher photosynthetic rate combined with minimum transpiration rate (i.e. minimum water loss) and lower leaf surface temperature.

Post-harvest technology

Steam blanching of green pepper in the solar curing unit

Blanching of black pepper for 4 minutes with steam generated from the solar unit ensured complete drying in 4 days and registered higher essential oil content compared to dipping in boiling water for 1 minute and control (unblanched pepper).

Plant health management

Phytophthora foot rot

Diversity of Phytophthora

A host range study comprising of four host differentials viz., black pepper, pothos, chilli and capsicum was carried out using 18 selected black pepper isolates of Phytophthora and compared with ATCC type cultures of *P. capsici and P. tropicalis.* The isolates could be primarily differentiated based on the formation of unrestricted lesions with fimbriate margin and restricted lesions with yellow halo on leaves.

Based on the differential expression of symptoms the isolates were separated into two major groups - Group I ("capsici-like") showing fimbriate margin in black pepper and restricted lesion in pothos, and Group II ("tropicalis") showing restricted lesion with yellow halo in black pepper and widely spreading lesions in pothos with a few exceptions.

The infectivity of two isolates (05-06 and 98-93) was compared with that of ATCC type cultures (ATCC 4034 and ATCC 76551) by SEM analysis. Interestingly, no hyphal penetration and ramification was observed in the case of both type cultures while the black pepper isolates (05-06 and 98-93) penetrated and ramified the pepper leaf tissues.

Black pepper infected by *P. tropicalis*

Host range studies in comparison with type cultures of *P. capsici* (ATCC 4034) and *P. tropicalis* (ATCC 76651) indicated that in contrast with 05-06, ATCC 4034 produced hypersensitive reaction in black pepper but was avirulent to pothos. On the other hand, ATCC 76651 induced expanding lesions in pothos and produced restricted lesions with yellow halo in black pepper as observed with 98-93. It was also evident that Phytophthora infecting black pepper comprises of more than one species, *P. tropicalis* as well as *P. capsici*-like species.

Genes involved in *Piper colubrinum - Phytophthora capsici* interaction

Candidate genes known to play a role in defence signalling or in HR reaction were studied in *P. colubrinum* challenged with *P. capsici* using qPCR. The gene *chorismate synthase* showed peak expression at 16 hpi. Genes like *metacaspase* was expressed at the highest level during 4 hpi. *Nitrate reductase* and *cinnamate 4 hydroxylase* showed high expression at 24 hpi and 72 hpi, respectively.

Screening of new molecules against Phytophthora

Six new fungicide molecules viz., cymoxanil 8% + mancozeb 64% (Curzate 60DF, 100- 500 ppm), iprovalicarb + propineb (Melody Duo, 750-1750 ppm), propineb (Antracol, 100 – 500 ppm), chlorothalonil (Chlorothalonil 75WP, 500 - 1500 ppm), famoxadone + cymoxanil (Equation Pro, 200 – 600 ppm) and Metalaxyl - mancozeb (Ridomil Gold, 62.5 – 1000 ppm) evaluated in five different concentrations against *Phytophthora* showed 100% suppression of *Phytophthora sp.*

Actinomycetes, a novel group of biocontrol agents

Out of the 50 actinobacterial strains tested, three Streptomyces isolates (IISRBPAct 1, IISRBPAct 25 and IISRBPAct 42) showed more than 90% inhibition of *P. capsici* and *Sclerotium rolfsii.* IISRBPAct 1 showed maximum growth promotion and inhibition (98.10%) of *S. rolfsii* while IISRBPAct 25 showed highest control of *P. capsici* (80.73%). IISRBPAct 2 in combination with IISRBPAct 5 was found effective in controlling *Radopholus similis* infection.

Slow decline disease

Field evaluation of new pesticides

Multilocation trials on nematicidal activity of carbosulfan 6 G and flubendamide 20 WG indicated that both the pesticides effectively suppressed *R. similis.*

Screening of botanicals

In vitro studies indicated that the leaf extracts of *Simarouba glauca* (Lakshmi taru) and *Manihot esculenta* (cassava) effectively inhibited *R. similis* and *M. incognita*

Anthracnose disease

Evaluation of fungicides

Among the fungicides evaluated, initial spray with Bordeaux mixture (1%) at 30 DAP followed by fenamidone – mancozeb (0.2%) at 45 DAP was more effective in reducing the disease under nursery condition.

Viral diseases

Elimination of Piper yellow mottle virus (PYMoV)

Cyclic somatic embryos, obtained from the micropylar region of mature seeds from PYMoV infected black pepper plants of six varieties viz., IISR Malabar Excel, IISR Shakthi, IISR Thevam, Panniyur 1, Sreekara and Subhakara, were regenerated and hardened in greenhouse. PCR of 227 somatic embryo-derived plants showed that 65 plants (28%) were positive to PYMoV. Variety wise data indicated 55- 100% virus elimination in different varieties. A protocol for meristem tip culture of black pepper was developed. About 84% of the hardened plants, when tested through PCR were free of PYMoV. Complete elimination of PYMoV from black pepper could be achieved when somatic embryogenesis or meristem tip culture was combined with ribavirin, an antiviral agent.

CARDAMOM

Genetic Resources

A total of 618 cardamom accessions are being maintained at National Active Germplasm Site. One accession was collected from Vallakadavu forest range, Periyar Tiger Reserve, Kerala.

Field screening of 106 cardamom accessions for leaf blight and rhizome rot resistance yielded five resistant accessions to rhizome rot (FGB 135, FGB 143, FGB 149, FGB 152 and FGB 159) and 36 resistant accessions to leaf blight.

Breeding

In Preliminary Evaluation Trial, the hybrid PV2 x IISR Vijetha registered more number of tillers, leaves, highest fresh and dry weight of the capsules.

Transcriptome analysis

PacBio single-molecule real-time sequencing in cardamom was done with RNA isolated from leaf samples of IISR- Vijetha plants challenged with cardamom virus. 56439 reads of insert with mean read length of 2267 bp in small cardamom was obtained with PacBio. The error corrected high-quality 8,351 isoforms were further clustered into 5253 contigs using Cap3 sequence assembly program. A bicistronic transcript coding for palmitoyl-acyl carrier protein thioesterase and ent-kaur-16-ene synthase was discovered. A transcript coding for a photosystem II gene having inverted repeats region for the coding sequence was also identified.

Crop management

Trials on nutrient management in cardamom indicated that the yield was significantly higher in the treatments involving FYM + neem cake (1.31 kg fresh plant^{-1}) followed by FYM + vermicompost (1.17 kg fresh plant^{-1}).

Plant health management
Viral disease

Kokkekandu (vein clearing) disease was noticed with high incidence (up to 60%) and severity only in Sirsi and Sakleshpur taluks of Uttara Kannada and Hassan districts of Karnataka, respectively.

Leaf blight

Natural incidence of leaf blight was recorded in 119 accessions and three released varieties (Appangala 1, IISR Avinash and IISR Vijetha). Among different morphotypes, maximum Per cent Disease Index (PDI) was recorded in Malabar (23.41-27.72), followed by Mysore (18.79-20.34) and Vazhukka (18.74-20.38).

Virulence characterization of *Colletotrichum gloeosporioides*

Virulence analysis of 20 isolates of *C. gloeosporioides* employing molecular markers (RAPD, SSR and ISSR) revealed that only ISSR markers were linked with virulence of the pathogen.

Endophytic fungi

A pot culture experiment with shortlisted endophytes indicated that Cb2 (against *F. oxysporum)*, AgR5D (against *P. vexans*), AgR5A (against *R. solani)* and Asupe 1 (against *C. gloeosporioides)* were promising.

Effect of promising isolate of Trichoderma

The effect of promising isolate of Trichoderma on growth inhibition of *Fusarium oxysporum, Rhizoctonia solani* and *Pythium vexans* was also tested and growth inhibition against the pathogens was found to be maximum at higher concentration (20%).

Cardamom thrips

Toxicity of insecticides to honey bees

Among the 4 promising insecticides (fipronil, 0.005%, imidacloprid 0.0089%, spinosad 0.0135% and quinalphos 0.05%) evaluated under laboratory conditions for their residual toxicity to honey bees, quinalphos was highly toxic and spinosad was the least toxic.

Evaluation of IPM strategies

Evaluation of IPM strategies for the control of cardamom thrips indicated that two sprays of spinosad 0.0135% and soil application of the entomopathogenic fungus, *Lecanicillium psalliotae* twice alternatively during March, April, May and August was effective in managing the pest.

GINGER

Genetic resources

Presently, 668 accessions are being maintained in the field gene bank. The germplasm conservatory was enriched with 20 accessions collected from West Bengal, Nagaland, Kerala and Arunachal Pradesh. The special collections include extra bold ginger and red ginger from Arunachal Pradesh.

Breeding

Among the eight accessions evaluated for high yield and low fibre content, Acc. 278 was found to be promising.

In vivo irradiation of ginger

IISR Rejatha was subjected to gamma irradiation at different doses of 0.8, 1.0 and 1.2 kR. All the M1V1 mutants were established in the green house for upscaling screening against *Pythium sp*. Besides this, 10 M1V4 and 102 M1V9 mutants have been maintained. Three potential mutants 'resistant' to *Pythium sp.* were identified (V 0.5/2, R 0.8/1 and R 1.25/4) for further confirmation.

Generation of autotetraploids

The rhizome buds of IISR Rejatha were submerged in different concentrations of colchicine (0.025, 0.050, 0.075, and 0.1 %) and oryzaline (5, 10, 25, 50, 100 µM) for 24 h and 72 h to induce polyploidy. Maximum sprouting was recorded in 0.025% colchicine and 5 µM oryzaline at 24 h.

Crop management

Fertigation in ginger using soilless medium consisting of coir compost and FYM in 1:1 proportion indicated that 75% of recommended dose of fertilizers applied through drip irrigation on daily basis produced maximum mean rhizome yield per plant (265g plant^{-1}) followed by 100% recommended dose (254 g plant^{-1}).

Photosynthesis and partitioning of dry matter under coloured shade nets in ginger and turmeric

Photosynthetic rate was highest in plants grown under red shade net in ginger (5.3 µ moles m^{-2} s^{-1}) while it was highest in plants grown under open conditions in turmeric (5.8 µ moles m^{-2} s^{-1}). Dry matter partitioning to rhizomes was on par in plants grown under different shade nets in ginger while it was highest in plants grown under open conditions in turmeric, at 120 DAP. Rhizome yield was highest in plants grown under red shade net in ginger while it was highest in plants grown under open conditions in turmeric.

Plant health management
Foliar diseases

Surveys were conducted in ginger and turmeric growing areas of Kerala, Karnataka and Tamil Nadu and samples were collected from 49 locations. The fungi isolated included *Phyllosticta* sp., *Helminthosporium* sp., *Fusarium* spp., *C. gloeosporioides, C. capsici, Exerohilum* sp., *Pestalotia* sp., *Curvularia hawaiinensis* and a few unidentified fungi.

Helminthosporium leaf blight

Leaf blight of ginger caused by *Helminthosporium* sp. was found to be severe in ginger growing tracts of Mysuru, Chamarajanagar and Uttara Kannada districts of Karnataka and Wayanad and Kozhikode districts of Kerala.

Bacterial wilt cross infectivity of *R. solanacearum* strains from India

Cross infectivity studies on ten *R. solanacearum* isolates from different crops and geographical locations using three host differentials showed that all the sequenced isolates are infective on tomato and chilli whereas ginger was infected by only the ginger isolates.

Defence responses

The interaction of *R. solanacearum* with resistant mango ginger and susceptible ginger plants was studied using nine candidate genes in different time course intervals by real-time PCR. The results showed that there was a strong and earlier expression of the selected transcripts in resistant mango ginger suggesting the involvement of these processes in the early containment of the pathogen.

Transcriptome-wide identification and characterization of resistant gene analogs

R-gene products obtained from the transcriptome of mango ginger and ginger were separated into distinct but related protein classes, according to their conserved structural domains. Screening for R-genes resulted in the identification of 160 clusters in mango ginger and 212 clusters in ginger with similarity to known R-genes. The gene expression studies of selected NBS-LRR transcripts identified that the R-genes were highly expressed in mango ginger in the initial hours post inoculation indicating their possible role in disease resistance.

Apoplastic bacterium for control of bacterial wilt

Soil solarization coupled with seed treatment and soil application (at the time of planting and 30, 45 and 60 days intervals) with the apoplastic bacterium, *Bacillus licheniformis* (GAB 107) inhibited bacterial wilt whereas under challenge inoculated conditions 81.73% inhibition was obtained.

Calcium chloride controls bacterial wilt

Solarization of soil followed by application of 3% calcium chloride (soil application at the time of planting and thereafter at 30, 45 and 60 days intervals) resulted in 100% inhibition of bacterial wilt in sick field and 98.21% inhibition under challenge inoculated conditions.

Secondary metabolites of *Bacillus licheniformis*

The secondary metabolites of *B. licheniformis* (GAB 107), extracted using ethyl acetate caused >90% inhibition of *R. solanacearum* and >75% inhibition of *P. myriotylum,* the causal agents of bacterial wilt and soft rot of ginger, respectively. Volatiles of *B. licheniformis* are also inhibitory to *R. solancearum.*

Viral disease

Surveys were conducted in ginger fields of Karnataka (Chamarajanagar, Mysuru, Uttara Kannada, Kodagu and Hassan districts) and Kerala (Wayanad, Idukki, Kozhikode districts) and the incidence of viral disease ranged from 10-70%.

Shoot borer

Molecular characterization

Conogethes punctiferalis populations infesting cardamom, ginger, turmeric and *Ammomum* sp. collected from nine locations in Kozhikode, Idukki and Wayanad districts of Kerala, Kodagu district in Karnataka and Dimapur district in Nagaland were characterized using universal primers

Association of *Wolbachia sp.*

The association of Wolbachia with *C. punctiferalis* populations infesting ginger, turmeric and cardamom was confirmed through multilocus sequence typing (MLST). The populations were found to be super infected by Wolbachia super groups A & B.

Seasonal incidence in relation to crop phenology

The incidence of shoot borer infesting ginger and turmeric in relation to crop phenology was studied at fortnightly intervals. On ginger, the shoot borer infestation was first observed during the second fortnight of August and was high during the second fortnight of October. On turmeric, the pest infestation was first observed during the second fortnight of July and was high during the first fortnight of November.

Screening of insecticides

Screening of 10 insecticides for their bioefficacy against shoot borer was carried out for the second consecutive year in ginger and turmeric under field conditions. On ginger, plots treated with chlorantraniliprole 0.01% had minimum pest infestation on the shoots that was on par with flubendiamide 0.02%, spinosad 0.135% and cyantraniliprole 0.005%. Chlorantraniliprole 0.01% treated plots recorded minimum pest infestation in turmeric that was on par with lamda-cyhalothrin 0.0125%, flubendiamide 0.02%, fipronil 0.003% and cyantraniliprole 0.005%.

Field evaluation of EPNs

Infectivity of promising EPNs such as *Steinernema sp.* (IISR-EPN 02) and *Oscheius gingeri* (IISR-EPN 07) was tested against shoot borer *Conogethes punctiferalis* infesting ginger and turmeric under field conditions. Among the treatments, integrated treatment with IISR-EPN 02 and malathion showed less shoot borer damage in ginger and turmeric (12.6 and 20.8%, respectively) which was on par with the malathion (14.7 and 22.6 %, respectively). In another trial, conducted in a farmer's plot, integrated treatment (IISR-EPN 07 + malathion and IISR-EPN 02 + malathion) showed less shoot borer damage (5.5 and 5.7%, respectively) compared to 21% in control.

Other insect pests

Infectivity of EPNs

Among the six entomopathogenic nematodes tested under *in vitro* conditions against *Spodoptera* sp. and root grub *Leucopholis coneophora* Burm infecting ginger, *Steinernema sp.* (IISR-EPN 02) and *O. gingeri* (IISR-EPN 07) caused 100% mortality within 72 h.

TURMERIC

Genetic Resources

To date, 1404 Curcuma accessions are being maintained in the field gene bank. The germplasm conservatory was enriched with 69 turmeric germplasm received from four centres.

Characterization of 102 turmeric accessions was done for different morphological traits as per the DUS guidelines. Among the qualitative characters, pseudostem growth habit and leaf disposition exhibited maximum variability. Maximum yield per plant was recorded in Acc. 48 with bold fresh rhizomes. Acc. 849 was unique with elongated mother rhizome and has purple pigmentation in the leaf mid-rib.

Forty four RAPD primers and 31 microsatellite (SSR) primers were used for molecular profiling of 10 genotypes. The dendrogram generated from the data revealed that the selected genotypes are distinct from each other. Accession 849 was found to be distinct from all the other genotypes in accordance with its distinct morphological identity.

Breeding

A high yielding, short duration turmeric variety has been developed through germplasm selection. The variety, christened IISR Pragati, was tested as Acc.48, for over three years in different turmeric growing regions of the country and under various climatic conditions. The characteristic features are:

- Short duration variety needing only 180 days to harvest: suitable for turmeric growing areas with serious irrigation problems.
- High yielding variety with average yield of 38 t ha^{-1} (fresh rhizomes).
- Stable and high curcumin content (5.02%) across locations.
- Moderately resistant to root knot nematode infestation.
- The variety is suitable for cultivation in Kerala, Tamil Nadu, Andhra Pradesh, Telangana, Karnataka and Chhattisgarh states.
- This variety was identified for release by the XXVII All India Coordinated Research Project on Spices (AICRPS) Group Meeting held at ICAR-NRCSS (Ajmer, Rajasthan) during October 2016.

Crop management

Eleven varieties of turmeric were tested under five treatments viz., organic 100%, organic 75%, INM (75% org + 25% chemical), INM (50% org + 50% chemical) and 100% chemical for yield and quality. Significantly higher fresh rhizome yield was recorded in INM 50:50 (14.45 kg 3 m^{-2} bed) & INM 75:25 (14.9 kg 3 m^{-2} bed). Among the varieties, Suguna and Sudharsana recorded significantly highest yield (20.4 kg 3 m^{-2} bed) under INM 50:50 & INM 75:25 on par with organic (100%) management followed by Suvarna, Kanti, Varna and Shoba (14-17 kg 3 m^{-2} bed). Highest curcumin content was observed in Prathiba under INM 75:25 (4.88%) followed by INM 50:50 (4.77%) and organic (100%) (4.70%) nutrient regimes.

Post-harvest technology

Quality of turmeric cured in the concentrated solar curing unit

The quality of turmeric cured in solar curing unit along with other curing methods indicated that there was no significant change in the quality of turmeric in terms of its essential oil and oleoresin content. However, there was significant reduction in the curcumin content with the increase in curing time.

Plant health management

Field screening for foliar diseases

Around 102 accessions of turmeric were screened for foliar diseases and 20 accessions were found to be infected with *Taphrina maculans.* Leaf blotch caused by *T. maculans* was found to be severe in accessions, Narendra Haldi, BSR 1, BSR 2, CO 2 and Rajendra Haldi. Nineteen accessions were found to be infected with leaf spot caused by *Colletotrichum spp.*

Root knot nematodes

Pochonia chlamydosporia, Trichoderma harzianum and neem cake were evaluated for management of root-knot nematodes infesting turmeric intercropped with coconut *P. chlamydosporia* followed by neem cake was found superior in controlling root knot nematodes.

NUTMEG

Genetic Resources

Three new accessions of nutmeg with bold nut and thick mace were added to the germplasm, collected through farmer participatory germplasm collection in Kozhikode district, Kerala.

The influence of weather parameters on sex expression in nutmeg was studied. Monthly observation of flowering pattern at two locations revealed that peak season of flowering at Kozhikode was during July to December whereas at Appangala, it was during March to May. With respect to the sex forms, male flower production was seen throughout the year at Kozhikode while at Appangala it was lean during January, February and August. Female flower peak season was from July to November and March to May at Kozhikode and Appangala conditions respectively.

Crop management

An investigation was carried out to study the effect of integrated nutrient management and benzyl adenine application on growth and yield in nutmeg variety IISR Viswashree. Application of coir pith compost 1 kg $plant^{-1}$ during May, soil application of recommended nutrients (80:72:200 g $plant^{-1}$) during June and September, foliar spray of micronutrients (0.5%) and spraying of BA (10 ppm) during June and September was effective in improving early fruiting (within four years) in young plants.

ALLSPICE

Incidence of auger beetle (*Sinoxylon anale)* and its entomopathogen

The incidence of auger beetle, *Sinoxylon anale* Lesne (Bostrichidae: Coleoptera), a destructive pest of cosmopolitan occurrence, was reported for the first time on allspice trees from Kozhikode, Kerala. Based on the morphological characterization and sequencing of a partially amplified fragment of the mitochondrial CO1 gene the insect was identified as *S. anale.* An entomopathogenic fungus was isolated from infected cadavers of *S. anale* which was identified as *Beauveria bassiana* (Bals.-Criv.) Vuill., sensustricto (s.s) (Ascomycota: Hypocreales). The fungus was virulent against adult beetles and this is the first record of *B. bassiana* naturally infecting *S. anale.*

VANILLA

Wilt and leaf spot diseases

Surveys conducted in Karnataka and Tamil Nadu indicated that the major diseases were wilt and leaf spot and their incidences ranged between 0-25% and 2-25%, respectively. *Fusarium oxysporum* f. sp. vanillae (Fov) and *Colletotrichum gloeosporioides* were found associated with wilt and leaf spot diseases, respectively.

Biological control

Predominant bacteria associated with the phyllosphere and rhizosphere of vanilla was *Bacillus subtilis, B. cereus, B. pumilis, B. thuringensis, B. coagulans and B. atrophaeus.* Among the bacteria, VREn1 was found to be inhibitory against Fov under *in vitro* conditions. Among the epiphytic and endophytic fungal genera isolated and characterized, FVLEP4 was found to be highly inhibitory against Fov.

Surveillance and documentation of pests and diseases

Forty three plantations of cardamom (9), black pepper (19) and cardamom – black pepper mixed cropping systems (15) representing diverse agro-ecological regions were surveyed for the occurrence of pests and diseases. In black pepper, foliar infection/foot rot due to Phytophthora, slow decline, anthracnose /spike shedding/necrosis and blight due to Colletotrichum, stunt disease were the major diseases. Foliar blight, an atypical symptom induced by Colletotrichum was more pronounced during post-monsoon period. Infestation of pollu beetle and scale insects were the major pests observed during the surveys.

In cardamom, leaf blight incited by Phytophthora and Colletotrichum, stem lodging and capsule anthracnose were the major diseases. The major viral diseases recorded during the survey were chlorotic streak, kokkekandu and katte. Pseudostem borer, thrips and infestation of minor pests were also observed in the surveyed regions.

Documentation of natural enemies of spice crop pests

Surveys for incidence of natural enemies of spice crop (black pepper, cardamom, ginger, turmeric, nutmeg, allspice and clove) pests were conducted in 34 locations in Kerala, Karnataka and Tamil Nadu. Three entomopathogens were documented from *Sinoxylon spp., Marsipococcus marsupialis* and *Mimegralla coeruleifrons.* The fungus infecting *Sinoxylon spp.* was identified as *B. bassiana* (IISR-EPF-13) and that infecting *M. marsupialis* as Isaria sp. (IISR-EPF-14). An entomophthoralean fungus recorded from *M. coeruleifrons* has been tentatively identified as *Batkoa sp.* (IISR-EPF-15).

High value compounds and phytochemicals

Antioxidant activity of spice extracts

Combinations of spice extracts (cinnamon: turmeric (2:1) showed maximum antioxidant potential tested by DPPH scavenging activity

In vivo anti inflammatory potential of turmeric and cinnamon

Study conducted in normal rats administered with methanolic extract of cinnamon and

turmeric (2:1) revealed that the activity of the enzymes catalase (CAT), superoxide dismutase (SOD), glutathione-S-transferase (GST), lacatate dehydrogenase (LDH), malate dehydrogenase (MDH), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were not affected indicating no adverse effect of the extract.

In vitro cytotoxicity

Studies on the *in vitro* cytotoxic effect of spice extracts carried out at RCC Thiruvananthapuram on the cell lines SKBR-3 (breast cancer) and HCT-116 (colon cancer) indicated that all extracts possessed concentration dependant activity between 50 µg mL^{-1} and 800 µg mL^{-1} and hexane extract of cinnamon had the highest cytotoxic effect.

Hypoglycemic potential of black pepper, cinnamon and turmeric extracts

In vitro hypoglycemic potential of methanol extract of cinnamon, turmeric and cinnamon: turmeric mixtures (2:1, 1:1 ratios) were studied using α-amylase enzyme. Higher inhibitory potential was observed for cinnamon extract followed by cinnamon: turmeric mixture (2:1 ratio). α- glycosidase inhibitory assay also showed the same trend.

Spice economics

Growth, instability and export trends in small cardamom

The instability of key variables affecting small cardamom production in the country during the last four decades was analyzed critically to explore the patterns of instability. A marked decline in instability was identified in production, yield and export quantity. The export quantity of small cardamom showed a higher compound annual growth rate (3.53%) during the second period (1993-94 to 2014-15) accompanied by a sharp decline in instability by 52.7% in comparison to the first period (1971-72 to 1992-93).

The decline in yield and production instability between the two periods was 44 and 33%, respectively.

The share of domestic production exported declined from 46.3% for the triennium ending 1974-75 to 20.0% for the triennium ending 2014-15. Though the production of small cardamom increased by 2.5 times during the last three decades, the share of domestic production in exports of cardamom remained constant. India's share in global cardamom exports have also declined from 48.6% in 1974-75 to 10.1% in 2014-15.

Price instability in spices

A study was conducted on the price movement of important spice crops to understand the price fluctuations in major spices and their magnitude. Using monthly time series nominal price data of spice commodities, the real prices were constructed using WPI (2004-05 series) index as deflator. A fluctuation margin for prices was considered at 20% deviation from predicted prices constructed using normal forecasting techniques.

Relative contribution of yield growth to spices production

A simple decomposition model was used to measure the relative contribution of yield component to increase in production of spices. The results indicated that the yield enhancement has contributed significantly to the increase in spice output. The results were similar across several spice crops like cardamom, turmeric and ginger where the direct and indirect yield effects contributed more than 50% of increase in output. For spices production as a whole the area effect, yield effect and interaction effect were 32.4, 45.2 and 22.4%, respectively.

INSTITUTE TECHNOLOGY MANAGEMENT AND BUSINESS PROCESS AND DEVELOPEMNT

During the year, the ITM-BPD Unit has issued three licenses for black pepper varieties IISR Thevam and IISR Girimunda to two clients. Turmeric variety, IISR Alleppey Supreme and ginger Variety IISR Varada were licensed to Centre for Overall Development, Thamarasserry, Kerala. The new turmeric variety IISR Pragati is under consideration for registration by PPV and FRA. Two clients have availed the license for commercial multiplication of IISR Pragati.

The Unit organized and conducted the market launch programme on 27.06.16 for two products "Powercap" and "Trichocap" on behalf of the licensee, M/s Codagu Agritech, Karnataka in presence of Honorable MP, Mysuru, Mr. Pratap Simha.

A planting material production unit cum nursery for spices, ornamentals, plantation and fruit crops was established at IISR, Chelavoor. License agreement for cleaning, grading, packing and powdering of black pepper and white pepper was signed with CAMPCO Pvt India Ltd. on 23rd February at Mangaluru.

The unit conducted two EDP programmes, one on curry powder production during July 2016 and another on fruit and vegetable processing for women self help groups during August 2016. The unit also participated in VAIGA-2016, exhibition organized during the "International Workshop on Agro Processing & Value Addition" conducted by Department of Agriculture, Development & Farmers' Welfare, Government of Kerala. The unit also participated in Kisan Melas and exhibitions for show-casing commercialized technologies of IISR.

EXTENSION AND TRAINING

The transfer of technology programmes of the institute was provided through regular channels like visitor advisory services which provided specific advice to more than 2700 farmers. The other visitors included 1800 students and 250 officials.

Skill development and capacity building programmes were implemented under the sponsorship of various state departments and central sector schemes of Tribal sub plan and programme for NE region. Thirteen training programmes were conducted on campus benefiting more than 300 partici-pants including stakeholder groups like farmers, youth, tribal beneficiaries and students. Under the Tribal sub plan eight training programmes were organized off campus benefiting 600 tribal farmers from the states of Kerala, Tripura and Arunachal Pradesh. The institute also facilitated the monthly technology advisory meeting of the district Agricultural Technology Management Agency (ATMA) by providing expert support for resolving field problems. The institute was also featured in a special educational programme as leading destination for higher education in the field of agricultural research. Eighteen programmes benefiting more than 100 farmers were organized.

A total of 48 exhibitions days were organized by the institute during the last year. The institute facilitated a total of 50 group visits for educational institutions to provide exposure to research and development activities in spice crops. About 15 farmer groups from within and outside the state under MIDH or ATMA visited the institute for learning about the technologies developed for improved spices productivity.

Several demonstrations aimed at tribal farmer empowerment were undertaken. Varietal demonstrations in black pepper were under taken in Kerala, Tripura and Arunachal Pradesh. Demonstration in collaboration with the Spices Board, on application of Trichoderma in capsule forms in black pepper and ginger is in progress in four districts of Arunachal Pradesh and in Shillong and Guwahati. Demonstration of single sprout transplanting method in ginger was laid out in four KVKs in Tripura.

In tune with the policy objective to step up revenue generation, efforts were taken through ATIC to generate more income from the sale of technology inputs and services which resulted in an increase of 143 % in revenue compared to last year.

Varietal dissemination

Feedbacks from farmers' plot revealed very good acceptance of the released turmeric and ginger varieties. Mr. Ramaprasad Reddy of Hyderabad, an IT professional turned turmeric grower, who has been growing Prathibha for the the last three years has ventured into value addition of turmeric. Mr. V. Sureshkumar of Kalarkode, Alleppey is another small scale entrepreneur who in a vlaue chain mode markets powdered Prathibha in southern Kerala.

Mr. K.C. Joseph Kavukatt, a small farmer from Venappara on the eastern part of Kozhikode, Kerala who grew Varada ginger in about 2.5 acres (intercrop in rubber plantations) reported about 40 q production this year. Mr Jojo Jacob, an ICAR-IISR KVK trained youth of Kadiyangad, Kozhikode district too obtained very good yield from Varada ginger. Mrs. Elzy Devasia, a women farmer from Chempanoda, Kozhikode harvested on an average 1.5 kg fresh rhizome from Varada raised in grow bags.

Integrated black pepper research and development in North Kerala districts

Twenty four FLDs on improved technologies that were initiated at farmer's plots in three panchayaths of Kozhikode district during last year were continued with necessary input supply along with two participatory nurseries. Five visits were made by the scientists to the FLD plots for giving advisories.

Six hundred and twenty soil samples from farmer's plots were analysed for macro and micro nutrients and issued with soil health card advisories. Demonstrations on site specific nutrient management were taken up in five farmer's plots. Amendments and fertilizer doses were applied based on the soil test and foliar supplementation of micronutrient based on leaf nutrient ratios were taken up.

Due to site specific management, the soil pH, OC, P, K, Ca, Mg and micronutrient availability showed a significant increase as compared to farmers practice. The spike intensity and yield (per std) also showed a significant increase in soil application of fertilizers (29.3 0.5 m^{-2} & 1.45 kg dry std^{-1}) and fertilizers + micronutrient foliar supplementation (30.5 0.5 m^{-2} & 1.48 kg dry std^{-1}) treatments as compared to farmers practice (25 0.5 m^{-2} & 1.3 kg dry std^{-1}). The site specific nutrient management also helped in increasing the bulk density (448 g L^{-1} in farmers practice and 500 g L^{-1} in treatments) and piperine content (5.3% in farmers practice and 5.6-6.5% in treatments).

Enhancing economic viability of coconut based land use systems

In pepper, application of amendments (dolomite + gypsum) significantly improved the pH of the surface (0-15 cm) and sub surface soil (15-30 cm) as compared to farmers practice. The soil availability of P, K, Ca, Mg and Zn also increased significantly at both the depths studied as compared to farmer's practice. The adoption of site specific soil fertility management resulted in significantly higher yield (1.6-1.78 kg dry std^{-1}) as compared to farmers practice (0.98 kg dry std^{-1}). In demonstration plots 33-68% increase in yield was recorded under site specific management treatments in addition to increase in oleoresin, piperine contents and bulk density as compared to farmers practice.

Under nutmeg system also the soil pH increase was higher in lime + gypsum treatment on par with that of lime application alone at both the soil depths studied. Lime + gypsum supplementation with site specific fertilizer application recorded 30% higher nut and mace yield (3.9 & 0.6 kg fresh $tree^{-1}$) as against farmers practice (3.0 & 0.45 kg fresh $tree^{-1}$). In demonstration plots an increase of 18-28% in fruit yield was observed in treated trees over farmers practice.

Area wide integrated pest management

Three demonstration plots were laid out in Muthappanpuzha (Kozhikode district, Kerala) for demonstrating the different packages for management of foot rot and slow decline disease of black pepper. Three black pepper nurseries were established in Omasserry, Muthappanpuzha and Anakkampoyil for demonstrating production of healthy and disease free planting materials in farmers' plots in a participatory mode. Biocontrol agents *T. harzianum + P. chalmydosporia* followed by *Ketasatospora setae + Streptomyces tauricus* were found promising in producing disease-free and healthy planting materials.

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 766), 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.

Mandates

- Basic, applied and strategic research on genetic resource management, crop improvement, crop production and protection technologies for enhanced produc tion of safe spices.
- Transfer of technology, capacity building and impact assessment of technologies.
- Coordinate research and validation of technologies under AICRP 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 1987 lakhs during the year, which included 506.5 lakhs under Plan and 1480.5 lakhs under Non Plan.

Resource generation: Institute earned a total of 67.7 lakhs through sale of planting materials, biocontrol agents, training, publications and consultancy services.

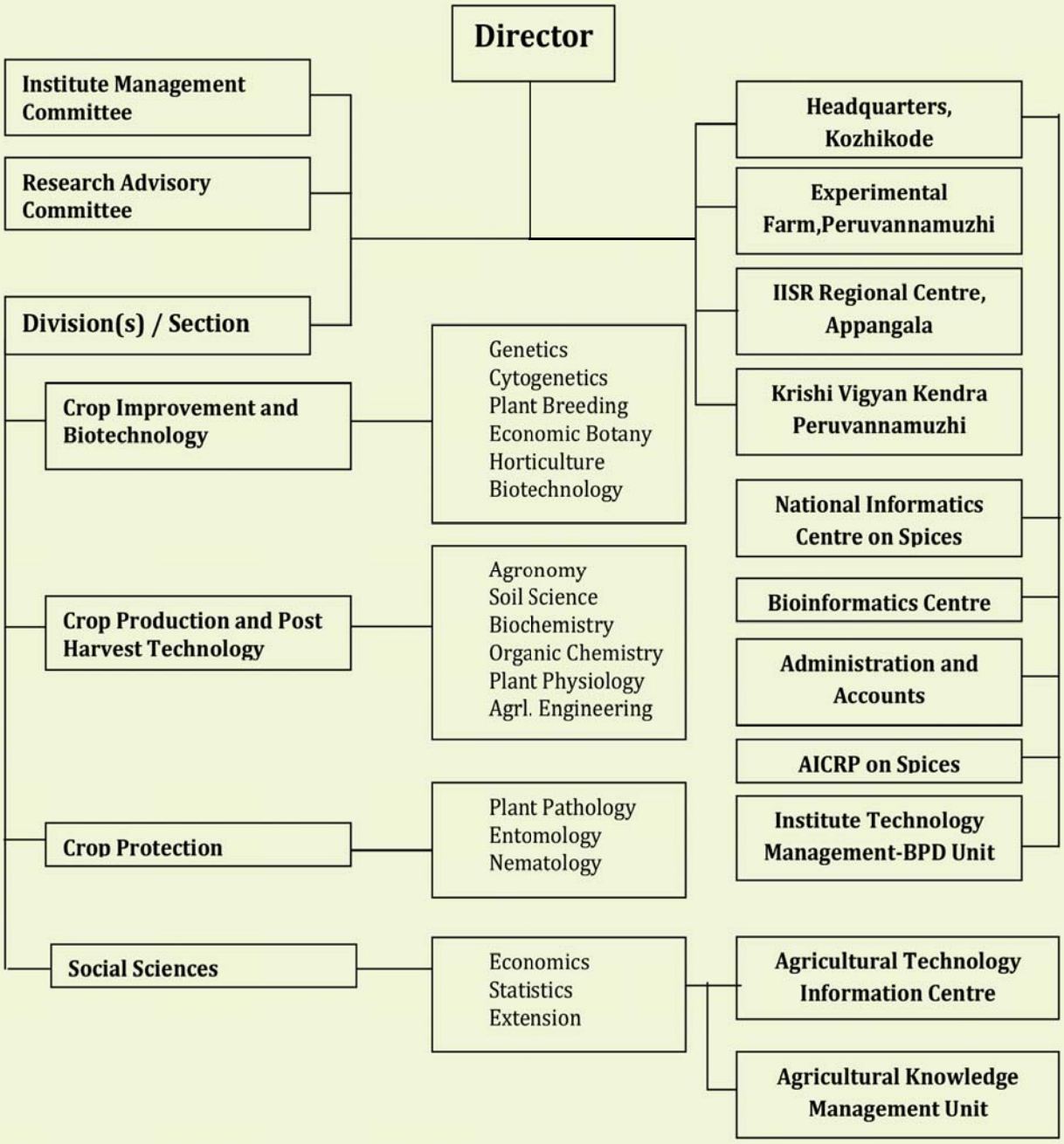
Staff

The institute has a sanctioned strength of 45 scientific, 24 administrative, 33 technical and 61 supporting staff, of which 38, 17, 23 and 13 of scientific, administrative, technical and supporting staff, respectively are in position. The KVK has a sanctioned strength of 2 administrative, 12 technical and 2 supporting staff

Staff position of the Institute

* Director

POSITION						
Category	Sanctioned	Kozhikode	Peruvannamuzhi	Appangala	Total	Vacant
Scientist	44+1*	32 +1*	0	05	37+1	07
Technical	33	14	06	03	23	10
Administration	24	15	-	02	17	7
Supporting	61	02	03	8	13	48
Total	162 +1	64+1	09	19	92+1	70
STAFF POSITION OF KVK						
Category	Sanctioned	Kozhikode	Peruvannamuzhi	Appangala	Total	Vacant
Technical	12	-	12	-	12	-
Administration	2	-	1	-	1	1
Supporting	2	-	2	-	2	-
Total	16	-	15	-	15	1



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 farmers' field in Kerala and Karnataka.

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 50L vine^{-1} enhanced yield substantially. High production technologies and mixed cropping systems were developed for increasing productivity. Among different forms of potash, water-soluble and available K had significant positive correlation with berry yield, oleoresin and piperine. 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 zizanoids* 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 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 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 stunted 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 more closely related to members of aster yellows group (16Sr I) 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 24h. Basal application of *T. harzianum* and aerial spray with 1% Bordeaux mixture was found effective in controlling anthracnose disease.

An integrated pest management schedule for management of root mealy bug has been developed. Metalaxyl-MZ sensitivity of 81 Phytophthora isolates was tested and the EC50 and EC90 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 farmers' 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, fertilisers 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 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 *Cardamom mosaic virus* (CdMV) and *Banana bract mosaic virus* (BBrMV) in cardamom was developed. Surveys conducted in Karnataka and Kerala, revealed the prevalence of *Banana bract mosaic virus* (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 *R. solanacearum* biovar 3 phylotype 1. Multiplex-PCR based phylotyping, 16s rDNA & 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, *C. 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 Prathibha, 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 'Prathibha' 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 two nutmeg varieties Viswashree and Keralasree 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 (45.0% 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 are 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 micro propagation 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

The germplasm accessions at the NAGS center are maintained at the Experimental farm, Peruvannamuzhi. At present, 3395 germplasm accessions are maintained at *ex situ* conservatory (germplasm nursery) of the institute which comprised of 1768 local cultivars, 1618 accessions of related taxa and nine exotic types. Improved varieties and example varieties are planted under protected condition for conservation. A field genebank of 200 accessions at Peruvannamuzhi, 223 at Chelavoor and 627 accessions at the alternate field genebank, CHES, Chettalli are the other attractions of the conservatory. The alternate field genebank at CHES, Chettalli was enriched with 100 more accessions during the year.

Thirty one cultivated black pepper accessions, including four unique types were collected from different estates of Kodagu district, Karnataka during the year. The unique accessions collected are:

- A black pepper accession with very long spike (about 30 cm long) from SLN Plantations, Madikeri
- An accession having male, female and bisexual flowers in the same vine
- A black pepper accession with very less pungent ('sweet') berries
- A black pepper variant resembling the triploid variety "Vadakkan" but with elongated leaves.

In addition to this, two wild accessions were collected from Arunachal Pradesh (Fig. 1)

Eighty five accessions were characterized based on IPGRI descriptors for 27 traits. Among the accessions characterized Acc. no. 7231(Karimunda) recorded maximum yield of 11.5 kg (fresh yield vine^{-1}) followed by Acc. 7232 (Kaniakadan) with 8.5 kg vine^{-1}. IC numbers were obtained for 217 cultivars and 108 wild accessions. With this, all the accessions conserved in the NAGS for black pepper are with IC numbers except the exotic collections.

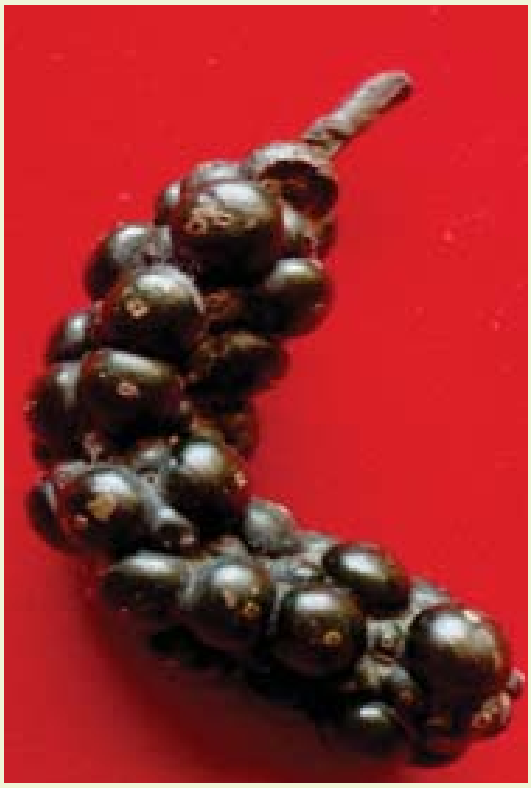


Fig. 1. Mature spike of Piper species collected from Arunachal Pradesh

Breeding

A replicated yield trail involving 10 improved lines/selections along with 2 controls laid out during 2012 started yielding. Maximum fresh yield vine^{-1} was recorded in the line Hp 117 x Thommankodi (3.46 kg vine^{-1} 30.2% dry recovery) (Fig. 2) followed by OPKM (2.679 kg vine^{-1} with 33.2% dry recovery) and Thevam (2.49 kg per vine with 31.3% dry recovery). However, Hp780 recorded highest dry recovery of 38.5% though the yield vine^{-1} was 1.5 kg.

Fig. 2. HP117 x Thommankodi

Sreekara (control) and HP 728 had 3.6% oil each followed by Hp 1411 and Coll. 820 with 3.5 and 3.4% oil, respectively. However Coll. 820 recorded highest oleoresin (10.2%) followed by Hp1411 (9.1%) and Hp 728 (9.0%).

Natural pollu beetle infestation ranged from 0 (Hp 1411, Hp 728, Hp 780, Hp 117 x Thommankodi, Sreekara and Coll. 820) to a maximum of 4 % (Coll. 1114). P24(04) and Coll. 1090 had 1 % infestation.

Screening for drought tolerance

Seventeen F1 progenies (Subhakara X Acc. 931) were screened for drought tolerance under field condition. Progenies showed variation for relative water content and membrane leakage at 12-13 % soil moisture content. Molecular characterization using SSR markers did not show any polymorphism.

Single-molecule long read sequencing -drought tolerance studies

Using long-read sequences from the combined RNA samples from drought induced and the control samples of black pepper, 8,380 polished high-quality isoforms were generated from 53689 reads of inserts (ROIs) with mean read length of 2378 bp. Error correction of these isoforms were done with Illumina sequencing data from the same samples.

Top protein domains in the transcripts were identified based on Pfam database. Among the genes involved in secondary metabolism, 11 transcripts belonging to the 2-C-methyl-D-erythritol 4- phosphate (MEP) or mevalonate (MVA)-dependent isoprenoid precursor pathways, 46 transcripts in the metabolism of terpenoids and polyketide and 36 transcripts in the biosynthesis of other secondary metabolites were identified. Piperine alkaloid, the main constituent of black pepper is derived from the products of lysine. Seven transcripts related to the biosynthesis of lysine and transcripts with similarity to two other downstream genes were found.

The transcripts were also aligned against the drought responsive gene sequences in the drought stress gene database (Drought DB) and 431 transcripts were found to be matching to molecular adaptation regulatory (MAR) sequence, 96 were aligned to molecular adaptation functional (MAF) sequences and 331 were aligned to physical adaptation (PA) sequences.

One thousand five hundred and fifty seven simple sequence repeats (SSRs) were also identified in 1247 transcript sequences. Organellar gene annotations done with the transcript sequences resulted in the identification of 61chloroplastic and 782 mitochondrial transcripts.

Mining of antimicrobial peptides (AMPs)

A cysteine rich peptide showing similarity to plant defensins with a mature peptide length of 48 amino acids was discovered from the black pepper derived transcripts. Comparative analysis of the deduced amino acid sequence with other members of the defensin family revealed that the peptide shares a disulphide bridge pattern common to major plant defensins.

Cyclotide type of AMPs are most preferred as they combine potent bioactivities with remarkable thermal and proteolytic stabilities. Probing for small cyclotide like sequences in the black pepper transcriptome data helped to identify one putative cyclotide with deduced amino acid composition, potential to form head-to-tail cyclized backbone topology that is stabilized by three disulfide bonds to form a cystine- knot (CCK) motif. The peptide with a length of 41 amino acids has the bracelet type pattern of cyclotides, C-X(3)-C-X(3 to 5)-C-X(4 to 7)-C-X-C-X(4 to 7)-C-X(4 to 9).

Crop Management

Management of virus affected gardens for yield sustainability

Trials on the management of virus affected black pepper gardens sustaining its health and yield was taken up in three estates at Madapura, Chettalli and Pollibetta in Madikeri district of Karnataka. The treatments were T1- FYM + Fertilizers as per recommendation, T2-T1 + Micro nutrient spray (twice), T3- T1 + PGPR soil application (twice), T4 – T3+ Micronutrient spray (twice) and T5 – Control. The vines categorized as mild recorded significantly higher spike intensity, canopy development, health status as compared to moderate infected vines. The spike intensity was 22.9-26.5/0.5 m^2 area of the canopy in mildly infected vines as compared to 17.5-21/0.5 m^2 in moderately infected vines. Even though the application of different treatments (FYM, NPK, Micronutrients and PGPRs) showed no significant influence on the spike intensity and canopy development in vines across estates, the health of the vines (virus infection intensity) improved significantly (with a score of 3.1-3.6) as compared to control (2.6-2.8) with highest health score in FYM+ NPK+ PGPR+ Micronutrient applications. The canopy build up was also good in all the treatments applied with NPK, PGPR or micronutrients as compared to control. The fresh yield was higher in application of FYM + NPK + PGPR + Micronutrients (3.6-7.1 kg std^{-1}) on par with FYM + NPK + Micronutrients application (3.2-6.4 kg std^{-1}) and significantly higher than control (2.4-4.4 kg std^{-1}) across estates.

Scheduling fertilizer dose for fertigation

An adaptive trial was conducted at Laxmi Estate, Hosahalli, Mudigere where fertigation unit was laid out by the farmer, to quantify the extra nutrient to be supplemented either by soil application or through foliar over and above the fertigation dosage. Based on initial soil nutrient status and yield levels the fertilizer dose to be supplemented through soil and leaf in addition to fertigation were calculated and applied. Supplemental application of NPK and micronutrients as foliar sprays increased the leaf concentration of K, Mg, Zn and B. Soil supplementation of fertilizers and foliar spray of NPK & micronutrients recorded significantly higher yield over fertigation alone. In terms of economics, an additional investment of Rs. 15 per standard yielded an additional profit of Rs. 175 per standard, over and above fertigation.

Biochemical parameters as influenced by moisture stress in field grown black pepper

Nine previously identified drought tolerant accessions (acc nos. 1439, 1622, 807, 4072, 1277, 4226, 4216, 1495 and 1368) along with Subhakara (check) field planted at Chelavoor farm were water stressed for 21 days. Physiological parameters such as relative water content (RWC), membrane leakage, catalase activity, ascorbate peroxidase activity *etc*. were estimated in these genotypes under control (19.1 % soil moisture) as well as 20 days after stress induction (14.1 % soil moisture). RWC, chlorophyll fluorescence and catalase activity were higher and membrane leakage and ABA content were lower under control compared to those under stress. Among the genotypes, Acc 4216 maintained highest RWC after 20 days of stress. There was significant variation among the accessions for catalase, peroxidase, ascorbate peroxidase activities and abscisic acid content both under control as well as under stress conditions.

Influence of rainfall and mitigation of climate change effects

For mitigation of climate change effects especially long drought spell, anti-transpirants such as kaolin 1.5%, and 2%, and spray lime 1.5% with 0.5% SOP were sprayed to black pepper vines in February 2017. Kaolin 2% sprayed leaves showed higher photosynthetic rate than other treatments with minimum transpiration rate and maintained lower leaf surface temperature than other treatments by reflecting sunlight incident on the leaf surface. Similarly, good rainfall and irrigation during rainless period recorded more number of spikes per unit area of the canopy and more number of berries per spike compared to low rainfall condition in black pepper. Delayed rainfall resulted in delayed flowering and partial setting of berries in Kodagu, Sakleshpur and Chikkamagaluru region during 2016-17.

Delineation of spice zone

The latest five years available data on area, production and productivity of black pepper from authorised sources for major pepper producing states of India were collected. Efficient cropping zones of black pepper were identified based on the criteria of relative yield index (RYI) and relative spread index (RSI). The zone efficiency is considered as high if RSI is > 100 and RYI is > 125; medium, if RSI is 75-100 and RYI is 75-125 and low if RSI and RYI are <75. Accordingly, nine zones were identified in the black pepper growing regions of India. The zone is considered as the most efficient (Zone 1) when RSI and RYI are high; if RSI is medium and RYI is high then it is the most efficient with variation (Zone 1a); low RSI and high RYI is considered as efficient zone (Zone 2); for high RSI and medium RYI - it is efficient zone with little year to year variation (Zone 2a); for medium RSI and medium RYI – efficient zone with medium year to year variation (Zone 2b); for low RSI and medium RYI – efficient zone with great year to year variation (Zone 2c); high RSI and low RYI – not efficient zone with greater variation (Zone 3); medium RSI and low RYI - not efficient zone with medium variation (Zone 3a) and if both RSI and RYI are low, it is not efficient zone with greater variation (Zone 4). Based on the analysis, it was found that only Chikkamagaluru in Karnataka, Dindigul and Theni in Tamil Nadu and Hailakandi in Assam are the most efficient black pepper cropping zones (Fig. 3).

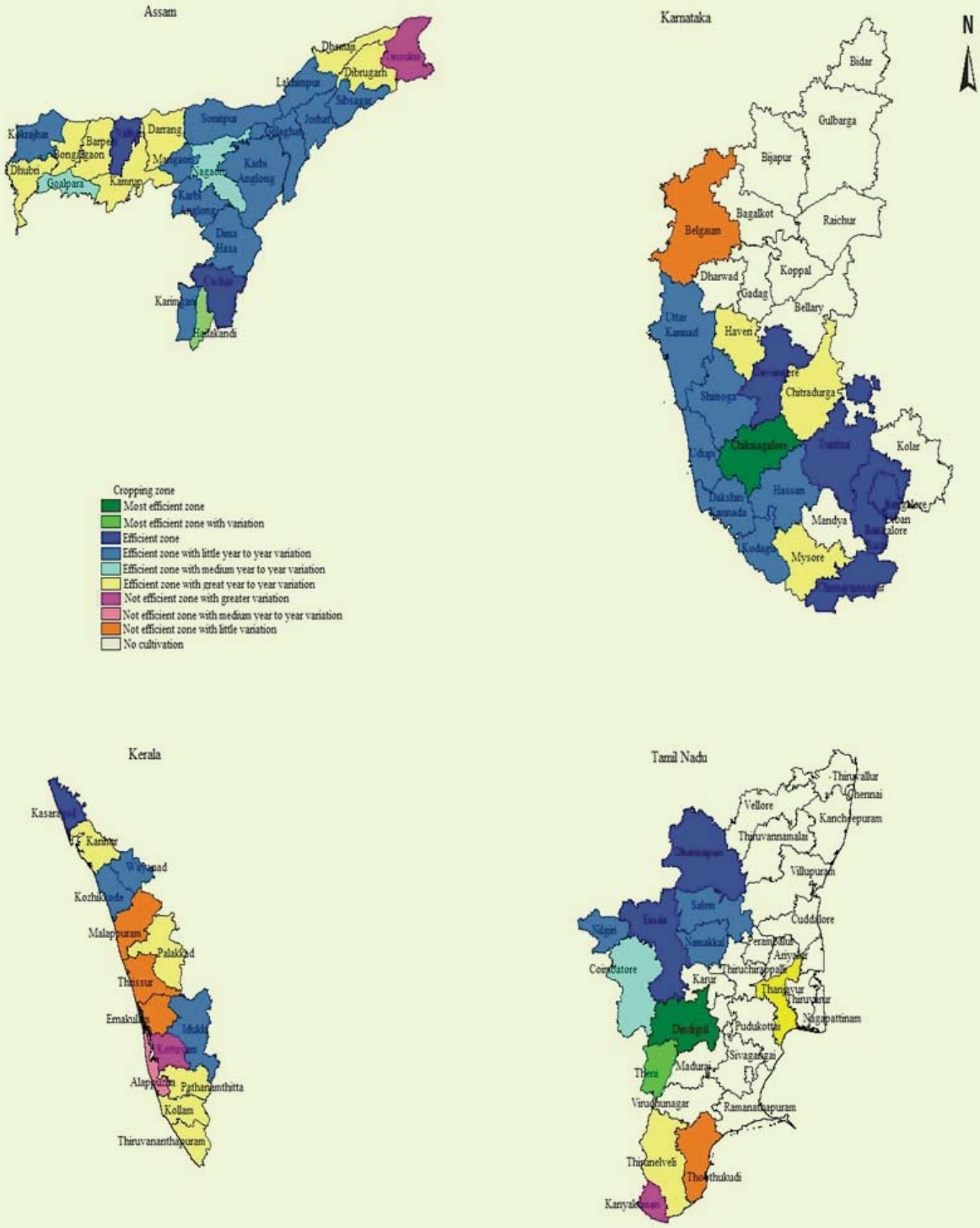


Fig. 3. Efficient cropping zones of black pepper

Fig. 4. Solar steam generating unit

Steam blanching of green pepper in the solar curing unit

Studies on steam blanching of green pepper (variety IISR-Thevam) using the steam generated by concentration of solar power in the solar steam generating unit was evaluated during January 2017. The steam generated was used to blanch green pepper in the newly installed tray type horizontal blanching vessel (of Inner diameter 89.6 cm and length 80.5 cm) provided with four perforated trays of size 67 x 54.7 x 7.6 cm. Four kg of freshly harvested green pepper was spread in each tray and was blanched with the steam generated from the solar steam generating system for 4 min. The other treatment followed for blanching was dipping in boiling water for 1 min and the control was unblanched pepper. It was observed that drying was completed in four days and the final moisture content of steam blanched pepper was significantly lower than other two treatments. The quality studies indicated that essential oil obtained was significantly higher in steam blanched black pepper than in other treatments (Table 2).

Table 2. Evaluation of the solar steam generating unit for blanching of green pepper

Treatment	Moisture (%)	Essential oil (%)	Oleoresin (%)
Un blanched black pepper	8.83	3.67	8.58
Water blanched black pepper	8.27	3.34	7.60
Steam blanched black pepper	7.77	4.00	7.30
Mean	8.29	3.67	7.83
SEd	0.15	0.12	0.11
CD (0.05)	0.37	0.30	0.27

Plant health management

Foot rot disease

Diagnostic tools for detecting Phytophthora

Genus - specific diagnostic assays like polymerase chain reaction, real-time PCR, Loop-mediated Isothermal Amplification (LAMP) and real-time LAMP based protocols were developed for detecting *Phytophthora spp.* Sensitivity assays indicated that, real-time PCR detected Phytophthora upto 1.3 fg, followed by LAMP (13 fg) and PCR (13 pg).

Investigations on mechanisms of Phytophthora resistance

The mechanisms of resistance in Phytophthora resistant line 04-P24 was studied based on structural, biochemical and molecular analysis. The results clearly revealed the mechanism imparted by 04-P24 towards *P. capsici* infection. The mechanisms include cell membrane integrity, increased cell wall reinforcement, higher level of OD phenols besides higher lignification and peroxidase activity with higher expression of cAPX gene in the resistant line. This resistant line can very well be used in crop improvement programmes either by conventional breeding or by genetic engineering or as a root stock to induce disease resistance in black pepper varieties.

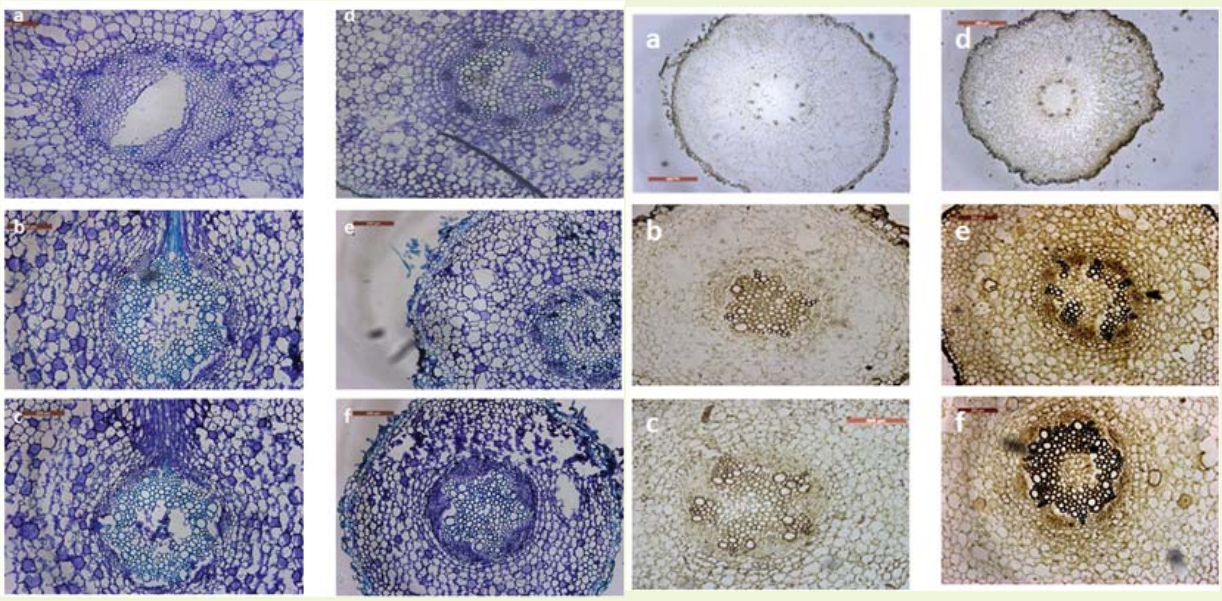


Fig. 5. Light microscopy images showing the response of root cells of Sreekara (a-c) and 04-P24 (d-f) to TBO (Left) and Maule (Right) staining. a and d are uninoculated roots of Sreekara and 04-P24 respectively. b and e are root tissues drawn on 4 DAI and c and f are drawn on 7 DAI. Characteristic blue or blue green staining of xylem vessel walls and parenchyma walls denote lignin and/or other cell wall associated phenols.

Expression analysis of defense-related genes in *Piper colubrinum*

Candidate genes known to play a role in defense signalling or in hypersensitive response (HR reaction) were studied in *Piper colubrinum* challenged with *Phytophthora capsici* using quantitative RT-PCR analysis. The genes, chorismate synthase, involved in shikimate pathway, and glutathione peroxidase associated with combating oxidative damage caused by reactive oxygen species (ROS) in plant cells showed peak expression at 16 hpi. Genes like metacaspase, one of the caspases which have been described as major regulators of apoptotic cell death, was expressed at the highest level during early hours, at 4 hpi. Nitrate reductase involved HR reaction cell death and cinnamate 4 hydroxylase, one of the phenylpropanoid biosynthetic enzyme, showed high expression at 24 hpi and 72 hpi, respectively.

Screening of new generation fungicides

Six new fungicide molecules viz. cymoxanil 8%+ mancozeb 64% (Curzate 60DF, 100ppm-500ppm), iprovalicarb + propineb (Melody Duo, 750ppm-1750 ppm), propineb (Antracol, 100ppm – 500ppm), chlorothalonil (Chlorothalonil 75WP, 500ppm – 1500ppm), famoxadone+ cymoxanil (Equation Pro, 200ppm – 600ppm) and metalaxyl - mancozeb (Ridomil Gold, 62.5ppm – 1000ppm) were evaluated in five different concentrations against Phytophthora. All the chemicals showed 100% inhibition of mycelial growth, sporulation and zoospore germination even at the lowest doses tested indicating the efficacy of these new generation fungicides in suppressing *Phytophthora sp.*

Actinobacteria, a novel group of biocontrol agents against Phytophthora

Out of the 50 actinobacterial strains screened, three Streptomyces isolates (IISRBPAct 1, IISRBPAct 25 and IISRBPAct 42) showed more than 90% inhibition against *Phytophthora capsici* and *Sclerotium rolfsii.* They produce different hydrolytic enzymes such as amylases, proteases, lipases, and cellulases. IISRBPAct 1 produce both IAA and siderophores while IISRBPAct 25 and IISRBPAct 42 produce only siderophores. IISRBPAct 1 showed maximum growth promotion and disease control (98.10%) due to *S. rolfsii* while IISRBPAct 25 showed highest control of *P. capsici* infection (80.73%) in an *in planta* experiment. Culture filtrates of these isolates showed 100% inhibition of *P. capsici* sporangial formation. Even 2% of IISRBP Act 1 and 5% of IISRBP Act 25 inhibited sporangial formation. In the detached leaf assay, 50-100% disease reduction was observed in the case of *P. capsici* and 46-55% lesion reduction in the case of *S. rolfsii.*

Field demonstration of foot rot and slow decline disease management

Five demonstration plots each were established at Muthappanpuzha (Kozhikode district) and Rajakkad (Idukki district) for demonstrating different packages for management of foot rot and slow decline diseases. The package consists of 1) *Trichoderma harzianum+ Pochonia chlamydosporia,* 2) 1% Bordeaux mixture + 0.25% COC + 0.1% carbosulfan and 3) 0.125% metalaxyl-mancozeb + 0.1% carbosulfan along with other recommended practices. There was no incidence of any disease in any of the treatments. However, the highest yield was recorded with pre and post monsoon application of *T. harzianum + P. chlamydosporia.*

Anthracnose disease

Nursery evaluation of fungicides

Among the fungicides evaluated against anthracnose under nursery condition, initial spray with Bordeaux mixture (1%) at 30 days followed by fenamidone – mancozeb (0.2%) at 45 days after planting was found to be effective compared to other treatments in reducing the disease. The differential expression of peroxidase isoforms (PO1 and PO2) upon treatment with different fungicides was found to be higher when the plants were sprayed with carbendazim – mancozeb (0.1%) at 45 days after planting. While, the expression of isoforms of polyphenol oxidase (PPO1 and PPO2) was higher with fenamidone – mancozeb (0.2%) sprays at 45 days after planting.

Viral diseases

Elimination of PYMoV in black pepper

Attempts were made to eliminate Piper Yellow Mottle Virus (PYMoV) infection in black pepper by adopting various tissue culture techniques like somatic embryogenesis, meristem tip culture and chemotherapy.

Somatic embryogenesis

Cyclic somatic embryos obtained from the micropylar region of matured seeds collected from PYMoV infected black pepper plants of six varieties namely, IISR-Malabar Excel, IISR-Shakthi,, IISR-Thevam, Panniyur 1, Sreekara and Subhakara, were regenerated in SH medium with 3.5% sucrose. The well differentiated plantlets were inoculated in WPM for rooting and rooted plants were hardened in the greenhouse. When total DNA isolated from 227 somatic embryo-derived plants belonging

to six varieties were subjected to PCR, 65 plants showed positive reaction indicating that 28% of plants are infected with PYMoV while rest of the plants (78%) were free from PYMoV. Variety wise data indicated 55 to 100% virus elimination in different varieties. Highest virus elimination (100%) could be achieved in the var. IISR-Thevam while the lowest virus elimination (55%) was observed in the var. IISR Malabar Excel.

Somatic embryogenesis combined with antiviral treatment

Cyclic somatic embryos obtained from the matured seeds of the black pepper variety Sreekara were treated with different concentrations (10, 20, 30, and 50 mg L^{-1}) of antiviral agent, ribavirin. The treated embryos were grown for 30 days in the same medium. Results indicated that proliferation of cyclic somatic embryo was not affected in 10 and 20 mg L^{-1}) ribavirin while at 30 mg L^{-1} proliferation was slow and at 50 mg L^{-1}) complete necrosis and death of somatic embryo was seen. In general the regeneration of the plantlets was slower in ribavirin treated cyclic somatic embryo compared to the control. The number of plants produced also decreased (upto 50% in 30 mg L^{-1}) in ribavirin treated cyclic somatic embryo. The ribavirin treated somatic embryos were regenerated using SH medium containing 3.5% sucrose. The regenerated plants were hardened in the greenhouse and tested for the presence of PYMoV through PCR using PYMoV specific primers. Thirty hardened plants from each treatment were tested for presence/absence of PYMoV by PCR. Seven out of 30 from 10mg L^{-1}) ribavirin treated plants tested positive for PYMoV. All thirty plants each tested from 20 and 30 mg L^{-1}) concentration of ribavirin tested negative for PYMoV indicating that ribavirin treatment of 20 mg L^{-1}) is sufficient for the complete elimination of the PYMoV from cyclic somatic embryo of black pepper.

Meristem tip culture

About 76% of the meristem derived plantlets were free from bacterial contamination while rest had slight endophytic contamination that didn't affect growth of the meristem. About 86% of meristems elongated within 35–50 days of inoculation. Four out of 30 meristems inoculated failed to develop roots while all other meristem-derived plants showed proper shooting and rooting by 90th day. Twenty-six well-developed plantlets were hardened in the greenhouse with potting mixture. Of the 26 hardened plants tested for PYMoV, four plants showed positive reaction indicating that 84% of meristem-derived plants were free of PYMoV.

Meristem tip culture combined with chemotherapy

Meristem excised from shoot tips of virus-infected plants of var. Sreekara was inoculated onto meristem regeneration medium (WPM with 3 mgL^{-1}BA + 1 mg L^{-1}) KN +1% tetracycline and 1% spectromycin) containing ribavirin at 0, 10, 20, 30, 50 mg L^{-1}) for a period of 30 days with two subculturing in the same medium at an interval of 15 days. Ribavirin treated meristems were then transferred to the same medium without ribavirin and antibiotics for proper shooting followed by rooting. Well-rooted plantlets were hardened in the greenhouse. Except for the 10 mg L^{-1}) ribavirin, all other treatments resulted in slow elongation and regeneration of meristem. The number of days taken for the regeneration of meristem was more (about 60–80 days) compared to control (about 35–50 days). The number of plantlets obtained also varied among treatments. Maximum number of plants (10) was obtained in 10 mg L^{-1}) ribavirin treatment while minimum (6) was obtained in 50 mg L^{-1}) ribavirin treatment. All ribavirin treated meristem-derived plants (36) from different treatments tested negative for PYMoV in PCR. Thus, meristem culture combined with ribavirin treatment was found to be more effective than meristem culture alone for PYMoV elimination in black pepper. Amending the WPM medium with 10 mg L^{-1}) of ribavirin was sufficient for the complete elimination of PYMoV from meristem culture

Plant parasitic nematodes

Root-knot nematode on Vigna unguiculata, a new report

The cowpea crop, *Vigna unguiculata* (L.) is an herbaceous legume crop used as a cover crop in coconut gardens. Severe root galling was noticed on cowpea planted as a cover crop in a coconut garden at ICAR-CPCRI, Kasaragod. The nematode was identified as *Meloidogyne incognita* on the basis of perennial pattern and morphological characterization. This is the first report from India.

R. similis incidence in Kozhikode district

Forty five soil samples collected from the rhizosphere of the black pepper from farmers' fields of Kozhikode district for nematode analysis. The samples were processed and nematodes were extracted from the soil. *R. similis* was present in 32% soil samples collected.

Evaluation of botanicals

Nematicidal activity of aqueous extracts of *Simarouba glauca* (Lakshmi taru) and *Manihot esculenta* (cassava) were tested against burrowing nematode *(Radopholus similis)* and root knot nematode *(Meloidogyne incognita)* under *in vitro* conditions. Results showed that both the extracts have nematicidal activity against these nematodes.

Evaluation of promising actinobacterial isolates

Promising actinobacterial combinations *viz.* Act2+Act9, Act2+Act5 and Act5+Act9 were tested in planta against nematode infection by challenging nematodes after inoculation with actinomycetes consortia in a sequential mode. The results showed that the consortia are effective in controlling nematode infection.

Evaluation of promising chemicals

Nematicidal activity of carbosulfan and flubendamide were evaluated against *R. similis* infesting black pepper under field conditions at ICAR-CPCRI, Experimental Farm, Kasaragod and farmers' fields at Wayanad district. Results indicate that both the tested pesticides suppressed *R. similis* under field conditions.

CARDAMOM

Genetic resources

A total of 618 cardamom accessions have been maintained at National Active Germplasm Site (NAGS) which consists of 442 accessions from Appangala; 73 accessions from Pampadumpara; 47 accessions from Mudigere and 56 from Sakleshpur. One accession of small cardamom (Malabar type) was collected from Vallakadavu forest range, Periyar Tiger Reserve, Kerala during the year.

Estimates of correlation coefficients for morphological and yield characters in 120 genotypes revealed that yield per plant exhibited highly significant and positive correlation with fresh weight of the capsules per plant (0.890), number of capsules per plant (0.574) and plant height (0.323).

Field screening of 106 cardamom accessions for leaf blight and rhizome rot resistance yielded five resistant accessions to rhizome rot (FGB 135, FGB 143, FGB 149, FGB 152 and FGB 159) and 36 resistant accessions to leaf blight. Significant variation was recorded for relative water content and specific leaf weight of the accessions.

Breeding

In Preliminary Evaluation Trial (PET III), 23 inter-varietal F1 hybrids were evaluated for morphological and yield characters. The hybrid Green Gold x Appangala 1 recorded highest plant height (260.33 cm) whereas the hybrid PV2 x IISR Vijetha registered more number of tillers (25.53), leaves (285.53), capsules with highest fresh and dry weight of the capsules. The disease intensity of leaf blight and rhizome rot disease ranged between 13.33 - 40.00 and 13.33- 33.33 % respectively among the hybrids.

In order to develop mapping population of resistant genes for katte disease, crosses were made with GG x IISR Vijetha and IISR Vijetha x GG. Hybridization resulted in the formation of 187 and 131 capsules in the crosses, GG x IISR Vijetha and IISR Vijetha x GG respectively. The seeds of these crosses were extracted and sown in the trays. The seedlings so developed (160 in the case of GG x IISR Vijetha and 125 in the case of IISR Vijetha x GG) were transplanted to main field.

Transcriptome sequencing

Survey of transcriptomes by direct sequencing of full-length transcripts in the range of 1 to 3 kb was carried out in small cardamom using single-molecule real-time (SMRT) sequencing with PacBio RS II System. Error correction was performed using Illumina sequence reads from the same samples. Contig assembly and the annotations were also carried out. Using the PacBio protocol, 56439 reads of insert with mean read length of 2267 bp was obtained. High-quality isoforms (9,270 nos.) were recovered and potential coding regions were predicted from these sequences.

A bicistronic transcript, coding for two genes, *palmitoyl-acyl carrier protein thioesterase* and *ent-kaur-16-ene synthase,* found among the full length transcripts is a rare discovery in plants. A transcript coding for a photosystem II gene having inverted repeats region within the coding sequence was also identified from the transcripts of small cardamom

Annotations carried out with the sequences resulted in the identification of 148 chloroplastic and 185 mitochondrial transcripts. A total 1382 Simple Sequence repeats (SSRs) in 1147 transcripts were identified. Top protein domains were identified based on Pfam data and members of major transcription factors belonging to 22 groups were found in the transcriptome. Two hundred and twenty five putative R genes belonging to different class including putative transcripts involved in plant-viral interaction (24 nos) were identified from the transcriptome.

Crop management

Organic farming

Under the network project on organic horticulture, trials on nutrient management of cardamom were initiated. For meeting the nutrient requirement of cardamom organic composts, FYM, and neem cake (NC) combinations are being tried under different treatments. The potential bio agents identified for cardamom under the institute research programmes like *Lecanicillium psalliotae,* spinosad a natural insecticide (derived from actinomycetes *Saccharopolyspora spinosa)* and *Trichoderma harzianum* are applied for pest and disease management trial and experiments were laid out at AVT Plantations, Wayanad and IISR Regional Station, Appangala. The no. of shoots with panicles, no of panicles per clump and number of capsules per panicle were higher in NC + VC and FYM + VC treatment as compared to FYM alone. The yield at AVT was significantly higher in FYM + NC (1.31 kg fresh plant^{-1}) followed by FYM + VC (1.17 kg fresh plant $^{-1}$) and FYM+NC+VC (1.12 kg fresh plant $^{-1}$) combinations. Pest management trial also showed higher capsule yield in alternate application of spinosad and Lecanicillium and spinosad with Trichoderma and Pochonia (1.0-1.6 kg fresh plant^{-1}) than control with no incidence of rhizome rot and <4% incidence of thrips damage on capsules. Similar trend was observed in yield trial conducted at Regional Station, Appangala also. Enzyme activities like dehydrogenase, acid phosphatase, alkaline phosphatase, and phosphodiesterase were higher under organic management as compared to chemical management.

Fungal (12 nos) and bacterial (6 nos) isolates were collected from organic treatments and isolation and identification of effective bioagnets was taken up. Compatibility of the short-listed efficacious isolates (*Trichoderma* sp. and *Chromobacterium* sp.) was assessed with fungicides viz., metalaxyl - mancozeb and copper oxychloride under *in vitro* conditions by poisoned food technique. Effect of promising isolate of Trichoderma on growth inhibition of *Fusarium oxysporum, Rhizoctonia solani* and *Pythium vexans* was also tested and growth inhibition against the pathogens was found to be maximum at the higher concentration (20%) (Fig. 6). Growth promotional activity of isolated Trichoderma on cardamom seedlings indicated that, plant height, number of leaves, fresh weight of shoot and root and root length were higher in seedlings treated with Trichoderma, compared with the control.

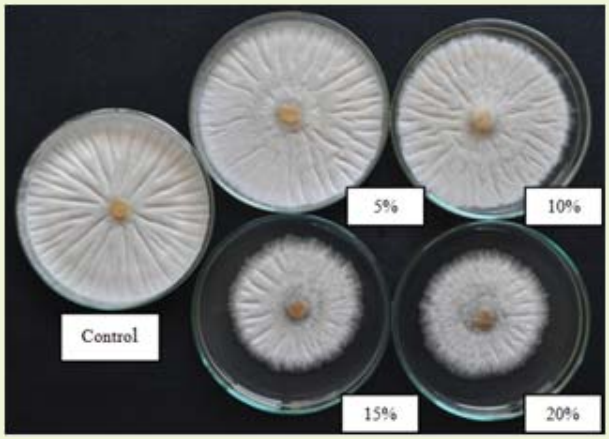
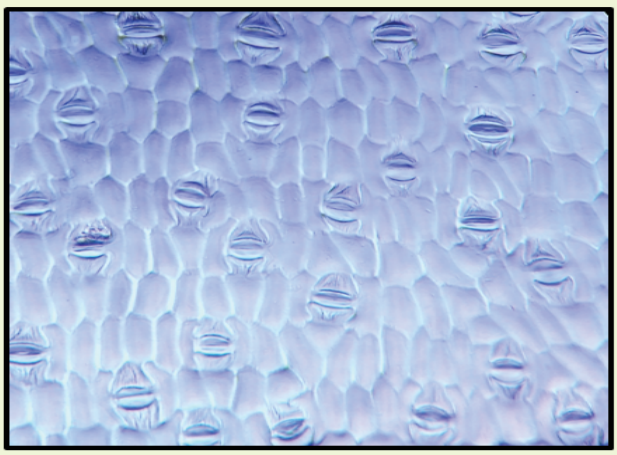


Fig. 6. *In vitro* evaluation of non-volatile compounds from Trichoderma isolate on *Rhizoctonia solani*

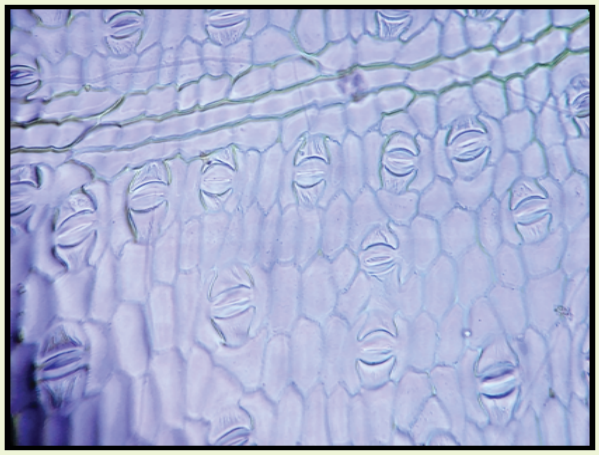
Physiological interventions

An experiment was conducted to optimize the light requirement in cardamom with open condition, 50% shade and 75% shade as treatments. During mid day, Photosynthetically active radiation ranged from 1100 to 1700, 500 to 850 and 250 to 600 mols m^{-2} sec^{-1} under open, 50% shade and 75% shade level respectively. The average leaf temperature during mid day was 35.6, 38.4 and 37.9^{0}C under open, 50% shade and 75% shade level respectively. Lower leaf temperature under open condition is due to leaf folding mechanism to reduce the incident sun light. More number of open stomata can be seen in the portion of the leaf in the shaded side and more number of closed stomata in the portion of the leaf exposed to sun (Fig. 7a)

Differential activity of stomata in same leaf under open condition



Leaf blade in sun side
(more number of closed stomata)



Leaf blade in shade side
(more number of opened stomata)

Fig. 7a. Same leaf showing the differential stomatal activity

Transpiration rate (5.45 mol m^{-2} s^{-1}), stomatal conductance (0.253 mol $m^{-2}s^{-1}$) and photosynthetic rate (11.1 µmol $m^{-2}s^{-1}$) under 75% shade was more than 50% shade and open condition. It is due to more number of open stomata under 75% shade compared to 50% shade and open condition during mid day. Light saturation occurs between 75 and 50% shade level and photo oxidation starts once shade levels goes below 50% (Fig. 7b).

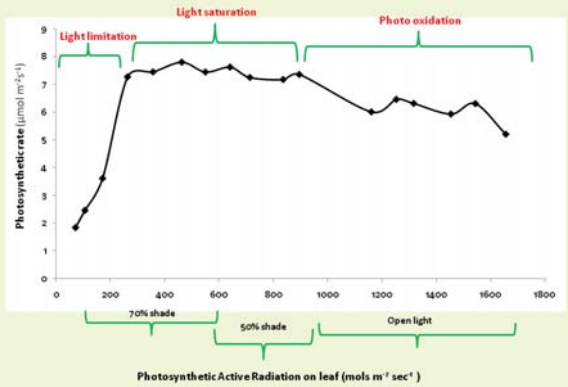


Fig. 7b. Light saturation curve

Plant health management

Fungal diseases

Epidemiology of leaf blight disease

Natural incidence of leaf blight was recorded in 119 Field Gene Bank (FGB) accessions which included Malabar, Mysore and Vazhukka morphotypes and three released varieties (Appangala 1, IISR Avinash and IISR Vijetha) during October 2015 to September 2016. Among the morphotypes, maximum Per cent Disease Index (PDI) was recorded in Malabar, followed by Mysore and Vazhukka. The PDI ranged from 16.66 to 41.66% during the observation period with a mean PDI of 23.41 to 27.22% as observed in 41 FGB accessions, observed during October and May, respectively. Comparatively the disease registered peaks during March to May and minimum during June. In Mysore types (29 accessions), the PDI was in the range of 16.66 to 35% during the period of observation. The mean minimum PDI (18.79%) was recorded during July and October, whereas the mean maximum PDI of 20.34% was noticed during April. A general decrease in the disease progression was observed during monsoon. During the above period, the PDI in Vazhukka types (52 accessions) ranged between 16.66 to 33.33%. The maximum mean PDI of 20.38% and the minimum (18.74%) were observed during September and December, respectively. The maximum temperature during the period of observation ranged from 24.3°C to 33.7°C, while the minimum was in the range of 13.1°C to 18.7°C. The rainfall ranged from 0 to 653.4 mm and the number of rainy days and relative humidity ranged between 0 to 29 days and 77.8 to 94.6%, respectively.

Virulence characterization of *Colletotrichum gloeosporioides*

Twenty isolates of *Colletotrichum gloeosporioides* previously characterized for virulence were used for virulence analysis employing molecular markers. Molecular characterization with RAPD, SSR and ISSR markers revealed that, ISSR markers were linked with virulence whereas, RAPD and SSR markers were not linked with virulence of the pathogen.

Fig. 8. *Neopestalotiopsis clavispora* Left – Colony morphology; Middle – Conidial morphology; Right – Conidial germination

Association of *Neopestalotiopsis clavispora* with leaf blight disease

Six symptomatological variants (SV 1 to SV 6) were identified based on the manifestation of foliar symptoms in cardamom morphotypes, Malabar, Mysore and Vazhukka. Among them, SV 1, SV 2, SV 3 and SV 6 were more pronounced in Vazhukka while, SV 4 and SV 5 were prominent in Malabar morphotype. The predominant symptom included formation of brown streaks surrounded by yellow halo which later turned brownish, coalescing extensively and advancing towards proximal and distal ends leading to foliar blight. Subsequent isolation from the symptomatic variants resulted in whitish colonies, turning slightly yellow in 5 to 7 days after which honey-brown colour. Profuse blackish exudations were produced randomly on the colony surface. The conidia were fusiform, 4 septate, with three median versicoloured cells and two hyaline bordering cells. Apical cells had 2 to 3 flexuous unbranched appendages and in which the appendages were solitary, tubular and unbranched. The conidia germinated by producing germ tube emerging from the coloured cell adjacent to the basal hyaline cell. Pathogenicity test was performed on Malabar and Mysore morphotypes with conidial suspensions which resulted in the development of symptoms 15 days after inoculation. Pathogenicity was further confirmed by Koch's postulates and re-isolating the fungus from symptomatic lesions. Molecular characterization was performed employing the internal transcribed spacer (ITS) rDNA region, partial β-tubulin (TUB), translation elongation factor 1 alpha (TEF) and large subunit (28S) of the nrRNA genes amplified using the primers ITS5/ITS4, T1/Bt-2b, EF1-728F/EF-2 and LR0R/LR5, respectively. The pathogen was identified as *Neopestalotiopsis clavispora* based on nucleotide blast search query in NCBI. Periodical isolations from the symptomatological variants during monthly intervals further confirmed association of the pathogen with symptomatic variants of cardamom leaf blight.

Viral diseases

Cardamom growing regions of Uttara Kannada, Kodagu and Hassan districts of Karnataka; and Wayanad and Idukki districts of Kerala were surveyed for the occurrence of viral diseases. In cardamom, kokke kandu (vein clearing disease) was noticed with high incidence (up to 60%) and severity only in Sirsi and Sakleshpur taluks of Uttara Kannada and Hassan districts, respectively. The prominent and characteristic symptom of the disease included continuous or discontinuous clearing of the veins. Leaf sheaths of the infected plants exhibited mottling symptoms. Newly emerging leaves were entangled in the older leaves leading to the formation of hook-like tiller. Light green patches with shallow grooves were noticed on immature capsules and cracking was observed on mature capsules. In the advanced stage of disease progression and in severely affected plants, rosetting, loosening of leaf sheath, shredding of leaves and severe stunting were observed.

Insect pests

Cardamom Thrips *(Sciothrips cardamomi)*

Toxicity of insecticides to honey bees

Four promising insecticides (fipronil, 0.005%, imidacloprid 0.0089%, spinosad 0.0135% and quinalphos 0.05%) were evaluated under laboratory conditions for their residual toxicity to honey bees against cardamom thrips. The study indicated that quinalphos was highly toxic and spinosad was least toxic to honey bees.

Compatibility of Lecanicillium psalliotae with pesticides

Compatibility of *L. psalliotae* with the promising insecticides for control of cardamom thrips (fipronil, 0.005%, imidacloprid 0.0089%, spinosad, 0.0135% and quinalphos, 0.05%) and fungicides (COC 0.2%, carbendazim 0.1%, mancozeb, carbendazim + mancozeb 0.1% and metalaxyl – mancozeb 0.0125%) were evaluated. Among the insecticides, quinalphos and among the fungicides, carbendazim + mancozeb 0.1% were found to be incompatible with the entomopathogen.

Compatibility of Lecanicillium psalliotae with biocontrol agents

Compatibility studies of *L. psalliotae* with other biocontrol agents (*Trichoderma harzianum* and *Pochonia chlamydosporia*) indicated that *L. psalliotae* was compatible with *P. chlamydosporia*, whereas, *T. harzianum* was antagonistic to *L. psalliotae.*

Evaluation of IPM strategies

Evaluation of IPM strategies for the control of cardamom thrips was undertaken in a partnership mode with M/s A V Thomas & Company at Wayanad, Kerala. The trial indicated that two sprays of spinosad (0.0135%) and soil application of the entomopathogenic fungus, *L. psalliotae,* twice alternatively during March, April, May and August was effective in managing the pest.

Endophytic and rhizospheric microflora

Efficacy of short-listed isolates

The efficacy of four shortlisted isolates was tested against different pathogens under pot culture condition using the variety Appangala-1.

The results indicated the most promising isolates as Cb2 (against *Fusarium oxysporum), AgR5D (against Pythium vexans),* AgR5A *(against Rhizoctonia solani)* and Asupe *1 (against Colletotrichum gloeosporioides).* Studies on differential expression of defense enzymes revealed that isoforms of peroxidase (PO 1 to 4) and polyphenol oxidase (PPO 1 to 4)were higher in endophytes treated as well as challenge inoculated plants, indicating the activation of biochemical defense pathways.

Mass multiplication

Seven types of substrates viz., coffee husk, neem cake, farmyard manure, talc and combinations like, coffee husk + neem cake, coffee husk + farmyard manure and coffee husk + farmyard manure + neem cake were evaluated for mass multiplication of endophytes and assessing shelf life period. Enumeration of the population (colony forming units per gram of substrates) at 15, 30, 45, 60 and 90 days interval after inoculation indicated that a combination of coffee husk + farmyard manure supported the maximum population of endophytes even at 90 days after inoculation (DAI).

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 collected from West Bengal, Nagaland, Kerala and Arunachal Pradesh. The characteristic collections include extra bold ginger and red ginger from Arunachal Pradesh.

Fig. 9. Red ginger accession collected from Arunachal Pradesh

Breeding

Eight accessions were evaluated during 2016-17 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.

In vivo irradiation of ginger

IISR Rejatha was subjected to gamma irradiation doses of 0.8, 1.0 and 1.2 kR (500 buds each). The M1V1 mutants are established in the green house for upscale screening against *Pythium sp.* Besides this, 10 M1V4 and 102 M1V9 mutants have been maintained. Three potential mutants 'resistant' against *Pythium* sp. are identified (V 0.5/2, R 0.8/1 and R 1.25/4) for further confirmation.

Generation of autotetraploids

The rhizome buds of IISR Rejatha were submerged in colchicine (0.025, 0.050, 0.075, and 0.1 %) and oryzaline (5, 10, 25, 50, 100 µM) solutions for 24 and 72 h to induce polyploidy. Maximum sprouting was recorded in 0.025% colchicine and 5 µM oryzaline at 24 h treatment. All the successful plants have been established for further screening.

Crop management

Fertigation conditions

The objective of the experiment was to standardize a soil less mixture and also fertigation schedule for ginger production. Fertigation method and fertigation schedule which were followed during the previous year were modified to fine tune the set up. Fertilizers were mixed with irrigation water through dosing pumps and two fertigation tanks were maintained. Individual dripper was maintained for each plant. Fertigation frequency was also altered. Two cycles of fertigation (one in the morning and one in the evening) were followed. Potash concentration in the tank was increased after three months. The total quantity of fertilizer supplied was reduced after six months and the quantum and frequency of irrigation were also reduced after 190 days.

Biomass accumulation, dry matter partitioning and yield as influenced by fertigation

Total biomass accumulation and partitioning of biomass were worked out in different treatments at 120 days after planting. Results showed that the total biomass was maximum in fertigation treatment with 75 % recommended dose of fertilizers (RDF) followed by 100 % recommended dose at 120 days after planting closely followed by 100 % recommended dose (solid fertilizers) applied at monthly intervals. Total biomass was least in fertigation treatment with 50 % recommended dose of fertilizers. Partitioning to rhizomes was on par in above said treatments except in fertigation treatment with 50 % recommended dose of fertilizers which showed lesser partitioning percentage to rhizomes. Rhizome yield at harvest also followed similar pattern. Oil, oleoresin and crude fibre contents did not show much variation among the treatments.

Table 3. Biomass and rhizome yield as influenced by fertigation

Treatment	Total FW at 120 DAP (g/plant)	Rhizome FW at harvest (g/plant)	Partitioning to rhizomes (%) at 120 DAP
50% RDF	198	228	42.3
75% RDF	247	265	47.5
100% RDF	234	251	47.1
100% Solid monthly	216	240	46.7
CD value	11.2	6.6	1.2

Partitioning and gas exchange, yield and quality as influenced by shade net colour

Coloured shade nets *viz.* red, green, black and white were used for the study with open as control. Light intensity under different shade nets was around 60 % of light under open condition. In ginger, red shade net showed maximum partitioning to rhizomes. Photosynthetic rate, transpiration rate and stomatal conductance were higher in plants grown under red shade net compared to plants grown under other shade nets or under open condition. Plants grown under red shade net recorded maximum total fresh weight at 120 days after planting and also at harvest. Oil and oleoresin were highest in plants grown under red shade net followed by black shade net.

Plant health management

Bacterial wilt

Comparative gene expression studies

With an aim to understand the resistance mechanism in mango ginger (*Curcuma amada*), the interaction of resistant mango ginger and susceptible ginger (*Zingiber officinale*) plants with the bacterial wilt pathogen was studied at different intervals. In this study nine genes, *ethylene response factor* (ERF), *HMGCoA synthase* (HMGS), *HMGCoA reductase* (HMGR), *ATP binding cassettes* (ABC), *WRKY8, β-1, 3-glucanase, callose synthase, heat shock protein* (HSP) and *MLO14*, shortlisted from the transcriptome database of ginger and mango ginger with possible role in disease resistance, were examined by real-time PCR (qPCR). These genes were found to be involved in cell wall modification and phytohormone signalling pathways, thus possibly playing important roles in combating exogenous pathogens. Compared to the leaf tissues, there was an earlier induction of defence response in rhizome tissues of ginger and mango ginger. The results showed that there was a strong and earlier expression of the selected transcripts in resistant mango ginger suggesting the involvement of these processes in the early containment of the pathogen.

Quantification of phenolic compounds revealed higher total phenolic and total lignin content in the mango ginger compared to ginger. The systemic induction in activities of rate-limiting enzymes of phenolic biosynthetic pathway were observed in the resistant mango ginger. Results are indicative of phenylpropanoid pathway regulation in a manner such that the induced defense metabolites contribute to restrict pathogen invasion in the mango ginger.

Transcriptome-wide identification and characterization of resistant gene analogs

R-gene products obtained from the transcriptome of *C. amada* and *Z. officinale* were separated into distinct but related protein classes, according to their conserved structural domains using bioinformatics tools such as Blast2Go, InterProScan, Conserved Domain Analysis tool. Screening for R-genes using bioinformatics-driven methods resulted in the identification of 160 clusters in mango ginger and 212 clusters in ginger with similarity to known R-genes, that were classified based on the presence and organization of conserved domains. A large number of R-gene clusters with gene ontology related to disease resistance were identified to be of NBS-LRR type. The gene expression studies of selected NBS-LRR transcripts identified that the R-genes were highly expressed in mango ginger in the initial hours post inoculation indicating their possible role in disease resistance.

Host physiology vs. ginger foliar diseases

Analysis of host physiological factors in healthy and leaf spot (*Phyllosticta sp.*) infected ginger plants indicated a decreased activity of catalase, increased activity of peroxidase and polyphenol oxidase enzymes. However, an increased activity of catalase, peroxidase and polyphenol oxidase enzymes was observed in healthy and leaf blight *(Helminthosporium sp.)* affected ginger plants. While reducing sugars and total proteins increased in disease affected plants, total carbohydrates and total phenols decreased in leaf spot and blight affected ginger plants.

Viral diseases

Ginger growing regions of Chamarajanagar, Mysuru, Uttara Kannada, Kodagu and Hassan districts of Karnataka; and Wayanad, Kozhikode and Idukki districts of Kerala were surveyed for the occurrence of viral diseases. Viral diseases were widespread in all the surveyed areas with an incidence ranging from 10-70%. The prominent symptoms observed were appearance of either spindle shaped light green spots formed intravenously or bright yellow intravenous streaks on the foliage. Light green to yellow mottles were also visible on the leaf sheath. In a few instances, yellow spindle shaped spots with green islands were also noticed. Similarly, bunching of leaves and severe stunting of infected plants were noticed in some cases.

Insect pests

Molecular characterization shoot borer

Conogethes punctiferalis populations infesting cardamom, ginger, turmeric and *Ammomum* sp. collected from nine locations in Kozhikode, Idukki and Wayanad districts of Kerala, Kodagu district in Karnataka and Dimapur district in Nagaland were characterized using universal primers. Initial studies indicate that the Conogethes populations from spice crops are different from the castor population.

Association of Wolbachia sp. with shoot borer

The association of Wolbachia with *C. punctiferalis* populations infesting ginger, turmeric and cardamom was confirmed through multi-locus sequence typing (MLST). The populations were found to be super infected by Wolbachia super groups A & B.

Seasonal incidence of shoot borer in relation to crop phenology

The incidence of shoot borer infesting ginger and turmeric in relation to crop phenology was studied by recording the incidence of the pest at fortnightly intervals at Chelavoor, Kozhikode for the second consecutive year during the crop season. On ginger, the shoot borer infestation was first observed during the second fortnight of August and was high during the second fortnight of October. On turmeric, the pest infestation was first observed during the second fortnight of July and was high during the first fortnight of November.

Screening of insecticides against shoot borer

Screening of 10 insecticides (malathion 0.1%, lambda-cyhalothrin 0.0125%, quinalphos 0.05%, fipronil 0.003%, imidacloprid 0.009%, thiamethoxam 0.0125%, spinosad 0.135%, flubendiamide 0.02%, chlorantraniliprole

0.01% and cyantraniliprole 0.005%) for their bioefficacy against shoot borer was carried out for the second consecutive year in ginger and turmeric under field conditions at Peruvannamuzhi, Kerala. In ginger, plots treated with chlorantraniliprole had minimum pest infestation on the shoots that was on par with flubendiamide, spinosad and cyantraniliprole. Chlorantraniliprole treated plots recorded minimum pest infestation in turmeric that was on par with lamda-cyhalothrin, flubendiamide, fipronil and cyantraniliprole.

Infectivity of EPNs

In vitro studies were taken up to understand the infectivity of EPNs *viz*., *Heterorhabditis* sp. (IISR-EPN 01), *Steinernema sp.* (IISR-EPN 02), *S. ramani* (IISR-EPN 03), *Oscheius sp.* (IISR-EPN 04, 05, 08), *S. carpocapsae* (IISR-EPN 03) and *O. gingeri* (IISR-EPN 07) against *Spodoptera* sp. and root grub *Leucopholis coneophora* Burm infesting ginger. Among them, *Steinernema* sp. (IISR-EPN 02) and *O. gingeri* (IISR-EPN 07) were more pathogenic to the *Spodoptera sp.* and *L. coneophora* as they brought about 100 per cent mortality within 72 h.

Field evaluation of EPNs

Infectivity of two promising EPNs, *Steinernema* sp. (IISR-EPN 02) and *O. gingeri* (IISR-EPN 07), were tested against shoot borer *Conogethes punctiferalis* infesting ginger and turmeric under field conditions at ICAR-IISR Experimental Farm, P'muzhi (ginger & turmeric) and a farmer's field in Kattikulam, Wayanad district (ginger). Among the treatments, integrated treatment with EPNs and malathion showed less shoot damage which was on par with malathion alone.

Plant parasitic nematodes

Field management of root-knot nematodes in coconut agro system

A field trial was laid out in a coconut garden at ICAR-CPCRI Experimental Farm, Kasaragod for management of root-knot nematodes infesting turmeric using *Pochonia chlamydosporia, Trichoderma harzianum* and neem oil cake. First year results clearly indicated the efficacy of *P. chlamydosporia* in suppressing root knot nematodes followed by neem oil cake.

TURMERIC

Genetic resources

One thousand four hundred and four Curcuma accessions have been maintained in the field gene bank. The germplasm conservatory is enriched with 69 turmeric germplasm received from four centres.

First generation true seedlings (239), second generation seedlings (512), third generation seedlings (38) , mother genotypes (23), first generation inbreds (33), second generation inbreds (2) and inter-varietal hybrids (4) were maintained besides two hundred and nine F2 lines of H1 (23), H2 (185), H3 (1) and seven open-pollinated progenies of high curcumin line SLP 389/1. Additionally intercross hybrids (40), back cross hybrids (12) and OP progenies of three inter-varietal hybrids were also maintained.

Chromosome number analysis was completed in five second generation seedlings, five inbreds and five F2 progenies. All of them had higher somatic chromosome numbers as against the normal chromosome number of 2n=63.

Characterization of 102 turmeric accessions is done for different morphological traits as per the DUS guidelines. A total of 12 quantitative and 10 qualitative characters are recorded. Among the qualitative characters, pseudostem growth habit and leaf disposition exhibited maximum variability. Maximum yield per plant is recorded in Acc. 48 with bold fresh rhizomes. Acc. 849 was unique with elongated mother rhizome and has purple pigmentation in the leaf mid-rib.

Forty four RAPD primers and 31 microsatellite (SSR) primers were used for molecular profiling of ten turmeric genotypes. The dendrogram generated from the data revealed that the selected genotypes were distinct from each other. Accession 849 was found to be distinct from all the other genotypes in accordance with its distinct morphological identity.

Breeding

ICAR-Indian Institute of Spices Research, Kozhikode through its systematic breeding programme developed a high yielding, short duration turmeric variety through germplasm selection. The variety, christened as IISR Pragati, was tested as Acc.48, for over three years in different turmeric growing regions of the country and under various climatic conditions.

This variety was identified for release by the XXVII All India Coordinated Research Project on Spices (AICRPS) Group Meeting held at NRC Seed Spices (Ajmer, Rajasthan) during 2016.

The characteristic features:

- Short duration variety and takes only 180 days to harvest: suitable for turmeric growing areas with serious irrigation problems.
- High yielding with an average yield of 38 t ha^{-1} (fresh rhizomes).
- Stable and high curcumin (5.02%) across locations.
- Moderately resistant to root knot nema tode infestation.
- The variety is suitable for cultivation in Kerala,Tamil Nadu, Andhra Pradesh, Telangana, Karnataka and Chhattisgarh states.

Fig.10. Rhizome characters of new turmeric variety IISR Pragati

Yield evaluation of inter varietal hybrids and OP seedlings

Yield and yield attributes of three intervarietal hybrids were recorded (Table 4). Hybrid- 1 showed highest yield of 812.50 g pot^{-1} but was on par with the pollen parent 'Suranjana'

Table 4. Yield and yield attributes of turmeric hybrids and parents

Genotype	Plant Height (cm)	Leaf lamina length (cm)	Leaf lamina breadth (cm)	Petiole length (cm)	Collar girth of main tiller (cm)	Number of tillers	Yield pot^{-1} (g) **
Hybrid-1	81.33 BC*	46.17 B	11.86B	32.50 D	7.65 A	8.17A	812.50 A
Hybrid-2	80.17 C	41.39 C	12.80B	34.56 CD	7.72 A	5.17B	483.30 B
Hybrid-3	86.17 BC	45.72 B	12.24B	36.61 C	7.38 A	5.00B	410.80 B
SLP 389/1 ♀ Parent	108.5 A	51.89 A	16.00A	47.94 A	8.70 A	4.17B	448.30 B
Suranjana ♂ Parent	88.17 B	43.05 BC	12.58 B	41.67 B	9.23 A	4.50 B	723.30 A

*Means followed by same letter are not significantly different at DMRT at p=0.05
** Yield obtained from 50 g seed material per pot

Seven open pollinated progenies of SLP 389/1 were evaluated in pot culture(Table 5). OP-4 and OP-6 showed higher multiplication rate of 603.3 and 593.3 g per pot, respectively.

Table 5. Yield and yield attributes of OP seedlings of turmeric

Genotype	Plant height (cm)*	Leaf lamina length (cm)	Leaf lamina breadth (cm)	Petiole length (cm)	Collar girth of main tiller (cm)	Number of tillers	Colour of emerging shoot	Yield pot^{-1} (g) **
SLP 389/1	108.50 A	51.89 BC	16.00 A	47.94 AB	8.70 ABC	4.17CD	Red	448.30 B
OP-1	94.83 C	48.22 D	14.17 BC	42.56 CD	8.08 ABC	5.67BC	Green	434.50 B
OP-2	96.33 BC	48.78 CD	14.81 B	45.00 BC	9.17 AB	5.67BC	Red	416.70 B
OP-3	101.30 B	50.89 BCD	13.32 C	44.22 BC	9.70 A	5.00ABC	Green	176.70 C
OP-4	92.67 C	48.82 CD	14.75 B	39.39 D	9.85 A	7.33AB	Green	603.30 A
OP-5	80.67 D	45.06 E	12.03 D	31.33 E	7.23 C	5.00CD	Light green	315.00 BC
OP-6	98.17 BC	52.56 AB	14.93 B	43.83 C	9.07 AB	7.67A	Red	593.30 A
OP-7	110.3 A	55.28 A	13.69 C	49.22 A	7.70 BC	3.67D	Light Red	253.30 C

*Means followed by same letter are not significantly different at DMRT at p=0.05
** Yield obtained from 50 g seed material per pot.

Reproductive biology

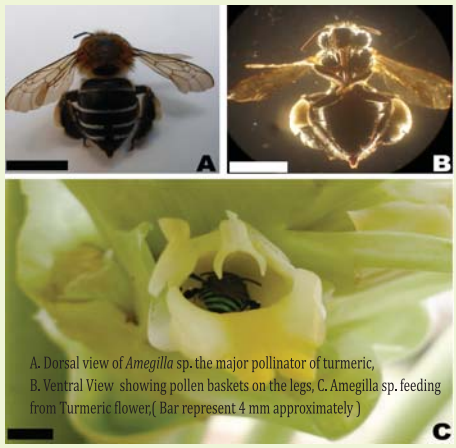
Selfing and pollination studies were carried out in true turmeric seedlings and hybrids of turmeric.

Selfing first generation inbreds, OP seedlings and cultivars

Self-pollination was performed in inbreds of 69/5/22, 138/11/1, 138/7/1, OP seedlings SLP 359/2,SLP 389/1, SLP 65/12 and cultivars Suranjana, Sudharsana and Suguna. Fruit and seed sets were observed in inbreds namely 69/5/22.In 1.7,138/11/1/ In1-7, 138/11/1/ In1-12 and seedlings namely SLP 359/2 and SLP 65/12. Three second generation inbreds of 138/11/1/In1-12 and one first generation inbred each of SLP 359/2 and SLP 65/12 were established as on date.

Pollination, vectors and pollen germination

Self-pollination in Hybrid-2 at different time intervals from 6 AM to 6 PM was performed to determine the ideal time for pollination. High fruit set was obtained in flowers pollinated from 6.00 to 8.00 AM (22-42%). Progressive reduction in fruit set was observed thereafter. Simple bagging and pollination of flowers 12 h before flower opening failed to set fruit. Fruit set on open pollination was 13.17%. The major pollinator of *C. longa* was identified as *Amegilla sp.* by Zoology Department of Calicut University. *In vitro* pollen germination studies were initiated in B&K medium with different sucrose concentrations using the pollen of H2. The results indicate that sucrose concentration of 5% gives pollen germination above 50% while at 10 % sucrose concentration pollen germination was less than 40%.



A. Dorsal view of *Amegilla* sp. the major pollinator of turmeric, B. Ventral View showing pollen baskets on the legs, C. Amegilla sp. feeding from Turmeric flower.(Bar represent 4 mm approximately)

Crop management

Organic farming

Under Network Project on Organic Farming, 11 varieties of turmeric were tested under five treatments *viz*., organic 100%, organic 75%, INM (75% org + 25% chemical), INM (50% org + 50% chem) and 100% chemical for yield and quality.

The soil pH, available P, K, Mg, Fe, Zn and Cu were significantly higher in 100% organic on par with 75% organic followed by 50+50% and 75+25% integrated nutrient treatments over 100% inorganic nutrient management. Significantly higher fresh rhizome yield was recorded in integrated nutrient management 50:50 (14.45 kg bed^{-1}) & 75:25 (14.9 kg bed^{-1}) on par with organic (100%) (14.45 kg bed^{-1}) over Organic (75%) (12.45 kg bed^{-1}) and inorganic (10.5 kg bed^{-1}) nutrient managements. Among the varieties, Suguna and Sudharsana recorded significantly highest yield (20.4 kg bed^{-1}) under integrated nutrient management 50:50 & 75:25 on par with organic (100%) management followed by Swarna, Kanti and Shoba (14-17 kg bed^{-1}) under similar management systems. The rhizome yield was lowest under organic (75%) and fully inorganic nutrient management systems for all the varieties studied (8-14 kg bed^{-1}).

Highest curcumin content was observed in Prathiba under INM 75:25 (4.88%) followed by INM 50:50 (4.77%) and organic (100%) (4.70%) nutrient regimes. Next higher curcumin content was observed in Kedaram under organic (100%) (4.35%) and INM 75:50 (4.05%) systems.

Developing energy efficient processing technologies

Curing of turmeric (var. Alleppey Supreme) was done in the solar curing unit provided with parabolic mirrors working on concentrated solar thermal technology. Freshly harvested turmeric was cured in the cooking vessels of the curing unit for 30, 45 and 60 min durations and dried on the concrete drying yard and the drying characteristics of turmeric were studied. The drying was completed in 12 days when turmeric was cured for 30 min and in 10 day when the curing time increased to 60 min.

The quality of turmeric cured in solar curing unit along with other curing methods was studied. Studies indicated that there was no significant change in the quality of turmeric in terms of its essential oil and oleoresin content of the dried sample. However, there was significant reduction in the curcumin content with the increase in curing time

Partitioning and gas exchange, yield and quality as influenced by shade net colour

Coloured shade nets viz. red, green, black and white were used for the study with open as control. Light intensity under different shade nets was around 60 % of light under open condition. In turmeric, plants grown under open condition recorded highest partitioning to rhizomes at 120 DAP and also maximum rhizome yield at harvest followed by black and least in white. Yield obtained under open condition (3.2 kg 2 m^{-2} bed) was significantly higher than all other treatments (all shade nets which were on par). Photosynthetic and transpiration rates among the treatments were on par except the white shade net which showed significantly lower values compared to other treatments. Oil and curcumin contents were highest in plants grown under red shade net which was on par with green shade net and while oleoresin was highest in plants grown under black shade net. In general, quality parameters were better in plants grown under red and green shade nets both in ginger and turmeric.

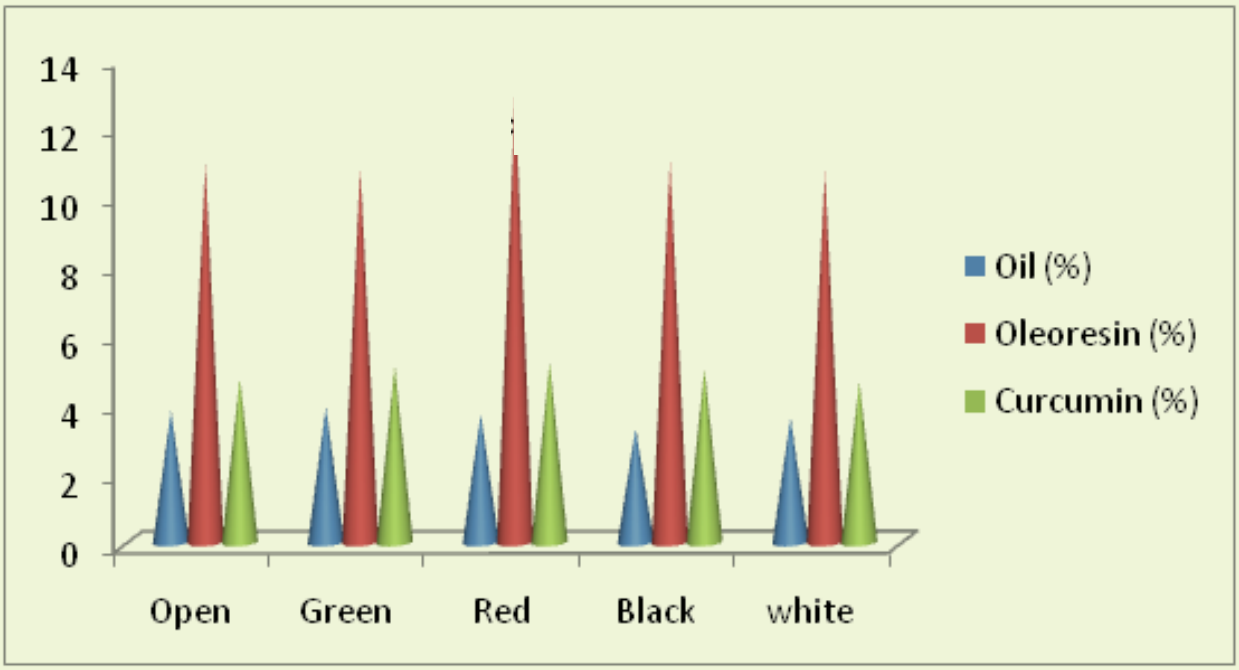


Fig. 11. Influence of shade net on oil, oleoresin and curcumin content in turmeric

Establishment of integrated organic farming system model plot

Institute established farming system model plot 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 6 tons of fodder grass, 4 kg vegetable cowpea, 30 kg tapioca, 400 kg turmeric and 90 kg banana. A dairy unit with three cows was established and 3720 liters milk was produced during 2016-17.

Plant health management

Fungal diseases

Surveys of foliar diseases

Surveys were carried out in 49 locations of ginger and turmeric growing areas of Idukki and Wayanad districts of Kerala, Chamarajanagar, Mysuru, Uttara Kannada and Hassan districts of Karnataka and North taluk of Coimbatore district and Gobi, Perundurai and Kodumudi taluks of Erode district of Tamil Nadu. Leaf blight of ginger caused by *Helminthosporium* sp. was severe in the ginger growing tracts of Mysuru, Chamarajanagar and Uttara Kannada districts of Karnataka and Wayanad and Kozhikode districts of Kerala. The incidence of leaf blight varied from 0 – 40 % in the surveyed locations. *Colletotrichum capsici* in ginger produced spots with white centre and dark margin surrounded by a yellow halo Leaf blight of turmeric caused by *Curvularia hawaiiensis (Helminthosporium hawaiiense)* was observed in the turmeric growing tracts of Erode district of Tamil Nadu (Fig. 12).

The soil samples collected were analyzed to understand the soil microbial dynamics like soil enzyme activity, total count of fungi and bacteria. Beneficial organisms such as nitrogen fixing bacteria, phosphate solubilizing bacteria, *Pseudomonas* spp., Trichoderma and actinomycetes were isolated from these soil samples using specific media.

Fig. 12. (From Left) Leaf blight of ginger caused by *Helminthosporium sp.;* Leaf spot caused *by Colletotrichum capsici* in ginger; Leaf blight caused by *Curvularia hawaiiensis (Helminthosporium hawaiiense) in* turmeric

Isolation of pathogens associated with foliar diseases

Different fungi were isolated from infected samples of ginger and turmeric collected from various locations. The fungi included *Phyllosticta sp, Helminthosporium* sp, *Fusarium* spp, *Colletotrichum gloeosporioides, Colletotrichum capsici, Exerohilum* sp., *Pestalotia* sp., *Curvularia hawaiiensis* and a few unidentified cultures. *Helminthosporium* sp. grew well on potato dextrose agar media and reached a diameter of 90 mm on the 6th day. The colony colour is greyish brown with white edge, darkened from centre outwards and sporulated on the 5th day. Vegetative hyphae were branched, septate, pale brown, darkening with age. Conidia was yellow to brown, darkening at maturity, elliptical with hemispherical ends, widest at the middle and 0—10 septate. The cultures of *C. capsici* were distinct with sparse, white to greyish black mycelium, acervuli were abundant with dark coloured setae and copious creamy white conidial masses and fusiform conidia (Fig. 13). Pathogenicity of respective isolates was proved on ginger (IISR Rejatha) and turmeric (IISR Prathiba).

Fig. 13. Morphological features of *Colletotrichum capsici*

Screening of germplasm

Turmeric germplasm accessions (102 numbers) were screened for foliar diseases and 20 accessions were found to be infected with *Taphrina maculans*. Leaf blotch caused by *T. maculans* was found to be severe in accessions, Narendra Haldi, BSR 1& 2, Co-2 and Rajendra Sonia. Nineteen accessions were found to be infected with leaf spot caused by *Colletotrichum* spp.

VANILLA
Fungal diseases

Isolation and characterization of pathogen associated with wilt disease

A survey was conducted in major vanilla growing states of Southern India. Browning and death of underground and aerial roots, yellowing, flacidity and shriveling of leaves and stems, drooping of vines are some of the symptoms observed. The wilt incidence ranged from 0-5% and maximum incidence (25%) was noticed in Madikeri taluk of Kodagu district followed by Sirsi. The leaf spot incidence was maximum in Sirsi. Seven isolates of *Fusarium sp.* have been isolated from two states (Tamil Nadu and Karnataka). Two isolates of *Colletotrichum gloeosporioides* and one *Rhizoctonia solani* have been isolated from Sirsi (Uttara Kannada). All the pathogens were characterized morphologically.

Fig. 14. Major symptoms of wilt disease in vanilla

Isolation and characterization of beneficial microbes

A total of 31 bacterial endophytes and epiphytes have been isolated from leaves, stem and roots of healthy vanilla plants collected from Madikeri and Sirsi. Twenty four bacterial isolates were test evaluated under *in vitro* conditions against *Fusarium* sp. Out of these, the maximum inhibition (53.33%) was recorded for VREN1, a root endophyte collected from Madikeri. Out of the 13 fungal microbes isolated from leaves, stem and roots of healthy plants, the maximum inhibition (68.89%) was noticed in FVLEP3.

Screening of fungicides against Fusarium sp.

Five fungicides *viz*., Tricyclazole (75% WP), Propiconazole (45% EC), Hexaconazole (5% EC), Bordeaux mixture (BM) and Tebuconazole (25.9% EC) at five different concentrations were screened against *Fusarium* sp. Among them, the maximum inhibition at lowest concentration of 500 ppm was obtained for BM and Tebuconazole.

TREE SPICES

NUTMEG

Genetic resources

Three new accessions of nutmeg collected from Kozhikode, Kerala, with bold nut and thick mace were added to the germplasm this year. Among the three accessions collected one of them was monoecious in nature. All the new germplasm accessions of nutmeg collected last year have been planted and the existing ones are maintained. Some of the seedlings progenies of monoecious trees planted at Chelavoor campus have started yielding in the 2nd year itself.

Breeding

Observations on weather parameters, flowering and sex forms in nutmeg from two locations *viz*., Kozhikode – humid tropical - 11°15'N latitude, 75°43' E longitude and altitude 30 MSL, (Kerala) as well as Appangala – sub humid tropical - 12o 26'N latitude, 75^0 45'E longitude and altitude 920 MSL, (Karnataka) was recorded. Monthly observations on the flowering pattern at the two locations revealed that the peak season of flowering at Kozhikode was in the months of July to December whereas at Appangala, it was in the months of March to May. With respect to the sex forms, male flower production was seen throughout the year at Kozhikode while at Appangala it was lean during January, February and August. Female flower peak season was from July to November and March to May at Kozhikode and Appangala conditions respectively. Maximum and minimum temperature had significant effect on male flower production whereas minimum temperature and relative humidity played a significant role on female flower production at Appangala. Maximum temperature along with rainfall had significant effect on bisexual flower production at Kozhikode. The observed variation in peak harvesting of nutmeg at Kozhikode (May to August) and Appangala (November to January) (Fig. 15) can be attributed to the variation in the flowering pattern and sex expression.

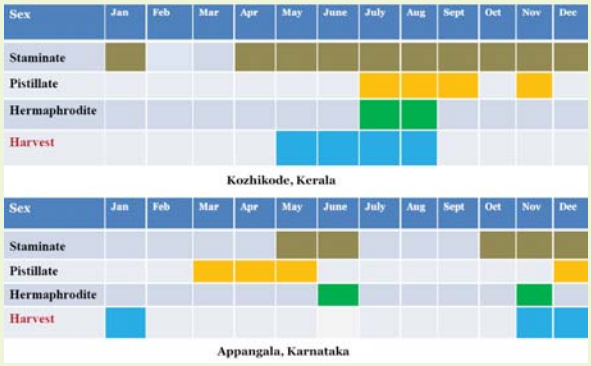


Fig. 15. Flowering pattern, sex expression and harvest chart in nutmeg

Quality evaluation of elite nutmeg lines

Two separate trials with grafts of A9/4-3(IC-537153); A9/4-11(IC-537153); A4/17 (IC-537043); A9/20 (IC-537169) to evaluate elite lines having high myristicin and elemicin and another trial with grafts of A4-22 (IC-537048); A9-69(IC- 537218); A9-71 (IC 537220,); A9-95 (IC-537244); A9-102 (IC- 537251) to identify elite lines having low myristicin, elemicin and safrole and high sabinene are in progress.

Air layering in nutmeg

Air layering was attempted during monsoon season and 40% rooting was observed. Rooting process is found to be slow in nutmeg which took 3 months for root initiation. Rooted twigs were transplanted to the polythene bag and is under observation for survival.

Antioxidant and anticancer potential of Myristica species

Antioxidant potential of methanol extracts of leaf, nut, mace and pericarp of *Myristica fragrans* was studied by DPPH free radical scavenging assay; effective concentration of the extracts to scavenge 50% free radicals (IC50 value) were 6.8 µg mg mL-^{1} 0.48 mg mL-^{1,} 0.96 mg mL-^{1} and 9.1mg mL-^{1} respectively. Among the extracts, methanol extract of leaf exhibited highest antioxidant activity which was followed by methanol extract of nut. In vitro cytotoxicity of methanol and hexane extracts of leaves of *M. fragrans, M. andamanica, M. malabarica* and *M. prainii* were studied at concentrations ranging from 50-800µg mL^{-1} on the colon cancer cell line HCT-116 and the breast cancer cell line SkBr-3. All extracts showed concentration dependant inhibition of proliferation of cell lines, which varied between 12-55%. Hexane extract of *M. andamanica, M. malabarica* and methanol extract of *M. prainii* showed more than 50% cytotoxicity on HCT-116 at 800µg mL^{-1} The extracts exhibited lower activity on SkBr-3 compared to HCT-116.

GARCINIA

Garcinia gummi-gutta var. papilla, (Fig. 16) an intra-specific taxa of malabar tamarind, endemic to Western Ghats was collected for the first time from Wayanad district. The rind of the new collection; *G. gummi-gutta* var. papilla can easily be dried under sun as it ripens in February-March. *G. gummi-gutta* var. papilla is polygamo- dioecious and the natural regeneration in the original habitat is found to be very less due to consumption of the seeds by the wild animals. Hence its domestication and conservation is very important. Grafts of this species were established on the root stocks G. *gummi-gutta* and *G. indica.*

Fig. 16. Garcinia gummi-gutta var. papilla

ALLSPICE

Incidence of auger beetle (Sinoxylon anale) and its entomopathogen

The incidence of auger beetle, *Sinoxylon anale* Lesne (Bostrichidae: Coleoptera), a destructive pest of cosmopolitan occurrence was reported for the first time on allspice trees from Kozhikode, Kerala. Based on the morphological characterization and sequencing of a partially amplified fragment of the mitochondrial CO1 gene the insect was identified as *S. anale.* An entomopathogenic fungus was isolated from infected cadavers of *S. anale* that was identified as *Beauveria bassiana* (Bals.-Criv.) Vuill., sensu stricto (s.s) (Ascomycota: Hypocreales) based on morphological and molecular studies (Fig 17). The fungus was virulent against adult beetles and this is the first record of *B. bassiana* naturally infecting *S. anale.*

Fig. 17. (Top) Allspice twig infested by *Sinoxylonanale;* (Bottom) Spore balls of *Beauveriabassiana* on the cuticle of *S. anale*

HIGH VALUE COMPOUNDS

Anti inflammatory/anti oxidant potential of turmeric and cinnamon

Methanolic extract of cinnamon and turmeric mixed proportionately and fed to the rats for 30 days at two different concentrations of 2.5% (T1) and 5% (T2). Tissues were assayed for the activity of catalase (CAT), superoxide dismutase (SOD), glutathione-S-transferase (GST), lactate dehydrogenase (LDH), malate dehydrogenase (MDH), alanine aminotransferase (ALT) and aspartate aminotransferase (AST). Animals showed higher catalase activity in liver, reduction in the activity of SOD, increase of GST activity in liver, increased LDH activity in all tissues. There was no evidence of inflammation or myocardial scarring. Results are illustrated in table 6. The results clearly established the fact that these extracts can be developed as health supplements for various lifestyle diseases.

Table. 6. Effect of cinnamon and turmeric extract on antioxidant and metabolic enzyme activities in rats

Tissue	Treatment	CAT (U/mg protein	SOD (U/mg protein)	GST (U/mg protein)	LDH (U/mg protein)	MDH (U/mg protein)	AST(U/mg protein)	ALT (U/mg protein)
Liver	Control	126.72±4.95	71.14±2.31	3.83±0.34	3.26±0.13	29.71±2.62	29.71±2.62	22.99±0.86
	T1 (2.5%)	132.62±3.64	71.72±2.30	4.23±0.13	3.02±0.20	28.86±3.75	28.86±3.75	21.67±0.69
	T2 (5%)	152.65±4.01	63.07±0.90	4.32±0.13	3.51±0.10	29.62±2.90	29.62±2.90	21.83±0.49
Kidney	Control	116.94±3.14	58.37±3.18	0.97±0.03	3.79±0.85	29.27±3.41	29.27±3.41	7.73±0.22
	T1 (2.5%)	131.76±7.64	54.44±2.82	0.91±0.05	4.71±0.67	27.10±1.82	27.10±1.82	7.61±0.29
	T2 (5%)	143.29±16.29	49.63±4.70	0.93±0.12	5.27±1.20	24.86±6.56	24.86±6.56	10.03±1.18
Heart	Control	347.99±20.78	21.16±1.37	1.25±0.09	13.11±0.83	91.63±11.78	91.63±11.78	56.90±3.09
	T1 (2.5%)	311.31±11.49	22.07±0.39	0.86±0.02	12.52±0.48	80.46±8.39	80.46±8.39	51.90±2.52
	T2 (5%)	298.84±27.14	20.05±1.92	0.77±0.08	13.27±1.28	80.19±15.02	80.19±15.02	45.88±3.81
Muscle	Control	12.41±0.62	21.18±1.14	0.52±0.02	11.95±0.98	175.77±15.31	175.77±15.31	72.08±3.46
	T1 (2.5%)	15.96±3.35	20.04±0.56	0.48±0.05	11.65±0.86	162.28±6.93	162.28±6.93	70.31±3.66
	T2 (5%)	19.55±2.21	17.42±1.10	0.51±0.01	12.94±0.86	157.26±13.77	157.26±13.77	71.69±1.90

Hypoglycemic potential of black pepper, cinnamon and turmeric extracts

α-amylase inhibitory assay:

In vitro hypoglycemic potential of methanol extract of cinnamon, turmeric and cinnamon:turmeric mixtures was studied using α-amylase enzyme. Higher inhibitory potential was observed for cinnamon extract followed by cinnamon:turmeric mixture. α-glycosidase inhibitory assay also shows the same trend.

In vitro cytotoxicity

Studies on the in vitro cytotoxic effect of spice extracts carried out at RCC, Thiruvananthapuram on the cell line SKBR-3 (breast cancer) and HCT-116 (colon cancer) indicated that all extracts possessed concentration dependant activity between 50 µg mL^{-1} and 800 µg mL^{-1} and hexane extract of cinnamon had highest cytotoxic effect (Fig. 18).

Developing phytochemical database

SpiceCom, a database on phytochemicals of major Spices namely black pepper, ginger, turmeric, clove, and cinnamon has been developed. Retrieved spices viz., ginger, turmeric, clove, cinnamon and black pepper compounds from Dr. Duke's Phytochemical and Ethnobotanical Databases and molecular docking studies were carried out using Schrodinger Suite10.5.014 to find out the anti-inflammatory, anti-diabetic, anti-depressant, anti-hypercholesteremia,anti-cancer, skeletal and bone growth and anti-chikungunya using corresponding protein targets. Based on already existing compounds and their corresponding DPPH IC50 values, a QSAR model was generated to predict the antioxidant activity of natural compounds. KPLS model with semi empirical descriptor shows good correlation with wet lab results.

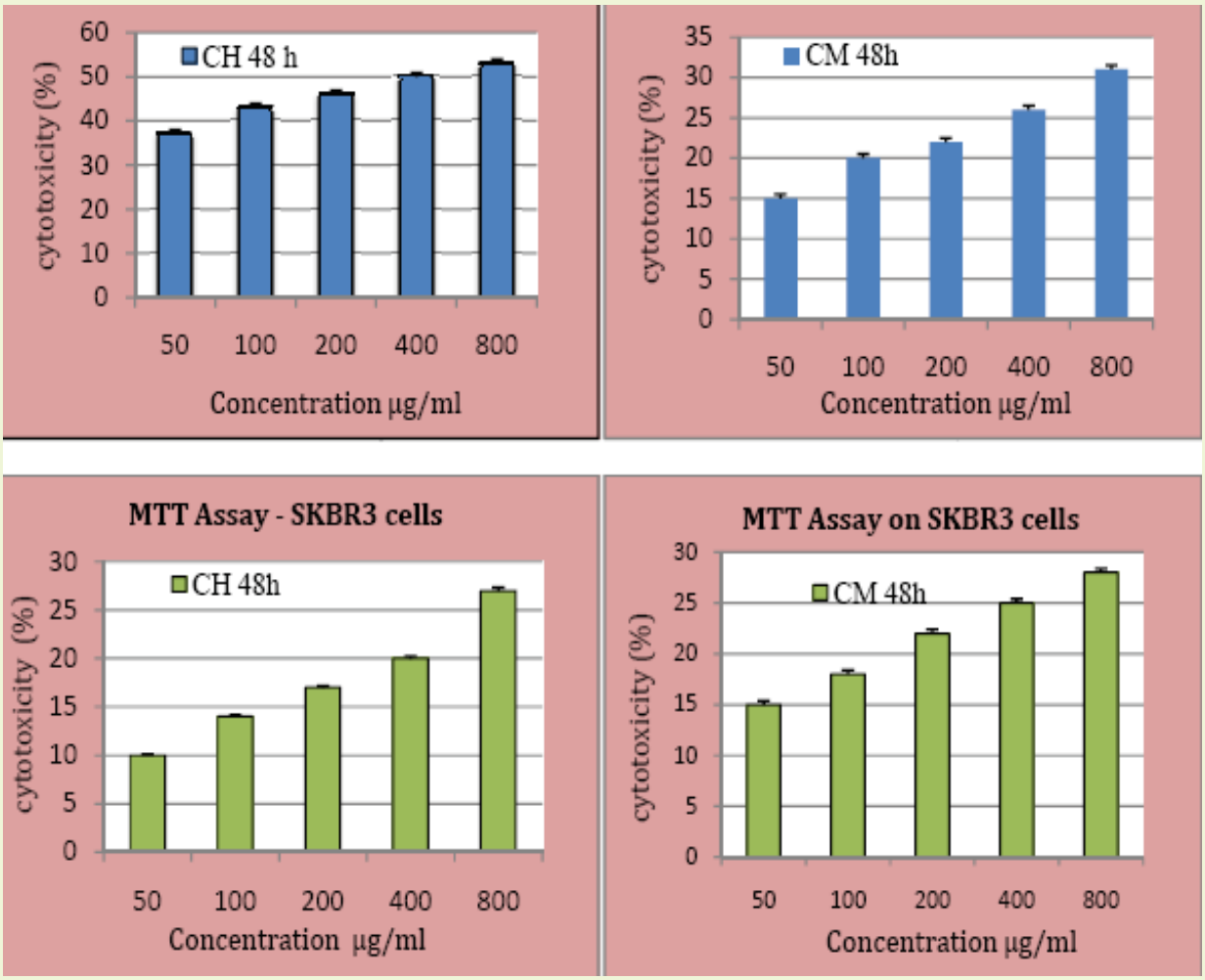


Fig. 18. Percentage cytotoxicity of cinnamon extract on two cancer cell lines

CONSORTIUM RESEARCH PROJECT ON SECONDARY AGRICULTURE – ESTABLISHMENT OF AGRO PROCESSING CENTRE FOR PROCESSING AND VALUE ADDITION OF SPICES

An 'Agro Processing Centre' for primary processing of cardamom is being established at ICAR-IISR, Regional Station at Appangala, Karnataka. The facility has a cardamom washer, cardamom drier, cardamom polisher, cardamom grader and sealing unit. The Agro processing centre for black pepper with facilities for black pepper threshing, cleaning cum grading of black pepper and a spiral separator for pepper cleaning is being set up at this centre. The machinery set up at the unit is to be evaluated for its performance and made available to startups. The established facility shall be used to extend hand holding services to potential entrepreneurs.

GENERAL

Surveillance and documentation of pests and diseases

Forty three plantations of cardamom (9), black pepper (19) and cardamom – black pepper mixed cropping systems (15) representing different agro-ecological regions in four districts of Karnataka (Hassan, Kodagu, Uttara Kannada, Chikkamagaluru) and three districts of Kerala (Idukki, Wayanad, Kozhikode) were surveyed for the occurrence of pests and diseases of cardamom and black pepper during monsoon and post-monsoon periods. In black pepper, foliar infection/foot rot incited by Phytophthora, slow decline, anthracnose/spike shedding and foliar blight due to Colletotrichum, stunt disease were the major diseases noticed during the surveys. Two discrete types of foliar symptoms induced by Phytophthora *viz.,* blackish necrotic lesions with fimbriate margin and lesions without fimbriate margin and dull grey center were observed during the surveys (Fig. 19). Colletotrichum species was predominantly found to be associated with leaf blight of black pepper, an atypical symptom pronounced more during post-monsoon/summer season especially when the vines were exposed to stress conditions. Pollu beetle and scale insects were the major pests recorded during the surveys.

In cardamom, leaf blight caused by Phytophthora and Colletotrichum, stem lodging and capsule anthracnose were the major diseases. While, chlorotic streak, kokke kandu and katte were the viral diseases recorded during the survey programmes. Pseudostem borer, thrips and infestation of minor pests were also observed in the surveyed regions. Colletotrichum species was found associated with stem lodging and capsule anthracnose of cardamom. Acervuli with setae were produced on the lesions when the anthracnose affected capsules were subjected to high humidity.

Fig. 19. Foliar symptoms on black pepper. Left - Blackish necrotic lesions with fimbriate margin by Phytophthora; Middle - Non-fimbriate lesions with grey center by Phytophthora; Right - Foliar blight by Colletotrichum.

A bio-intensive strategy for production of disease-free planting materials of black pepper

A trial was laid out in a farmer's nursery using virus-free planting materials of four released varieties of black pepper viz., IISR Girimunda, IISR Malabar Excel, IISR Shakthi and IISR Thevam. Solarized potting mixture was mixed with different consortia of bioagents to control both soil-borne fungal pathogens and nematodes. Biocontrol agents like *Trichoderma harzianum*, *Pochonia chlamydosporia, Ketosatospora* setae strain Act2, *Streptomyces* sp. strain Act5 and *S. tauricus* strain Act9 were made into different consortia in such a way that each consortium contained bioagents for inhibiting both fungal pathogens and nematodes. Metalaxyl mancozeb (0.125%) + carbosulfan

(0.1%) was included as check. The plant growth parameters, soil microbial population, dehydrogenase activity, presence of pathogens (Phytophthora, Sclerotium, *R. similis* and *M. incognita)* and soil nutrient status were recorded. Results revealed that the bio intensive strategy is very effective in producing healthy rooted plants in which the variety IISR Thevam and Malabar Excel responded very well with all the biocontrol agents with increased plant growth characters (Table 7). Both dehydrogenase activity and root biomass were also higher in the bioagent treated plants when compared to chemical treatment. No root infection due to Phytophthora, Sclerotium or nematode was observed in any of the soil samples collected from different treatments. Among the consortia *T. harzianum* + *P. chlamydosporia* and *K. setae* strain (Act2) + *S. tauricus* strain (Act9) were found very promising.

Table 7. Number of cuttings produced in nine months from a single plant

Variety	*T. harzianum* + *P.chlamydosporia*	Act 2+9	Act 5+9	Met-Mz + Carbosulfan	Control	Main plot Mean
IISR Girimunda	36.00	36.00	34.00	25.40	23.60	31^{C}
IISR Malabar Excel	59.60	45.60	34.00	26.40	29.40	39^{A}
IISR Shakthi	23.00	32.00	32.60	34.00	41.60	32.64^{B}
IISRThevam	51.00	38.00	45.80	32.60	30.60	39.6^{A}
Sub-Plot total	42.4^{A}	37.9^{B}	36.6^{C}	29.6^{E}	31.3^{D}	General Mean=35.56

LSD at 5% = Variety = 0.87; Treatments- 0.95, Variety x Treatments - 1.90

Documentation of natural enemies of spice crop pests

Surveys for incidence of natural enemies of spice crop (black pepper, cardamom, ginger, turmeric, nutmeg, allspice and clove) pests were conducted in 34 locations in Kerala, Karnataka and Tamil Nadu. Four entomopathogens were documented from *Sinoxylon* spp., *Marsipococcus marsupialis-Mimegralla coeruleifrons* and *Conogethes punctiferalis.* The entomopathogenic fungus infecting turmeric shoot borer has been identified as *Metarhizium* sp.(IISR-EPF-14) based on molecular studies. The fungus infecting *Sinoxylon* spp. was identified as *Beauveria bassiana* (IISR-EPF-15) and that infecting *M. marsupialis* as *Isaria* sp. (IISR-EPF-16) based on morphological characters. An entomopthoralean fungus recorded from *M. coeruleifrons* has been tentatively identified as *Batkoa* sp. (IISR-EPF-17). Mermithid nematodes (IISR-MN-01 & IISR-MN-02) parasitizing shoot borer of ginger and turmeric were identified as closely related to *Aranimermis* sp. Larval and pupal hymenopterous parasitioids parasitizing *C. punctiferalis* were recorded from Idukki and Nagaland.

SPICE ECONOMICS

Growth, instability and export trends in small cardamom

The instability of key variables affecting small cardamom production in the country during the last four decades was analyzed critically to explore the patterns of instability. A marked decline in instability was identified in production, yield and export quantity. The export quantity of small cardamom showed a higher compound annual growth rate (3.53%) during the second period (1993-94 to 2014-15) accompanied by a sharp decline in instability by 52.7% in comparison to the first period (1971-72 to 1992-93). The decline in yield and production instability between the two periods was 44 and 33%, respectively.

The share of domestic production exported declined from 46.3% for the triennium ending 1974-75 to 20.0% for the triennium ending 2014-15. Though the production of small cardamom increased by 2.5 times during the last three decades, the share of domestic production in exports of cardamom remained constant. India's share in global cardamom exports have also declined from 48.6% in 1974-75 to 10.1 per cent in 2014-15.

Analysis of price instability in spices

A study was conducted on the price movement of important spice crops to understand the price fluctuations in major spices and their magnitude. Using monthly time series nominal price data of spice commodities, the real prices were constructed using WPI (2004-05 series) index as deflator. A fluctuation margin for prices was considered at 20% deviation from predicted prices constructed using normal forecasting techniques.

Relative contribution of yield growth to spices production

A simple decomposition model was used to measure the relative contribution of yield components to increase in production of spices. The results indicated that the yield enhancement has contributed significantly to the increase in spice output. The results were similar across several spice crops like cardamom, turmeric and ginger where the direct and indirect yield effects contributed more than 50% of increase in output. For spices production as a whole the area effect, yield effect and interaction effect were 32.4, 45.2 and 22.4%, respectively.

Study on spice crops in Darjeeling, West Bengal

Institute undertook a meticulous study of the major technical constraints in enhancing production and productivity of large cardamom, ginger and turmeric in Darjeeling district of West Bengal. The initiative guided by the Horticulture Sciences Division of ICAR was undertaken in collaboration with Spices Board, Uttar Banga Krishi Vishva Vidyalaya, Pundibari and Department of Agriculture, Government of West Bengal and other institutional stakeholders. The study team brought out the important extant technical constraints in the selected crops and submitted a detailed report containing the recommendations and a multipronged action plan for enhancing productivity of these crops through technology infusion, adaptive research programme and value chain support activities.

INSTITUTE TECHNOLOGY MANAGEMENT AND BUSINESS PROCESS AND DEVELOPMENT

During the year, the ITM-BPD Unit has issued three licenses for black pepper varieties IISR Thevam and IISR Girimunda to two clients. Turmeric variety, IISR Alleppey Supreme and ginger Variety IISR Varada were licensed to Centre for Overall Development, Thamarasserry, Kerala. The new turmeric variety IISR Pragati is under consideration for registration by PPV and FRA. Two clients have availed the license for commercial multiplication of IISR Pragati.

Fig. 20. Signing of MoU for non exclusive licensing of turmeric variety, IISR Pragati

The Unit organized and conducted the market launch programme on 27.06.16 for two products "Powercap" and "Trichocap" on behalf of the licensee, M/s Codagu Agritech, Karnataka in presence of Honorable MP, Mysuru, Mr. Pratap Simha.

A planting material production unit cum nursery for spices, ornamentals, plantation and fruit crops was established at IISR, Chelavoor. License agreement for cleaning, grading, packing and powdering of black pepper and white pepper was signed with CAMPCO Pvt India Ltd. on 23rd February at Mangaluru.

Fig. 21. Signing of MoU with CAMPCO Pvt India Ltd

The unit conducted two EDP programmes, one on curry powder production during July 2016 and another on fruit and vegetable processing for women self help groups during August 2016. The unit also participated in VAIGA-2016, exhibition organized during the "International Workshop on Agro Processing & Value Addition" conducted by Department of Agriculture, Development & Farmers' Welfare, Government of Kerala. The unit also participated in Kisan Melas and exhibitions for show-casing commercialized technologies of IISR.

EXTENSION AND IMPACT ASSESSMENT

The transfer of technology programmes of the institute was provided through regular channels like visitor advisory services which provided specific advice to more than 2700 farmers. The other visitors included 1800 students and 250 officials.

Skill development and capacity building were implemented under the sponsorship of various state departments and central sector schemes of Tribal sub plan and programme for NE region. Thirteen training programmes were conducted on campus benefiting more than 300 participants including stakeholder groups like farmers, youth, tribal beneficiaries and students. Under the Tribal sub plan eight training programmes were organized off campus benefiting 600 tribal farmers from the states of Kerala, Tripura and Arunachal Pradesh. The institute also facilitated the monthly technology advisory meeting of the district Agricultural Technology Management Agency (ATMA) by providing expert support for resolving field problems. The institute was also featured in a special educational programme as leading destination for higher education in the field of agricultural research. Eighteen programmes benefiting more than 100 farmers were organized.

A total of 48 exhibitions were organized by the institute during the last year. The institute facilitated a total of 50 group visits for educational institutions to provide exposure to research and development activities in spice crops. About 15 farmer groups from within and outside the state under MIDH or ATMA visited the institute for learning about the technologies developed for improved spices productivity.

Several demonstrations aimed at tribal farmer empowerment were undertaken. Varietal demonstrations in black pepper were under taken in Kerala, Tripura and Arunachal Pradesh. Demonstration in collaboration with the Spices Board, on application of Trichoderma in capsule forms in black pepper and ginger is in progress in four districts of Arunachal Pradesh and in Shillong and Guwahati. Demonstration of single sprout transplanting method in ginger was laid out in four KVKs in Tripura.

In tune with the policy objective to step up revenue generation, efforts were taken through ATIC to generate more income from the sale of technology inputs and services which resulted in an increase of 143 % in revenue compared to last year.

Integrated black pepper research and development in North Kerala districts

Twenty four FLDs on improved technologies that were initiated at farmer's plots in three panchayaths of Kozhikode district during last year were continued with necessary input supply along with two participatory nurseries (Fig. 22). Five visits were made by the scientists to the FLD plots for giving advisories. Six hundred and twenty soil samples from farmer's plots were analysed for macro and micro nutrients and issued with soil health card advisories. Demonstrations on site specific nutrient management were taken up in five farmer's plots. Amendments and fertilizer doses were applied based on the soil test and foliar supplementation of micronutrient based on leaf nutrient ratios were taken up. Due to site specific management, the soil pH, OC, P, K, Ca, Mg and micronutrient availability showed a significant increase as compared to farmers practice. The spike intensity and yield (per std) also showed a significant increase in soil application of fertilizers (29.3 0.5 m^{-2} & 1.45 kg dry std^{-1}) and fertilizers + micronutrient foliar supplementation (30.5 0.5m^{-2} & 1.48 kg dry std^{-1}) treatments as compared to farmers practice (25 0.5 m^{-2} & 1.3 kg dry std^{-1}). The site specific nutrient management also helped in increasing the bulk density (448 g L^{-1} in farmers practice and 500 g L^{-1} in treatments) and piperine content (5.3% in farmers practice and 5.6-6.5% in treatments).

Fig. 22. Technology demonstration: Black pepper variety – Subhakara at Mr. Agustin's, plot, Chakkittapara

Enhancing the economic viability of coconut based land use systems

The objective is to test and demonstrate the productivity of coconut based mixed farming systems (black pepper and nutmeg) can be substantially enhanced through site specific soil management. The treatments for correcting the sub soil acidity (in combination of gypsum + liming materials) were imposed for nutmeg in AEU 9 (in Ernakulam district) and for pepper in AEU 11 (Kozhikode).

Soil and leaf test based amendment and fertilizer (including micronutrient) application was imposed at one experimental plot each of black pepper and nutmeg and four demonstration plots each of pepper (in Naduvannur and Arikulam panchayaths of Kozhikode) and nutmeg (at Mookanur panchayath of Ernakulam). In addition similar treatments were imposed in one experimental plot and 10 demo plots of coconut also. The required inputs were procured, weighed on per plant basis and supplied in ready to apply form to each farmer.

Foliar supplementation of the micronutrients for black pepper and nutmeg were done twice in a year. Application of bioagents and plant protection operations were carried out as per recommended package of practices.

In pepper, application of amendments (dolomite + gypsum) significantly improved the pH of the top (0-15 cm) and sub surface soil (15-30 cm) as compared to farmers practice and interspaces. The soil availability of P, K, Ca, Mg and Zn also increased significantly at both the depths studied as compared to farmers practice. The adoption of site specific soil fertility management has given significantly higher yield (1.6-1.78 kg dry std $^{-1}$) as compared to farmers practice (0.98 kg dry std $^{-1}$). In demonstration plots 33-68% increase in yield was recorded under site specific management treatments in addition to increase in oleoresin, piperine contents and bulk density as compared to farmers practice. Under nutmeg system also, the soil pH increase was higher in lime + gypsum treatment on par with that of lime application alone at both the depths studied. The concentration of soil Al significantly reduced at all the depths studied in BMP treatments as compared to farmers practice (Fig.23). Lime +gypsum supplementation with site specific fertilizer application recorded 30% higher nut and mace yield (3.9 & 0.6 kg fresh tree $^{-1}$) as against farmers practice (3.0 & 0.45 kg fresh tree $^{-1}$). In demonstrated plots also an increase of 18-28% in fruit yield was observed in treated trees over farmers practice. Also conducted four trainings/ soil and plant health campaigns under the project at the identified panchayaths benefitting 250 farmers and extension officials.

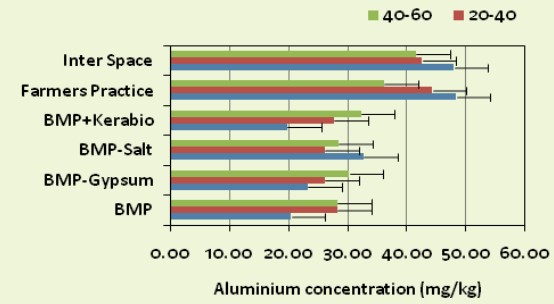


Fig. 23. Effect of best management practices (BMP) on soil Al concentration at different soil depths .

Fig 24. Awareness campaign for farmers and extension functionaries to demonstration plots under the project

Varietal spread

Mr. K.C. Joseph Kavukatt, a small farmer from Venappara on the eastern part of Kozhikode, Kerala who grew Varada ginger in about 2.5 acres (intercrop in rubber plantations) reported about 40 q production this year. Mr Jojo Jacob ,an ICAR-IISR KVK trained youth of Kadiyangad, Kozhikode district too obtained very good yield from Varada ginger (Fig. 25). Mrs. Elzy Devasia, a women farmer from Chempanoda, Kozhikode harvested on an average 1.5 kg fresh rhizome from Varada riaised in grow bags.

Feedback from Col P C Rana,Vill Soran, P O Balugloa, Teh Baroh, District Kangra (HP) indicates the very good acceptance of Pragati in the district of Himachal Pradesh.

Feedback from farmers from Telegana also revealed very good acceptance of the released turmeric varieties. Mr. Ramaprasad Reddy of Hyderabad, an IT professional turned turmeric grower, who has been growing Prathibha for the the last three years has ventured into vlaue addition of turmeric. Mr.V. Sureshkumar of Kalarkode, Alleppey is another small scale entrepreneur who in a vlaue chain mode market powdered Prathibha in southern Kerala.

Fig. 25. Mr. Jojo Jacob with his harvested Varada

Plant Genome Savior Award

Mr. Mathew Sebastian, who evolved Keralasree nutmeg in a participatory breeding programe with IISR received the Plant Genome Savior Award from the Hon'ble Union Minister of Agriculture & Farmers Welfare at Champaran, Bihar. IISR nominated Mr. Sebastian for this coveted award which carries a cash award of Rs.1.5 lakhs and a citation. Earlier, Mr. Sebastian also won the IARI Innovative Farmer Award .

Fig. 26. Mr. Mathew Sebastian receiving the Plant Genome Savior Award from the Hon'ble Union Minister of Agriculture and Farmer's Welfare.

KRISHI VIGYAN KENDRA

During the period, KVK conducted a total of 112 on-campus and off-campus training programmes. A total of 4153 trainees were benefitted. Two On Job Trainings to Vocational Higher Secondary School students (89 numbers) were organized. A seven day's training programme on soil testing was conducted for six students of AVAH Arts and Science College, Meppayyur. Three day's paid training programmes on broiler goat rearing; breeding and culture of fresh water ornamental fishes and bee keeping were organized. National Fisheries Development Board (NFDB), Hyderabad sponsored five and three day's duration trainings on "Fresh water ornamental fish culture" and "Fish Processing Techniques" were conducted for 60 participants. Twenty five farmers of Kozhikode district were trained on "Cocoa cultivation and value addition" under the training sponsored by Directorate of Cocoa and Cashew Development, Cochin. In addition, three inter institutional collaborative training programmes on "Scientific coconut cultivation and value added products development" with ICAR-CPCRI, Kasaragod; "Tapioca based biological pest management in banana" with ICAR-CTCRI, Trivandrum and "Spices propagation and integrated management" with ICAR-IISR, Kozhikode were also organized.

Fig. 27. Hon'ble Union Minister Shri. Radha Mohan Singh presenting the Deen Dayal Upadhyaya Anthyodaya Agriculture Award 2016

Fig. 28. Farmers fair and awareness programme on "Pradhan Mantri Fasal Beema Yojana" inauguration by Sri. M.K. Raghavan, Honourable Member of Parliament (Lok Sabha)

A mass awareness programme and presentation ceremony of the "Pandit Deen Dayal Upadhyaya Anthyodaya Agriculture Award 2016" was organized at ICAR-IISR, Kozhikode on 25th September 2016. The award was presented by Hon'ble Union Minister for Agriculture and Farmers Welfare Shri. Radha Mohan Singh to Shri. Baburaj, an aqua farmer from Kozhikode, Kerala.

Seminar cum training on "Scientific coconut cultivation"; farmers fair and awareness programme on "Pradhan Mantri Fasal Beema Yojana"; celebration of Agriculture education day; World soil day and Rabi awareness programme on "Organic vegetable cultivation"; Jai Kisan Jai Vigyan Week - 2016 and "Agriculture Farmers' Innovation Meet" were organized at KVK, Peruvannamuzhi. The Kendra conducted two field days, four seminars, participated in 12 exhibitions, delivered seven radio talks and conducted three studies cum exposure tours for farmers to various research institutes. During the period, KVK organized about 10 awareness programmes on soil health management, and issued 225 soil health cards.

Fig. 29. Shri V.S. Sunilkumar, Hon'ble Minister for Agriculture, Govt. of Kerala visiting KVK stall at Kootalida, Kerala

Fig. 30. Rabi awareness programme on "Organic vegetable cultivation" – lecture delivered by Dr. P Raji, RARS, KAU, Pattambi

ICAR-ALL INDIA COORDINATED RESEARCH PROJECT ON SPICES

XXVII Workshop of ICAR- All India Coordinated Research Project on Spices

The 27th Workshop of ICAR-All India Coordinated Research Project on Spices was conducted during 24-26 October 2016 at ICAR-National Research Centre on Seed Spices (NRCSS), Ajmer, Rajasthan Dr. T. Janakiram, ADG (HS II), ICAR, New Delhi inaugurated the workshop and emphasized the importance of co-ordinated programme in the varietal evaluation and technology development. He urged the researchers to work on water saving techniques for getting more crop per drop so that we can save these precious natural resources for the future generation. Dr. Gopal Lal, Director NRCSS, Ajmer delivered presidential address. Dr. Homey Cheriyan, Director, Directorate of Arecanut and Spices Development (DASD), Kozhikode, Dr. P. N. Jagadev, Director of Research, OUAT, Bhubaneshwar and Dr. S. R. Maloo, Former Director Research, MPUAT, Udaipur were the Guest of Honour and expressed their views towards coordinated research in evolving new technologies and varieties for farmers. "Best AICRPS Centre Award 2015-16" was presented to SKNAU, Jobner, Rajasthan and 15 booklets/pamphlets on AICRP technologies in English and local languages from different AICRPS centres were released during the occasion.

In the XXVII work shop, seven new varieties were recommended for release. The varieties are;

Crop	Variety	Organization	Salient features of the variety	Recommended for
Black Pepper	Cul. 5308 (Panniyur – 9)	Pepper Research Station (KAU), Panniyur, Kerala	High yield potential	Black pepper growing areas of Kerala, Karnataka and Andhra Pradesh.
Ginger	GCP-49 (UBKV AADA 1)	Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal	High yield potential	All ginger growing regions of the country
Ginger	V_1S_1-2 (Sourabh)	High Altitude Research Station (OUAT), Pottangi	High yield potential	Odisha
Turmeric	NDH-98	Narendra Dev University of Agriculture & Technology, Kumarganj, Faizabad, Uttar Pradesh	High yield potential	All turmeric growing regions of the country
Turmeric	IISR Pragati (Acc. 48)	ICAR-Indian Institute of Spices Research, Kozhikode, Kerala	High yield potential, short duration, moderately tolerant to root-knot nematodes and curcumin content of 5%	Turmeric growing areas of Kerala, Karnataka, Andhra Pradesh, Chhattisgarh and Telangana
Coriander	RD 385 (Dr.RPCAU Dhania-1)	Dr. Rajendra Prasad Central Agricultural University, DHOLI, Bihar	High yield potential	All Coriander growing regions of the country
Fenugreek	HM 444 (Hisar Manohar)	Chowdhary Charan Singh Haryana Agricultural University, Hisar, Haryana	High yield potential and unique green seed colour	Haryana

Six location specific technologies on spices for various states were recommended

- Application of Ponneem (2 mL L^{-1} of water) was recommended for controlling shoot and capsule borer in cardamom for Kerala.

- Pre-planting treatment of seed rhizome and foliar spray of standing crop at 90, 105, 120 days after planting with Propiconazole (0.1%) was recommended to control foliar disease of turmeric in Bihar.

- Seed rhizome treatment with Carbendazim + Mancozeb (1:1) (0.1%) + foliar spray of Carbendazim + Mancozeb (0.1%) on 45 and 90 days or seed rhizome treatment with Azystrobin (0.1%) + spray on 45, 75 and 105 DAP for the management of Colletotrichum and Taphrina leaf blotch of turmeric for Chhattisgarh.

- Hexaconazole spray two times at 20 days interval (0.1%) was recommended for management of Phyllosticta leaf spot in ginger in Himachal Pradesh.

- Carbendazim (0.1%) + Mancozeb (0.1%) first at disease appearance and subsequently two sprays at 20 DI after I^{st} spray or foliar spray with Propiconazole (0.1%) first at disease appearance and then two times at 20 DI or foliar spray with Tricyclazole (0.1%) first at disease appearance and then two times at 20 DI was recommended for Bihar.

- Foliar spray with Carbendazim:Mancozeb (1:1) (0.1%) first at a disease appearance and then two times at 20 days interval was recommended for Chhattisgarh.

- Hexaconazole (0.1%) or Propiconazole (0.1%) spray first at disease appearance and then two times at 20 days interval was recommended for Pundibari, West Bengal.

BIOINFORMATICS

IPVdb, a new database on plant viruses reported from India, has been developed and launched by Bioinformatics Centre. This database attempts to assemble information about different plant virus species infecting various crop plants in India, along with their host range, symptomatology, distribution, transmission, particle morphology, diagnosis, available sequence data and literature as a searchable database. Details of 129 species of plant viruses reported to occur are made available in this database. Feature like sequence comparison is added to the database, which can be used to compare between strains of a virus species or between virus species. Viro Blast provides users with the facility to check identity/similarity of a sequence against all available plant virus sequences. The database also contains a search window to search the viruses using their species name, host or disease. This database will help in comparison of different plant virus species occurring in India by providing all available resources under a single platform, thus making studies on plant viruses occurring in India simple and easy. The database can be accessed at: http://220.227.138.213/virusdb/. (image)

Piperpep is another database which is a compilation of peptide data from mass spectrometry analysis of black pepper. This database has 1001 peptides, including 36 antimicrobial peptides annotated from the leaf of black pepper. The user friendly browsing and search tools would help the researcher with crop improvement in black pepper and also in other crops via peptide or protein data. The information on antimicrobial peptides in this database is expected to cater towards development of new drugs for agricultural and medicinal uses. The database is freely accessible at http://220.227.138.213/piperpep/.

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HUMAN RESOURCE DEVELOPMENT

The Bioinformatics Centre (DISC) organized a short-term training "Bioinformatics for Transcriptome Analysis" during 22-25 March 2017. Sixteen participants from various ICAR institutes, SAUs and other institutions participated in this four day program. Apart from the Institute faculty, experts from Central University of Kerala, Xcelris Labs Ltd., Ahmedabad and NCBS, Bengaluru handled various classes.

Fig. 31. Faculty members and trainees of short-term training on bioinformatics for Transcriptome Analysis

Post harvest technology section conducted 10 days in-plant training programme for students of KAU, Tavanur during 1-10th March 2017.

Fig. 32. In-plant trainees visiting Spice Processing Facility at Peruvannamuzhi

Ph.D. Awarded

Nandakishore O.P., A comparison on morphology, biochemistry and molecular markers of Indian *Garcinia* Spp. In relation to geographical variation", Mangalore University (Dr. Utpala Parthasarathy, Applied Botany), 20116.

Anupama K, "Development of micro-satellite markers for black pepper (*Piper nigrum*) and related spices" University of Calicut (Dr. K. Nirmal Babu, Biotechnology), 2016.

Sruthi D., Chemoprofiling and antioxidant potential of selected Piper species, University of Calicut (Dr. T. John Zachariah, Biochemistry), 2016.

Training attended

Sl. No.	Name of the Official	Training Programme	Duration	Organization
		Sciertists		
1	Dr. P. Rajeev	Impact assessment of agriculture extension	6-10 June 2016	ICAR-NAARM, Hyderabad
2	Dr. Muhammed Faisal Peeran	Intellectual Property and Technology Management	13-18 June 2016	ICAR-NAARM, Hyderabad
3	Dr. Rashid Pervez	Use of advanced taxonomic tools for identification of nematodes	16-30 August 2016	AMU, Aligarh, UP
4	Dr. Sharon Aravind	Short course on Utilization of Plant Genetic Resources through classical and innovative pre breeding approaches	20- 29 September 2016	TNAU, Coimbatore
5	Dr. Rashid Pervez	Hindi Officers Training	17-21 October 2016	Central Hindi Training Institute, New Delhi
6	Dr. M.S. Shivakumar	Training programme on "Agrobiodiversity conservation, sustainable livelihoods and need for climate change adaptation"	18-24 November 2016	MSSRF, Wayanad
7	Dr. E. Jayashree	Short Course on 'Food Business Management'	28- 30 September 2016	Indian Institute of Crop Processing Technology, Thanjavur
8	Dr. T. E. Sheeja	Short Course on 'Food Business Management'	28- 30 September 2016	Indian Institute of Crop Processing Technology, Thanjavur
9	Dr. E. Jayashree	Training programme on Competency Enhancement Programme for Effective implementation of Training Functions by HRD Nodal Officers of ICAR	13-15 February 2017	ICAR- NAARM, Hyderabad
10	Dr. C. K. Thankamani	'Analysis of Experimental Data'	20-25 February 2017	ICAR-NAARM, Hyderabad

	Dr. K.S. Krishnamurthy	Training programme- `Physiological and molecular aspects of improving crop adaptation to drought'	27 February - 11 March 2017	Dept. of Crop Physiology, UAS, GKVK, Bengaluru
Technical				
11	Ms. P.K. Chandravally	Competency enhancement programme on soft skills and personality development for technical officers	1-10 June 2016	ICAR-NAARM, Hyderabad
12	Dr. E. Radha	Competency enhancement programme on soft skills and personality development for technical officers	1-10 June 2016	ICAR-NAARM, Hyderabad
13	Mr. N. Cholurappa	Selection, Adjustment, Operation and Maintenance of Agricultural Implements for Field and Horticultural Crops	16-25 August 2016	ICAR – Central Institute of Agricultural Engineering, Bhopal
14	Mr. K. Krishnadas	Selection, Adjustment, Operation and Maintenance of Agricultural Implements for Field and Horticultural Crops	16-25 August 2016	ICAR – Central Institute of Agricultural Engineering, Bhopal
15	Mr. N.A. Madhavan	Principles of Seed Production, Processing, Storage and Quality Assurance	14- 23 November 2016	ICAR-Indian Institute of Seed Science, U.P.
16	Mr. C.K. Jayakumar	Cyber Security	28 September - 5 October 2016	ICAR-Indian Agricultural Statistics Research Institute, New Delhi
Administrative				
17	Mr. R.N. Subramanian	Workshop on Income tax for DDOs and Dealing Assistants	4-5 July 2016	ISTM, New Delhi
18	Ms. P.V. Sali	Enhancing efficiency and behavioural skills	28 July - 3 August 2016	ICAR-NAARM, Hyderabad
19	Mr. K.V. Pillai	Self-Management through Personal Profiling	9 - 12 August 2016	SAMETI, Thiruvananthapuram

HINDI CELL ACTIVITIES

Official Language Implementation Committee meeting

The Official Language Implementation Committee (OLIC) meets once in every quarter; First meeting was held on 21st June 2016; second on 16th September 2016; third on 17th December 2016 and forth on 28th February 2017 under the chairmanship of Dr. K. Nirmal Babu, Director and reviewed the official language implementation activities of the institute.

Workshops conducted

Four Hindi workshops were organized at ICAR-IISR, Kozhikode to popularize official language. First on "Noting and drafting", lecture delivered by Dr. B. Balakrishnan, Deputy Director (OL), Regional implementation office, Mumbai, at Kozhikode on 15th June 2016; second on "Noting and drafting", lecture delivered by Mr. Santhosh Ram Kumar, Asst. Manager (OL), Union Bank, Zonal Office, Kozhikode on 21st September 2016; third on "Noting and drafting", lecture delivered by Dr. O. Vasan, Asst. Director (OL), Akashvani, Kozhikode on 10th December 2016 and fourth on "Noting and drafting", lecture delivered by Mrs. Mini Agustin, Manager (OL), Canara Bank, Zonal office, Kozhikode on 22nd February 2017.

Hindi Day and Hindi Fortnight celebration

Hindi day was celebrated on 15th September 2016 and Hindi fortnight from 19th September to 3rd October 2016. Hindi fortnight inauguration was held on 19th September 2016 under the chairman ship of Dr. B. Sasikumar, Director (In Charge). During this period various competitions viz., extempore speech, hindi song, noting and drafting, memory test, caption writing and anthakshari were conducted for the staff members and prizes were distributed to the winners in the valedictory function on 3rd October 2016 under the presidentship of Dr. K. Nirmal Babu, Director. Ms. Vasu, Chairman, TOLIC Kozhikode and DGM, SBT, Kozhikode was the chief guest. Institute official language magazine *Masaloon Ki Mehak* was released during the occasion.

TOLIC activity

Dr. T. John Zachariah, Head, Division of Crop Production and Dr. Rashid Pervez, Principal Scientist & Hindi Officer attended Hindi seminar at Hotel Malabar, Kozhikode on 5th October 2016.

Dr. Rashid Pervez and Ms. N. Prasannakumari attended the half yearly and subcommittee TOLIC meeting on 16th July and 15th December 2016.

Dr. Rashid Pervez attended Hindi workshop on Parliamentary document at Zoological Survey of India, Kozhikode on 17th February 2017.

Publications

Following publications were published during 2016-17

- Annual report (2015-16), Pages 100 + iv
- *Anusandhan ke mukhya ansh* (2015-16), Pages 28 + iv
- Executive summary of annual report of the institute and AICRPS (Spices)
- *Masala Samachar* (4 issues)
- *Masaloon ki Mehak* (OL magazine), Pages 100 + iv
- Bulletins *(Elaychi)*, Pages 32 + iv
- Bulletins (*Lavang*), Pages 20 + iv
- 16 scientific popular hindi articles published in various journals/magazines.

OL Reports

Quarterly and annual reports on official language activities of the institutes prepared and sent to ICAR, New Delhi, TOLIC, Kozhikode and Regional Implementation Office, Cochin. Online quarterly and annual reports on official language activities of the institutes submitted to Department of Official Language, Ministry of Home Affair, Govt. of India. The half yearly reports on Official Language implementation were prepared and submitted to Regional Implementation Office, Cochin.

Other activities

Translated various items under 3(3) viz., office order, circular, documentaries, rubber stamps, name board, envelops and web site into hindi. Displayed daily a word/phrase in hindi and its meaning in english.

RECOMMENDATIONS OF RAC AND ACTION TAKEN REPORT

Recommendations	Director's comments	Council's comments	Action taken
Prior permission need to be obtained from the council for printing of spices germplasm catalogue as well as posting it on the public domain.	Printing may be done at the institute level. However, for posting in public domain we may seek Council's guidance	Agreed. The information on genetic resources may not be made available in Public Domain	Document on black pepper germplasm has been compiled.
More funding for conservation and maintenance of germplasm need to be envisaged.	More funding for germplasm conservation and maintenance will be envisaged in future programs	There is no separate provision for funding the activities on conservation and maintenance of germplasm and the institute is expected to manage such issues out of the consolidated Plan budget. However, the institute may indicate specific budgetary requirements, if any, for such issues like creation of infrastructure etc. and submit to Council for further consideration.	Noted for future programmes
Plant volatiles influencing resistance of black pepper lines to pollu beetle need to be studied.	The differences in plant volatiles, if any, in pollu beetle resistant and susceptible black pepper cultivars would be studied during the flushing season	Agreed.	Will be initiated during this flushing season

The anti-cancer property of curcuminoids and its derivatives need to be explored.	Detailed study using curcuminoids will be taken up under Network project on high value compounds and phytochemicals	Agreed.	Induvidual curcuminoids have been widely studied for anticancer properties. Efforts were made to conduct studies at RCC Triruvanathapuram with other spices and slot availability was very limited.
For better profiling of spice extracts the use of Super Critical Fluid Extraction need to be studied	Supercritical extraction unit allotted under Network project on high value compounds and phytochemicals could not be purchased due to lack of funds. Once it is purchased, profiling of spice extracts will be taken up.	Agreed. The institute should make fresh efforts to purchase the scientific equipment for high impact research. If needed the issue may be taken up with the SMD to find out alternate ways for purchasing the equipment. Further, in the meantime the work may be initiated in collaboration with any other institute, if the facility is available.	Initiated with support of DMAPR, Anand
Separate Food Safety Cell may be created in the Institute to address Food Safety and Supply Chain Management issues in spices	The Principal Investigator of Network project on organic horticulture is identified as Nodal Officer for the Food Safety Cell.	Agreed. The institute may identify and prioritize the issues on food safety and supply chain management.	A Codex cell with scientists of IISR as members has been formed.

Bio efficacy and residue study of pesticides on spices following GAP may be undertaken as per established protocols in collaboration with Kerala Agricultural University /Accredited Laboratories.	Studies on bioefficacy and residues of pesticides on spices would be undertaken as per established protocols in collaboration with Kerala Agricultural University, Vellayani and accredited laboratories in consultation with AINP on Pesticide Residues, New Delhi.	Agreed. Food safety is an important aspect in spices and may be taken up on priority. The matter may be discussed with relevant laboratories/ organizations and process of collaborative work expedited in a definite timeframe.	A group meeting on "Gap trial and generation of monitoring data in spices" was held on 8th September 2016 at Spice Board, Cochin, which was attended by Dr. K. K. Sharma, Network Coordinator, AINP on Pesticide Residues. It was decided that the following four pesticides fipronil, spinosad, imidacloprid and quinalphos would be taken up for the study in cardamom. KAU, TNAU, IISR and ICRI, Spices Board would finalize the protocol for the study, including optimization of the spraying schedule and the sampling procedure for residue analysis. SHM has allotted funds to IISR to establish a pesticide residue lab. The institute is in the process of signing MOU to initiate the program during 2017-18.
NABL accreditation of IISR laboratories may be attempted.	NABL accreditation of IISR laboratories will be attempted this year.	Agreed. The institute may come up with a strong proposal with sound justification in the matter.	Letter sent to Director, CIFT, Kochi to impart training on accreditation. Awaiting for funds.
Further inputs from the Subject Matter Division: The Director may review the overall recommendations of the present RAC and, in the light of recommendation of previous QRT, furnish his specific comments on action being taken by the institute on various recommendations with milestones and timeframe of activities.			

INSTITUTE MANAGEMENT COMMITTEE

1	Dr. K. Nirmal Babu	Director ICAR - Indian Institute of Spices Research, Marikunnu P.O , Kozhikode – 673 012	Chairman
2	Director, Directorate of Agriculture, Thiruvananthapuram	Director, Directorate of Agriculture, Vikas Bhavan, Thiruvananthapuram	Member
3	Director (Hort.), Tamil Nadu	Director (Hort.), Directorate of Horticulture & Plantations Crops, 3rd Floor, Agriculture Complex, Ezhilagam, Chepauk, Chennai – 600 005	Member
4	Associate Director, RARS Pattambi	Associate Director, Regional Agricultural Research Station, Pattambi, Palakkad, Kerala – 679 306	Member
5	Shri. T.P Suresh	Srigovindam (H), MLA Road. Kunnamangalam P.O, Kozhikode, Kerala – 673 571.	Non – Official Member
6	Shri. K.K. Rajeevan	Karuvangadiyil (H), Kadameri P.O., Villyapalli (Via), Kozhikode – 673 542	Non – Official Member
7	Dr. Viswanathan R	Head, Plant Protection ICAR – Sugarcane Breeding Institute Coimbatore – 641 007, Tamil Nadu	Member
8	Dr. V. Niral	Principal Scientist ICAR – Central Plantation Crops Research Institute NH – 66, Chowki, Kudlu P.O, Kasargod – 671 124	Member
9	Dr. K. Kandiannan	Principal Scientist ICAR – Indian Institute of Spices Research, Marikunnu P.O, Kozhikode – 673 012	Member
10	Dr. P.K. Asokan	Principal Scientist & Scientist – in – Charge Calicut Research Centre of CMFRI West Hill P.O, Kozhikode – 673 005	Member
11	Assistant Director General (H) – II Indian Council of Agricultural Research Krishi Anusandhan Bhavan – II, Pusa, New Delhi – 110 001		Member
12	Smt. Saribai. R Finance & Accounts Officer, ICAR Central Tuber Crop Research Institute Sreekariyam P.O, Thiruvananthapuram – 695 017		Member
13	Mr. K.V. Pillai Administrative Officer, ICAR – Indian Institute of Spices Research, Marikunnu P.O, Kozhikode – 673 012		Member Secretary

Note: The tenure of members at Sl Nos. 5 and 6 is 3 years with effect from 27.07.2016

LIST OF PROJECTS

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 & Dr. M.S. Shivakumar]

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)

1. 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. T.K. Jacob, Ms. S. Aarthi & Dr. M.S. Shivakumar]

2. 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 Chowdary]

3. 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. S. Aarthi]

4. 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]

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

6. ICAR-CIB 1. Mining and validation of candidate gene markers and screening of antimicrobial peptides of black pepper and small cardamom (2015-17) [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)]

7. 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]

Project III: Development of resource conservation and management technologies for improving productivity of spices (Project Leader : Dr. K. Kandiannan)

1. 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 & Dr. M. Alagupalamuthirsolai]

2. 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]

3. 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. S. Hamza]

4. 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, Mr. Narendra Chaudhary & Dr. P. Rajeev]

5. ICAR-CPPHT-4: Micronutrient management in horticultural crops for enhancing yield and quality (2014-17) (Dr. R. Dinesh, Dr. V. Srinivasan, Dr. S.J. Ankegowda, Dr C Sarathambal & Dr. S. Hamza)

6. AGR. XXXI (813). Development of fertigation schedule for better productivity in black pepper (2015-18) (Dr. C.K. Thankamani, Dr. R. Dinesh, Dr. K Kandiannan & Dr. M. Alagupalamuthirsolai)

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

8. 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]

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

1. 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]

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

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)

1. 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. S. Shanmughavel]

2. ICAR-CPPHT-2: Network on Organic farming in horticulture crops (2014-17) (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)

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

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

3. ICAR-CPPHT-3: Network project on high value compounds and phyto-chemicals (2014-17) (Dr. T. John Zachariah, Dr. N.K. Leela, Dr. Santhosh J. Eapen & Ms. R. Sivaranjani)

4. PHT VIII (813): Consortium research project on Secondary agriculture (2016-17) [Dr. E. Jayashree]

Project VII: Bio-Intensive management of pests in spices (Project Leader: Dr. T.K. Jacob)

1. 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. S. Devasahayam]

2. 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. S. Devasahayam]

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]

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

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

1. 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]

2. 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]

3. Outreach Programme on Phytophthora, Fusarium & Ralstonia diseases of horticultural and field crops (2008-2017) [Dr. M. Anandaraj, Dr. R. Suseela Bhai, Dr. Santhosh J. Eapen, Dr. K. Nirmal Babu, Dr. Johnson K. George, Dr. D. Prasath, Dr. R. Praveena & Ms. P. Umadevi]

4. Outreach Programme on Fungal foliar diseases (2009-2017) [Dr. C.N. Biju, Dr. R. Praveena & Mohammed Faisal Peeran]

5. 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]

6. 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 and Dr. C. Sarathambal)

7. 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]

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

1. 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]
2. 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]

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

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

2. 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)

3. Eco. III (813): Economic analysis technology, market dynamics and policy scenario in major spice crops (2014-19) (Dr. Lijo Thomas & Dr. P. Rajeev)

4. ICAR-SC1: Network project on Economic impact studies on crop diversification and technology adoption in Horticulture (2014-17) (Dr. P. Rajeev & Dr. Lijo Thomas)

5. Kerala State – CPPHT-4: 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)

6. 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]

7. DBT-SS2: Empowerment of rural women and youth in Kozhikode district through ornamental fish culture applying biotechnologies (2015-17) (Dr. B. Pradeep and Dr. P. S. Manoj)

PERSONNEL

Headquarters

Scientific

Name	Designation
Dr. K. Nirmal Babu	Director & Project coordinator (AICRPS)
Dr. B. Sasikumar	Head, Crop Improvement & Biotechnology
Dr. Santhosh J. Eapen	Head, Crop Protection
Dr. C.K. Thankamani	Head i/c, Crop Production & PHT
T. John Zachariah	Principal Scientist (Biochemistry)
Dr. T.K. Jacob	Principal Scientist (Entomology)
Dr. J. Rema	Principal Scientist (Horticulture)
Dr. Johnson K. George	Principal Scientist (Gen. & Cytogenetics)
Dr. R. Dinesh	Principal Scientist (Soil Science)
Dr. R. Suseela Bhai	Principal Scientist (Plant Pathology)
Dr. A. Ishwara Bhat	Principal Scientist (Plant Pathology)
Dr. R. Ramakrishnan Nair	Principal Scientist (Gen. & Cytogenetics)
Dr. K.S. Krishnamurthy	Principal Scientist (Plant Physiology)
Dr. K. Kandiannan	Principal Scientist (Agronomy)
Dr. N.K. Leela	Principal Scientist (Org. Chemistry)
Dr. K.V. Saji	Principal Scientist (Economic Botany)
Dr. P. Rajeev	Principal Scientist (Agril. Extension)
Dr. V. Srinivasan	Principal Scientist (Soil Science)
Dr. T.E. Sheeja	Principal Scientist (Biotechnology)
Dr. Rashid Pervez	Principal Scientist (Nematology)
Dr. D. Prasath	Principal Scientist (Horticulture)
Dr. E. Jayashree	Principal Scientist (AS & PE)
Dr. C.M. Senthilkumar	Senior Scientist (Entomology)
Dr. C.N. Biju	Scientist (Plant Pathology)
Dr. R. Praveena	Scientist (Plant Pathology)
Ms. P. Uma Devi	Scientist (Biotechnology)
Dr. Lijo Thomas	Scientist (Agri. Economics)
Ms. S. Aarthi	Scientist (Spices Plantation Medicinal & Aromatic Plants)
Dr. Sharon Aravind	Scientist (Spices Plantation Medicinal & Aromatic Plants)
Ms. R. Sivaranjani	Scientist (Biochemistry)
Dr. C. Sarathambal	Scientist (Agricultural Microbiology)
Mr. V.A. Muhammed Nissar	Scientist (Plant Biochemistry)
Dr. M.S. Shivakumar	Scientist (Genetics & Plant Breeding)

Technical Officers

Dr. Hamza Srambikkal	Chief Technical Officer (Lab)
Mr. M.P. Ramesh Kumar	Chief Technical Officer (Library)
Dr. E. Radha	Asst. Chief Technical Officer
Mr. K. Jayarajan	Asst. Chief Technical Officer (Stat.)
Ms. N. Prasannakumari	Sr. Technical Officer (Hindi Translator)
Mr. A. Sudhakaran	Technical Officer (Artist-cum-Photographer)
Mr. N.A. Madhavan	Technical Officer
Mr. K. Krishnadas	Technical Officer
Ms. P.K. Chandravally	Technical Officer

Administrative

Mr. K.V. Pillai	Administrative Officer
Mr. T.D.S. Prakash	Finance & Accounts Officer
Ms. P.V. Sali	Private Secretary
Mr. K.G. Jegadeesan	Asst. Finance & Accounts Officer
Mr. R.N. Subramanian	Asst. Administrative Officer
Mr. P. Sundaran	Asst. Administrative Officer

IISR Experimental Farm, Peruvannamuzhi

Technical Officers

Mr. E. S. Sujeesh	Senior Technical Officer

Krishi Vigyan Kendra

Scientific

Dr. P. Ratha Krishnan	Programme Coordinator

Technical Officers

Dr. P.S. Manoj	Subject Matter Specialist (T9) (Hort.)
Dr. S. Shanmugavel	Subject Matter Specialist (T9) (Veterinary Science)
Mr. K.M. Prakash	Subject Matter Specialist (T9) (Agronomy)
Dr. B. Pradeep	Subject Matter Specialist (T-7-8) (Fisheries)
Ms. A. Deepthi	Subject Matter Specialist (T-7-8) (Home Science)
Dr. K. K. Aiswariya	Subject Matter Specialist (T-7-8) (Plant Protection)

IISR Regional Station, Appangala, Karnataka

Scientific

Dr. S.J. Ankegowda	Principal Scientist (Plant Physiology)
Dr. Alagupalamuthirsolai	Scientist (Plant physiology)
Ms. H. J. Akshitha	Scientist (Spices Plantation & Aromatic Plants)
Mr. Narendra Chaudhary	Scientist (Spices Plantation & Aromatic Plants)
Dr. Mohammed Faisal Peeran	Scientist (Plant Pathology)

Administrative

Mr. P. Muraleedharan	Asst. Administrative Officer

WEATHER DATA 2016

Experimental Farm, Peruvannamuzhi, Kerala

Month	Rainfall		Temperature (°C)		Relative Humidity (%)	
	Total Rainfall (mm)	Rainy days	Max. (Mean)	Min. (Mean)	Max. (Mean)	Min. (Mean)
January	0.0	0	34.41	21.45	90.35	48.58
February	0.0	0	35.41	22.50	91.03	47.10
March	0.0	0	36.98	23.75	84.09	48.32
April	3.0	1	37.73	25.58	79.26	53.66
May	284.4	17	35.06	23.04	90.35	63.03
June	930.6	28	29.40	22.91	94.80	86.00
July	830.2	26	29.43	23.45	95.61	86.51
August	438.4	23	29.82	24.17	95.48	78.93
September	280.4	18	30.46	23.55	93.63	71.33
October	64.4	5	32.27	23.24	92.51	63.93
November	42.0	3	33.80	22.88	91.66	51.96
December	20.0	2	34.00	21.12	91.90	44.41
Total/Mean	**2893.4**	**123**	**33.23**	**23.13**	**90.88**	**61.98**

Regional Station, Appangala, Karnataka

Month	Rainfall		Temperature (°C)		Relative Humidity (%)	
	Total Rainfall (mm)	Rainy days	Max. (Mean)	Min. (Mean)	Max. (Mean)	Min. (Mean)
January	1.0	0	28.20	13.10	79.58	77.68
February	0.0	0	32.95	14.83	93.25	65.50
March	0.0	0	33.60	18.20	89.50	74.30
April	13.4	2	33.70	18.20	92.98	71.38
May	161.2	10	32.90	18.70	92.10	86.50
June	653.4	25	27.50	17.20	95.22	93.46
July	537.2	26	25.28	16.48	89.94	85.52
August	440.9	29	25.88	16.09	79.86	76.12
September	251.4	19	24.30	16.00	88.58	87.28
October	60.0	3	26.04	15.72	92.90	92.52
November	28.0	1	28.30	13.51	91.18	89.09
December	42.7	4	28.65	9.50	91.06	73.70
Total/Mean	**2189.2**	**119**	**28.94**	**15.63**	**89.68**	**81.09**

MAJOR EVENTS OF ICAR-IISR

Event	Particulars
Swachhta Pakhwara celebrations	17-28 May 2016
World Environment Day	5 June 2016
International Day of Yoga	21 June 2016
Presentation ceremony of the "Pandit Deen Dayal Udpathya Anthyodaya Agriculture Award 2016	25 September 2016
Interactive meeting of ICAR-IISR scientists with UPASI Spice Committee members	10 August 2016
Swachhta Pakhwara celebrations	17-31October 2016
Vigilance Awareness Week	31 October – 5 November 2016
Student-Scientist interface on "New Vistas in Invertebrate Research"	25 January 2017
Productivity Week	12-18 February 2017
Two days District Level Seminar on Spices	18-19 February 2017
National Science Day	25 February 2017