भा कृ अनु प
ICAR

वार्षिक प्रतिवेदन
Annual Report
2015-16

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भा कृ अनु प - भारतीय मसाला फसल अनुसंधान संस्थान

ICAR-Indian Institute of Spices Research

(Two times winner of Sardar Patel Outstanding ICAR Institution Award)

कोषिक्कोड, केरल, भारत Kozhikode - 673 012, Kerala, India

The laboratories and administrative offices of the institute are located at Chelavoor 11 km from Calicut (Kozhikode), Kozhikode District, Kerala, on the Calicut-Kollegal road (NH 766), in an area of 14.3 ha. The research farm is located 55 km North East of Calicut at Peruvannamuzhi on the Peruvannamuzhi-Poozhithode road in Kozhikode District, in an area of 94.08 ha. The Regional Station at Appangala (920 m above MSL), is located in Hervanad Village of Madikeri Taluk, Kodagu District, Karnataka on the Madikeri – Bhagamandala Road, 8 km from Madikeri, in an area of 17.4 ha.

"Our mission is to serve the spice growers by conducting goal-directed, peer-reviewed research and educating future generation to be science literate. Our institute seamlessly integrates research, education and global networking into its programs, products and services".

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PREFACE

The research achievements of the institute during 2015-16 are presented here. During the year our germplasm is enriched with 193 *Piper* accessions including 134 cultivars and 59 wild types were collected. The alternate field gene banks for black pepper are maintained at CHES, Chettalli, Karnataka and IISR, Chelavoor, Kerala. Farmer participatory surveys were conducted in Thrissur, Idukki and Kottayam districts of Kerala and 19 germplasm accessions of nutmeg were collected. A high yielding, high curcunim, short duration turmeric line, Acc. 48, performed well under MLT and AICRPS trials. Key genes and transcription factors with putative regulatory roles on curcumin biosynthesis were identified.

Strategy for management of virus affected black pepper gardens for yield sustainability was developed through which, marked improvement in the health of the vines was recorded. A renewable solar energy unit for turmeric curing was established at Experimental Farm, Peruvannamuzhi. A QSAR model was developed to predict anti-oxidant properties of natural compounds in spices.

Application of *Lecanicillium psalliotae,* an entomopathogenic fungus, as soil drench was found to be promising for the management of thrips in cardamom. Comparative genomics of 10 Indian isolates of *Ralstonia solanacearum* was undertaken. Morphological and molecular characterization of eight *Phytophthora* isolates causing leaf and fruit fall of nutmeg revealed their close relatedness to *P. meadii.*

The advisory services of the Agricultural Technology Information Center were delivered to more than 6200 clients. Twelve training programmes were conducted by the institute targeting diverse stakeholder groups like farmers, youth, tribal beneficiaries and students. A total of 14 exhibitions were organized by the institute during the year. In KVK, about 88 training programmes for practicing farmers and farm women, rural youth and extension functionaries were conducted. Nine front line demonstrations and five on-farm trials on technology assessment and refinement were carried out.

During the year, the ITM-BPD Unit facilitated non-exclusive licensing of ginger and nutmeg varieties. The Spice Processing Unit at Experimental Farm became operational this year. Consequently, four license agreements were signed with clients for utilizing this facility. The novel method for delivery of PGPR *viz.*, "Biocapsule Technology" has attracted many biofertilizer manufacturing companies and the institute signed a non-exclusive agreement for commercialization.

I consider it a privilege to place on record the encouragement given by Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR; Dr. S. Ayyappan, former Secretary, DARE and Director General, ICAR and Dr. M. Anandaraj, former Director, ICAR-IISR. I am also grateful for the strong support and necessary guidance received from Dr. N.K. Krishna Kumar, Deputy Director General (Hort. Science) and Dr. T. Janakiram, ADG (Hort. Science). The efforts and zeal shown by all the project investigators in executing various programmes are greatly appreciated. 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.

(K. Nirmal Babu)

Kozhikode
25.06.2016

EXECUTIVE SUMMARY

BLACK PEPPER

Genetic resources

A total of 193 *Piper* accessions including 134 cultivars and 59 wild types have been collected, including an accession resembling Narayakkodi with persistent stigma, ovate fruits and short spikes.

Presently, 3213 *Piper* accessions are being maintained in the conservatory. A field gene bank with 200 accessions has been established at Peruvannamuzhi, Kerala. The alternate field gene bank at CHES, Chettalli, Karnataka now comprises of 627 accessions. A field gene bank comprising of 223 accessions is being maintained at Chelavoor campus.

The black pepper accessions were characterized and a catalogue was prepared. Passport details, morphological, reproductive, qualitative and quantitative characters and reaction to biotic and abiotic stresses of each accession along with photographs are included in the catalogue.

Breeding

A trial involving 10 improved lines/ selections was laid out at Peruvannamuzhi farm. An early maturing entry, (HP117 x Thommankody) came to harvest by November with a mean fresh yield of 1.45 kg/vine.

Mining and identification of single nucleotide polymorphisms (SNP)

Unique SNP profiles have been developed for 14 cultivars *viz*., Panniyur 1, Panniyur 5, Panniyur 6, Panniyur 8, IISR Girimunda, IISR Malabar Excel, Subhkara, Panchami, Pournami, PLD2, Chumala, Acc. 819, OPKM and Narayakkodi. Five different SNP patterns were found to be shared by two cultivars each, Panniyur 2 - Vadakkan, Panniyur 3 – Arka Coorg Excel, Panniyur 4 - Agali pepper, Panniyur 7 - Sreekara and Thevam – Shakthi.

Mining of antimicrobial peptides (AMP) from *Piper* transcriptome

One hundred and twenty seven sequences of *P. colubrinum* transcripts showed significant similarity with the reference AMPs and 111 of the *P. nigrum* transcript sequences also showed significant similarity.

Eleven sequences with motif CX{3,30}CX{3} CX{3,30}CX{3,30}CXC and 48 AMPs with motif CX{3,5}CX{8,17}CX{4,6}C (where C is cysteine, X is any residue except cysteine and numbers in curly braces denote a range of variable residues) were discovered in *P. nigrum*.

Crop management

Climate change and production

Studies undertaken at Madikeri, Karnataka indicated that low rainfall (73 mm), few rainy days (10) and low temperature (16^{o}C mean during May) during pre-monsoon season (March-May) and very heavy rainfall (2917 mm), more number of rainy days (89), low light intensity (60-140 µ moles) with cloud cover, and low maximum and minimum temperatures during June to August (spike initiation period) in 2013 negatively influenced black pepper productivity. This resulted in very low and delayed (September) spike emergence.

Management of virus affected gardens

Trials were taken on the management of virus affected black pepper gardens for rejuvenating its health and sustaining the yield at three estates in Madikeri district of

Karnataka. By the application of treatments (FYM, NPK, micronutrients and PGPR) there was a marked improvement in the health of the vines (with a health score of 3.1-3.3) as compared to control (2.8). The spike intensity (per 0.5 m^2) and yield were also significantly higher in treatments with nutrients and PGPR application (3.2 kg/ standard) as compared to control (1.9 kg/ standard).

Development of mechanical unit for production of white pepper

A mechanical unit was developed and evaluated for production of white pepper from black pepper (Panniyur 1). The white pepper obtained had a dry recovery of 68.7% and the capacity of the pulping unit was 125 kg/h.

Plant health management

Variability in *Phytophthora* spp.

Comparative studies on colony morphology, sporangial ontogeny, sporangial morphology, mating and physiological studies of *Phytophthora* isolates revealed prevalence of two groups – *P. capsici* and *P. tropicalis* with wide variations within the group. However, a multi-locus sequence typing (MLST) and whole genome sequencing (WGS) indicated the presence of a wide variety of genotypes with mixed characters indicating species diversification.

Piper colubrinum - Phytophthora capsici interaction

Defense related genes, peroxidase and PAL, showed highest level of expression at 24 hpi in *P. colubrinum* challenged with *P. capsici*, with a fold increase of 450 and 18, respectively. Genes like catechol oxidase, cinnamoylcoA reductase and polyphenol oxidase showed the highest expression at 16 hpi with a fold increase of 350, 70 and 220.

R genes in *P. colubrinum*

In silico analysis revealed 1371 unique R gene sequences in *P. colubrinum* transcriptome and transcripts belonging to all four major R gene classes were identified. The expression patterns of 12 candidate R genes were evaluated at different hpi on challenge inoculation with two isolates of *P. capsici*, 05-06 and 98-93. Eleven R genes showed similar expression pattern with both isolates and the expression of R genes was maximum in the initial hours of interaction.

P. nigrum- P. capsici interaction

Differential expression analysis of 11 resistant gene analogues (RGAs) in resistant (IISR Shakti) and susceptible (Subhakara) black pepper lines showed significantly higher transcript levels of PnRGA1, PnRGA8, PnRGA11 and PnRGA24 in IISR Shakthi, with maximum expression level at 8 hpi for PnRGA24.

Evaluation of new fungicides against anthracnose disease

Among the seven fungicide molecules tested *in vitro* against *Colletotrichum gloeosporioides*, fenamidone + mancozeb (0.3, 0.2, 0.1, 0.05, and 0.025 %) and carbendazim + mancozeb (0.15, 0.1, 0.05, 0.025 and 0.0125 %) were found to completely inhibit the growth of the pathogen.

Complete genome sequencing of *Cucumber mosaic virus*

The complete genome of *Cucumber mosaic virus* (CMV) was sequenced and compared with 27 CMV isolates reported worldwide from groups I and II. Percent identity and phylogenetic analysis clearly indicated that the current isolate belongs to subgroup IB. Sequence analysis also showed the presence of a rare deletion of nine nucleotides in the

putative methyltransferase domain of 1a gene which was observed only in one more isolate of CMV. The level of gene conservation among the CMV subgroups was highest in the coat protein gene and lowest in 2b.

Production and testing of somatic embryo derived plants for *Piper yellow mottle virus* (PYMoV)

Mature berries obtained from black pepper plants infected with PYMoV were used for somatic embryogenesis. Out of 53 somatic embryo derived plants tested for PYMoV using primers specific for four ORF regions of the virus, nine plants showed freedom from PYMoV.

Occurrence of endogenous *Piper yellow mottle virus* (ePYMoV)

Studies based on polymerase chain reaction, reverse transcription (RT) PCR, and Southern hybridization of total DNA from PYMoV infected black pepper plants probed with PYMoV specific sequence indicated the occurrence of integrated PYMoV sequence in black pepper.

Studies on physiological parameters in virus infected plants

Physiological parameters such as stomatal conductance, photosynthetic rate, chlorophyll fluorescence, chlorophyll content and mid-day relative water content were studied in healthy and virus infected plants of three varieties of black pepper namely, IISR Malabar Excel, IISR Thevam and Subhakara. Results showed slightly higher values for all parameters in healthy plants of all three varieties compared to infected plants.

Differential protein expression in PYMoV infected plants under temperature stress

The LC-MS analysis of a few selected differentially expressed proteins showed down regulation of membrane kinase, NBD sugar kinase, rubisco activase, plastocyanin and heat shock protein 60 family suggesting that catalytic activity, photosynthesis and metabolism were affected during virus symptom expression. Unique proteins expressed in symptomatic plants included thylakoid acid phosphatase which has a role in symptom development, 2 cys-periredoxin BAS1, SOD (copper/zinc binding family), miraculin like protein with trypsin activity (increased protease inhibitor in CTV infected libraries).

New pesticides against nematodes

Out of five new pesticides (thiamethoxam, flubendiamide, cartap hydrochloride, carbosulfan (granular formation) and chlorantraniliprole) tested for nematicidal activity under greenhouse conditions, carbosulfan and flubendiamide were found promising in suppressing *Radopholus similis*. Field trials indicated that application of carbosulfan/fipronil at quarterly intervals or twice a year (pre- and post-monsoon) significantly reduced *R. similis* population in soil.

Differential display of genes on colonization with endophytic bacterium

Differential display of gene expression consequent to colonization of black pepper roots (Sreekara) with *Pseudomonas putida* BP25 was studied through Suppression Subtractive Hybridization technology. Analysis of ESTs revealed the differential expression of genes responsible for different defence responses such as pathogenesis related proteins (PR1 and PR4), glutathione S- transferase, catalase, metallothionein-2, WRKY transcription factor 40 etc.

Field evaluation of endophytic bacteria

Maximum growth of plants and least incidence of disease were observed in black

pepper plots treated with *Trichoderma-Pochonia* combination followed by endophytic bacterium (*Curtobacterium luteum*) + metalaxyl-mancozeb and *P. putida* + carbosulfan combinations.

EPNs suppress leaf feeding caterpillars

Infectivity of eight native entomopathogenic nematodes was tested against semi-looper (*Synegia* sp.) under *in vitro* conditions. Among the EPNs, *Steinernema* sp. (IISR-EPN 02) and *Oscheius gingeri* (IISR-EPN 07) were found more pathogenic to the insect causing 100% mortality within 72 h.

CARDAMOM

Genetic resources

About 405 cardamom accessions conserved at the germplasm repository were replanted and 105 accessions were characterized for morphological and yield characters. FGB 75 recorded maximum yield and more number of capsules per plant. Field screening of accessions for leaf blight and rhizome rot resistance resulted in identifying highly resistant accessions to rhizome rot (FGB 63, FGB 70, FGB 82, FGB 83, FGB 85 and FGB 108) and highly resistant accession to leaf blight (FGB 130).

Breeding

In a Preliminary Evaluation Trial (PET III), 23 inter-varietal F_1 hybrids were evaluated for morphological and yield characters. The hybrid, Mudigere 2 x IISR Avinash recorded highest plant height with more number of leaves whereas the hybrid Mudigere 2 x Appangala 1 registered more number of capsules with highest fresh weight. The disease intensity of leaf blight and rhizome rot disease in these hybrids ranged between 3.33 - 43.33% and 0.00- 8.88%, respectively.

Crop management

Organic farming

Organic composts, FYM, neem cake combinations and bio agents like *Lecanicillium psalliotae*, *Pochonia chalmydosporia*, *Trichoderma harzianum* and spinosad (a natural insecticide derived from actinomycetes *Saccharopolyspora spinosa*) were evaluated at AVT Plantations, Wayanad and IISR Regional Station, Appangala, Karnataka. The yield recorded was higher in Spinosad and *Lecanicillium* applications along with *Trichoderma* and *Pochonia* than control.

Plant health management

Evaluation of potential *Trichoderma* isolates against rhizome rot pathogens

Nine shortlisted *Trichoderma* isolates *viz.*, TN-3, KA-1, KA-20, KA-3, KL-3, KL-10, KL-19 and KL-17 were evaluated against *Pythium vexans*, *Rhizoctonia solani* and *Fusarium oxysporum* under greenhouse conditions. The isolate KA-3 was found to be the most effective isolate against *P. vexans* and *F. oxysporum*, whereas KA-20 was most effective against *R. solani*.

Screening of endophytic fungi and bacteria

Endophytic fungi and bacteria isolated from *Alpinia mutica*, *Alpinia galanga* and *Amomum microstephanum* were evaluated for their antagonistic efficacy against *R. solani*, *F. oxysporum* and *C. gloeosporioides*. Among the isolates, AmL 1C, AgR 5A, AgR 5D and AmiPs 4C were found promising against *R. solani*. AmL 1B, AgR 5D and AmiPs 4A were effective against *F. oxysporum* while AmL 1B and AmiPs 4A were inhibitory to *C. gloeosporioides*.

Evaluation of chemicals against pathogens causing rhizome rot

Efficacy of four shortlisted fungicides *viz*., fenamidone + mancozeb (0.2%), captan + hexaconazole (0.2%), metalaxyl + mancozeb (0.125%) and tebuconazole (0.05%) against *P. vexans*, *R. solani* and *F. oxysporum* was studied in a glasshouse. Among the fungicides tested, tebuconazole proved to be effective against *R. solani* and *F. oxysporum*, whereas metalaxyl + mancozeb was effective against *P. vexans.*

Standardization of spray schedule against cardamom thrips

Four promising insecticides and natural products (fipronil 0.005%, imidacloprid 0.009%, quinalphos 0.05% and spinosad 0.135%) were evaluated in the field for the management of cardamom thrips (*Sciothrips cardamomi*) at Appangala, Kodagu. The spray schedule included three sprays during March, May and August along with standard spray schedule (five sprays during March, April, May, August and September). The trial indicated that reduction of damage by thrips by three sprays was equally effective as five sprays and all the treatments were on par with each other and significantly superior over control.

Effect of insecticide spray schedules on pollinators

The effect of insecticide spray schedules on honey bee pollinators was studied in insecticide treated plots from 6.00 am to 5.00 pm at Appangala, Kodagu. Honey bee activity in all the treatments including control was higher during 1.00 pm to 3.00 pm and there were no activity after 5.00 pm. The mean bee visits per flower during 6.00 am to 5.00 pm was maximum in quinalphos treated plots (35.1), followed by imidacloprid (28.6), control (20.9), fipronil (16.8) and spinosad (14.2).

Evaluation of entomopathogenic fungus

Evaluation of the entomopathogenic fungus *L. psalliotae* in the field at Wayanad, Idukki and Kodagu districts for the management of cardamom thrips indicated that application of *L. psalliotae* as soil drench was promising for the management of thrips in all locations.

Role of *Wolbachia* in physiology of cardamom thrips

Studies on the effect of tetracycline treatment in removal of *Wolbachia* from cardamom thrips indicated that *Wolbachia* was removed from the test insects and tetracycline treatment in laboratory-bred populations of thrips reduced egg hatchability to 15.3%, whereas in control, egg hatchability was 53.7%. In F_1 generation, the survivability of thrips from egg to adult was 36.6% and in control it was 53.7%.

Evaluation of insecticides against shoot borer

Evaluation of four insecticides and natural products (fipronil 0.005%, imidacloprid 0.009%, quinalphos 0.05% and spinosad 0.135%) in the field at Appangala, Kodagu in two spray schedules namely, three sprays during March, May and August and five sprays during March, April, May, August and September, indicated that reduction in shoot borer damage on the capsules was promising in plots treated with fipronil (3 and 5 sprays) and spinosad (3 and 5 sprays).

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 24 ginger accessions collected from Nagaland, Kerala

and Karnataka. The characteristic collections includes, extra bold ginger from Nagaland and putative wild types from Periyar Tiger Reserve, Kerala, red ginger (*Z. officinale* var. *rubra?)* and Ella Kallan from Santhan Para, Idukki, Kerala.

Breeding

Evaluation of extra bold ginger accessions resulted in short listing of accessions Acc. 723, Acc. 247 and Acc. 713 for high yield and bold rhizomes. Chromosome indexing of bold rhizome type ginger accessions confirmed that all the accessions had 2n=22, indicating that boldness is not due to polyploidy but genotypic in nature. Two bold accessions showed aneu-somatic variation with 2n=21 and 2n=23.

In order to induce resistance to rhizome rot, five genotypes (Gorubathane, Rejatha, Acc. 578, HP 0.5/16 and M 0.5/12) were subjected to different doses gamma irradiation (0.80 and 1.00 kR). The M_1V_1 mutants were established in the green house for screening against *Pythium* sp. Two genotypes (Gorubathane and M 0.5/12) were also tried against chronic exposure of gamma rays (0.1 and 0.2 kR for 4 h) for inducing more variability and needs further standardization to fix the dosage and exposure time.

Crop management

Fertigation scheduling in ginger

A soil-less culture consisting of coir pith and farm yard manure in 1:1 proportion with fertigation is being standardized for ginger production. Two fertigation frequencies, once in three days and once in six days with five treatments were tried. Micronutrient spray and calcium nitrate drenching were given in alternate weeks. Results showed that 75% recommended dose of fertilizers (RDF) through fertigation had the maximum partitioning to rhizome (35%) at 120 days after planting. Rhizome yield was also maximum in the same treatment (15% higher compared to RDF). In general, fertigation once in three days had better response than fertigation once in six days.

Yield and quality of ginger as affected by coloured shade nets

Ginger was grown under red, green, white and black shade nets with open as control. Light (PAR) intensity in shade nets varied from 58-63% of open light intensity. Sampling at harvest revealed that rhizome dry weight was about 10-12% higher in ginger under red shade net compared to open condition.

Plant health management

New isolate of *Ralstonia*

A new isolate of *R. solanacearum* biovar 3 was collected from wilted *Gomphrena globosa* plant from Ambalavayal, Kerala.

A new diagnostic tool for *Ralstonia*

Real Time LAMP was found as a quick diagnostic tool for the on-farm detection and quantification of *Ralstonia* in soil as well as seed rhizomes of ginger. The detection was found to the limit of 10^3 CFU/g of soil or rhizomes.

Apoplastic bacteria suppress bacterial wilt

Treatment with apoplastic bacterium, IISR GAB 107, reduced bacterial wilt of ginger by 60% under greenhouse conditions. The study showed that individual treatments are better than consortia of bacteria in suppressing disease.

Comparative genomics of Indian isolates of *Ralstonia solanacearum*

Whole genome sequences of 10 isolates of *R. solanacearum* were collected, reassembled

and compared. The *de novo* assembly of ten *Ralstonia* strains yielded 5.6 to 6.2 Mb genome size at an N50 contig length of 58,400 to 68073 bp. While 1463 genes are common in all the strains of *R. solanacearum,* a number of unique genes present in each strain were identified. Maximum numbers of unique genes were found in Rs-2 and Rs-75. Cell wall degrading enzymes like polygalacturonases (PehA, PehB and PehC) were not present in majority of the isolates. On the other hand, pili-driven twitching motility factors (pilQ, pilT or pliA), endoglucanases and most of the metabolism and stress related factors were present in all the isolates.

Gene expression analysis in ginger and mango ginger

Tissue specific expression analysis of candidate genes/ESTs in *Curcuma amada* and *Zingiber officinale* showed significantly higher expression of Ethylene Response Factor, HMG-CoA reductase, HMG-CoA synthase and WRKY transcription factor 8 in both leaf and rhizome tissuesof *C. amada*.

TURMERIC

Genetic resources

One thousand four hundred and four *Curcuma* accessions have been maintained in the field gene bank. The germplasm conservatory was enriched with six new turmeric accessions. Eighty seven turmeric accessions have been characterized for morphological and flower characters as per DUS guidelines. Also, ten genotypes of turmeric comprising of three pre-release selections (Accs. 48, 79, 849) and seven released varieties (IISR Prabha, IISR Prathibha, IISR Kedaram, Suguna, Suvarna, Rajendra Sonia and Megha turmeric -1) were characterized for quality.

Breeding

Multi-locational trials with three promising accessions (Acc. 48, Acc. 79 and Acc. 849) along with IISR Prathiba and local check were laid out in Kerala (Peruvannamuzhi), Andhra Pradesh (Vijayawada), Tamil Nadu (Erode) and Karnataka (Chamrajanagar and Chettali). The long duration genotype, Acc. 849 recorded maximum yield of 9.10 t/ha (mean across locations and years, 2013-14 and 2014-15) followed by the short duration genotypes Acc. 48 (7.95 t/ha). The performance of the Acc. 48 was also evaluated in AICRPS, CVT trials across nine locations during 2013-14 and 2014-15. The Acc. 48 recorded 26.6 and 20.6 increase in yield over local and national checks, respectively.

Curcumin biosynthesis

R2R3-MYB, WRKY transcription factors with putative regulatory roles on curcumin biosynthesis genes were identified. Expression analysis of key genes (*pal, c4h, 4cl, c3h, hct, comt, dcs, curs1, curs2* and *curs3*) and a novel *pks* (*clpks11*) was completed under different growth conditions and developmental stages and gene to curcuminoid correlations were analysed. Two genes *c4H* and *clpks 11* showing positive correlation and *hct* showing negative correlation to curcuminoid content were identified.

Crop management

Yield and quality of turmeric as affected by coloured shade nets

Turmeric was grown under red, green, white and black shade nets with open field as control. Light (PAR) intensity in shade nets varied from 58-63% of open light intensity. Sampling at harvest revealed that rhizome dry weight was 13-15% higher in turmeric under red shade net compared to open condition. The oleoresin content under red shade net was 12.9% (20% higher compared to open and also black, white and green nets) and essential oil was 2.1% (5% higher compared to open).

Post-harvest technology

Turmeric curing with solar steam

A parabolic trough concentrating unit was installed at ICAR-IISR, Experimental Farm at Peruvannamuzhi, Kozhikode for curing of turmeric. The unit has a cooking vessel of capacity 50 kg/batch. The initial trial indicated that complete cooking of rhizomes could be achieved in 45 min.

Supercritical fluid extraction (SFE)

Dried turmeric (IISR Kedaram) rhizomes were extracted with compressed CO_2 at two different flow rates namely, 30 and 40 g/min. and pressure range of 20-30 MPa using methanol as modifier. The yield of SFE extract varied from 3.5 - 4.7%. GC-MS profile of SFE extracts was compared with that of essential oil. The general constituents in turmeric oil, such as α-pinene, α-phellandrene, limonene, α-terpinolene and β-caryophyllene was not detected in SFE extracts.

Plant health management

Molecular characterization of shoot borer populations

PCR conditions for the amplification of mitochondrial cytochrome-c oxidase subunit 1 (COI) gene region of *Conogethes* spp. infesting ginger, turmeric and cardamom using the primer pairs, Lep F1/ LepR1 were standardized.

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. On ginger, infestation by the shoot borer on shoots was first observed during the second fortnight of July and was high during the second fortnight of September to the second fortnight of October. On turmeric, the pest infestation was first observed on the shoots during the second fortnight of July and was high during the first and second fortnights of October.

Screening of insecticides for shoot borer management

Ten 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%) were screened for their efficacy against shoot borer. Plots treated with chlorantraniliprole had minimum pest infestation on the shoots that was on par with lambda-cyhalothrin, flubendiamide and cyantraniliprole.

Field evaluation of EPNs against shoot borer

Among the EPNs, *Steinernema* sp. (IISR-EPN 02) treated plants showed less shoot damage (34.5%) compared to malathion treatment (33.0%) and control (65.8%).

NUTMEG

Genetic resources

Farmer participatory surveys were conducted in Thrissur, Idukki and Kottayam districts of Kerala and 19 germplasm accessions of nutmeg were collected. Monoecious trees were recorded across the nutmeg tracts and three types of flowers *viz*., male (75%), female (19%) and hermaphrodite (6%) were noticed in the monoecious trees studied.

ANTI-OXIDANT PROPERTIES OF SPICES

Anti-oxidant properties of natural compounds: a QSAR model using semi empirical descriptors

In this study multiple linear regression (MLR) and kernel-based partial least square regression (K-PLS) methods with semi

empirical, topological and a combination of both descriptors were employed to generate QSAR models to predict the antioxidant activity of natural compounds. For this, the training set comprised of 31 compounds while the test set included 10 compounds already reported in the literature. The models generated were internally and externally validated with 19 and 16 additional compounds, respectively.

Antioxidant potential among four major spices

The study was used to evaluate the antioxidant potential of sequential extracts of major spices in relation to total phenols. DPPH radical scavenging activity of these extracts as determined by IC_{50} values, ranged from 11.9 to 1500 µg/mL. Antioxidant activity by PM method and FRP varied from 0.30-2.99 MAAE/g and 0.27 - 1.56 MAAE/g of extract, respectively. By PM method chloroform extract of turmeric showed highest activity (2.99 MAAE/g) which was followed by methanol extract of cinnamon (2.34 MAAE/g).

Antioxidant potential of *Myristica* species

Studies on antioxidant potential of leaf extracts of *Myristica fragrans*, *M. malabarica*, *M. andammanica* and *M. prainii* indicated that methanol extracts of all four species had higher antioxidant activity compared to petroleum ether extract. Among the methanol extracts the *M. fragrans* and *M. malabarica* showed higher antioxidant activity which was comparable with that of the synthetic antioxidant BHA.

PLANT HEALTH MANAGEMENT

Phytophthora meadii infects nutmeg

Eight *Phytophthora* isolates causing leaf and fruit fall of nutmeg in Kerala were characterized using morphological and molecular tools. ITS sequencing, restriction analysis using MSP1 and MLST analysis nuclear and mitochondrial genes revealed that these isolates are closely related to *P. meadii.*

Dimethyl trisulfide a new compound for soil fumigation

Soil fumigation assays with different concentrations of dimethyl trisulfide resulted in 100% inhibition of *Phytophthora capsici*, *Pythium myriotylum*, *Rhizoctonia solani*, *Gibberella moniliformis*, *Athelia rolfsii*, *Colletotrichum gloeosporioides* and *Radopholus similis* at different concentrations.

MVOCs suppress a range of phytopathogens

Microbial volatile organic compounds (MVOCs), identified from *Pseudomonas putida* BP25R, such as 2,5-dimethyl pyrazine, methyl pyrazine, dimethyl trisulfide, 2-ethyl 5-methyl pyrazine, 2-ethyl 3,6-dimethyl pyrazine were evaluated at different concentrations under *in vitro* conditions and their EC_{50} values were calculated. All the tested compounds showed significant inhibitory activity against oomycete pathogens, *P. capsici* and *P. myriotylum*; fungal pathogens *R. solani, C. gloeosporioides, A. rolfsii, G. moniliformis* and *M. oryzae,* bacterial pathogen *R. solanacearum*; and plant parasitic nematode *R. similis*.

New synthetic media for production of EPNs

A new artificial media was developed for the mass production of entomopathogenic nematodes. By this technique around 23 lakh infective juveniles of EPNs can be multiplied from a single flask (250 mL). The media is suitable to multiply infective juveniles of *Steinernema* spp., *Heterorhabditis* sp. and *Oscheius* spp.

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 22 locations in Idukki, Wayanad and Kozhikode districts of Kerala. Six entomopathogens and a mermithid nematode were documented from different spice crop pests (*Sinoxylon* spp., *Aspidiotus destructor*, *Aphis craccivora*, *C. punctiferalis* and *Udaspes folus*). The fungus infecting *S. anale* has been identified as *Beauveria bassiana* (IISR-EPF-04). The entomopthoralean fungus recorded from *A. craccivora* has been tentatively identified as *Neozygites* sp (IISR-EPF-12). An NPV (IISR-NPV-03) infecting *Pericallia ricini*, a pest of cardamom, was isolated.

New species of *Spilarctia obliqua NPV*

A new species of group I tetrahedral shaped multiple nucleopolyhedrovirus isolate, belonging to the genus *Alphabaculovirus* of family *Baculoviridae*, infecting *Spilarctia obliqua*, a polyphagous pest of ginger, turmeric and other crops was isolated and characterized based on morphological and molecular data. The isolate showed high virulence against the pest based on LC_{50} and ST_{50} data.

NEW DATABASES

The Bioinformatics Centre has developed and hosted three new databases *viz*., SpiceComDB, PiperPepDB and Radobase. SpiceCom comprise of plant based compounds and their bioactivity. It allows the user to search using compound name, plant name as well as based on activity. Facility to download compounds individually as well as in batch mode is provided.

INSTITUTE TECHNOLOGY MANAGEMENT AND BUSINESS PROCESS AND DEVELOPEMNT

During the year ITM-BPD Unit has facilitated the non-exclusive licensing of nutmeg variety, IISR Keralashree, the first variety of its kind developed through a farmer's participatory research approach. One of the elite ginger varieties, IISR Mahima was also licensed. ICAR-IISR signed a non-exclusive agreement for commercialization of Biocapsule Technology with Codagu Agritech, Karnataka. The same company has availed the technology of PGPR consortium for black pepper and *Trichoderma harzianum*. Another private firm have also availed the license for commercial production of *T. harzianum*. The Spice Processing Unit at Peruvannamuzhi, farm started functioning this year. Four license agreements were signed with clients this year for utilizing facilities.

EXTENSION AND TRAINING

The advisory services of the Agricultural Technology Information Center were delivered to more than 6200 clients including visitor advisory services to more than 3000 visitors. Twelve training programmes were conducted by the institute targeting diverse stakeholder groups like farmers, youth, tribal beneficiaries and students. The scientists from the institute served as resource persons in more than 33 training programmes across various states of the country benefiting more than 6000 participants. 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 on a popular TV channel as leading destination for higher education in the field of agricultural research. A total of 67 exhibitions days were organized by the institute during the year. The institute facilitated a total of 31 group visits for educational institutions to provide exposure to research and development activities in spice crops. About

17 farmer groups from within and outside the state visited the institute for learning about the technologies developed for improved spices productivity.

Trade competitiveness of black pepper

The trends in trade competitiveness of black pepper exports from India were examined through a time series of Revealed Comparative Advantage over the period 1988-90 to 2011-14. A sharp and steady decline in revealed comparative advantage (RCA) in black pepper trade could be identified from the analysis. The RCA declined from 26.8 during 1988-90 to 7.9 during 2001-05 and further declined to 4.6 for the period 2011-14. The instability in area, production and yield was higher during the period 2002-13 than the previous period of similar duration (1991-2001).

Comparison of ginger production in Kerala and Karnataka

The commercial high input intensive cultivation practices followed by commercial ginger farmers in Karnataka yields higher level of profits in the short run. The cost benefit ratio was 1: 3.39 for the sample ginger farms in Karnataka where as it was significantly lower in Kerala. The study also identified key intervention points for enhancing sustainable production of ginger. The cost of cultivation of ginger in commercial production system was found to be Rs. 412837/ ha.

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, Appangala (920 m above MSL) is located at Appangala, Kodagu District, Karnataka, on the Madikeri-Bhagamandala road, 8 km from Madikeri, in an area of 17.4 ha.

Mandate

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

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

Organization

The Director is the administrative head of the institute. The Institute Management Committee, Research Advisory Committee and Institute Research Council assist the Director in matters relating to management and research activities of the institute. Research on various aspects of the mandate crops is conducted in three divisions, namely, Division of Crop Improvement and Biotechnology, Division of Crop Production and Post Harvest Technology and Division of Crop Protection and a Social Sciences Section. The other facilities available at the

institute include Agricultural Technology Information Centre, Agricultural Knowledge Management Unit, Bioinformatics Centre, ITM-BPD and Krishi Vigyan Kendra. The institute also functions as the headquarters for the All India Coordinated Research Project on Spices (AICRPS), and Indian Society for Spices (ISS). The institute has 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 2007.50 lakhs during the year, which included 636.50 lakhs (including OPR on *PhytoFuRa, HVC* and *NPOH*) under Plan and 1371.00 lakhs under Non Plan.

Resource generation: Institute earned a total of 63.65 lakhs through sale of planting materials, biocontrol agents, training, publications, consultancy services and technology commercialization.

Staff

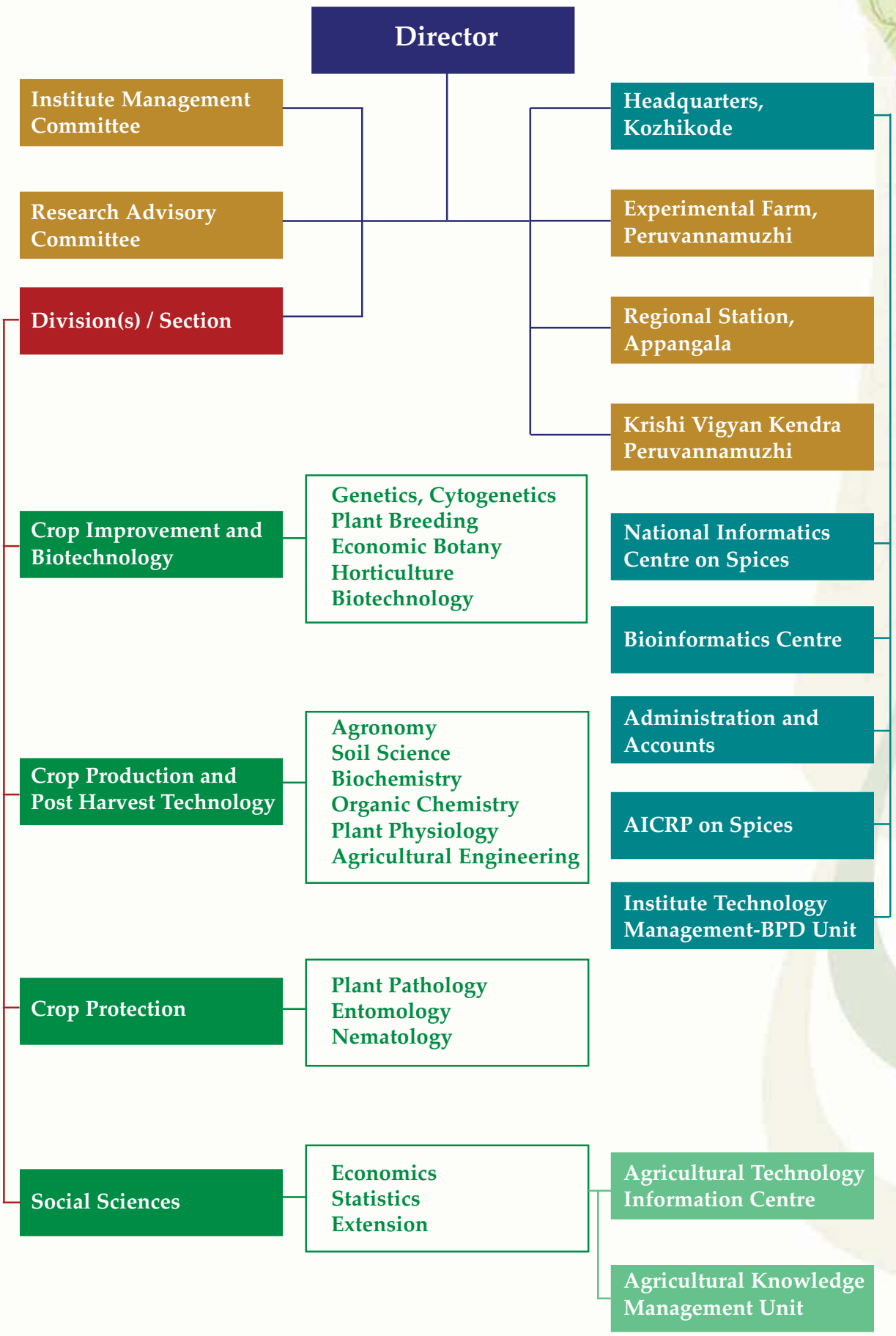
The institute has a sanctioned strength of 44 scientific, 24 administrative, 33 technical and 61 supporting staff, of which 39, 19, 24 and 14 of scientific, administrative, technical and supporting staff, respectively are in position. The KVK at Peruvannamuzhi has a sanctioned strength of one scientific, two administrative, 12 technical and two supporting staff.

Staff position of the Institute

Category	Sanctioned	Position			Total	Vacant
		Kozhikode	Peruvannamuzhi	Appangala		
Scientist	44	34	0	05	39	05
Technical	33	14	06	04	24	09
Administration	24	17	0	02	19	05
Supporting	61	02	03	09	14	47
Total	162	67	09	20	96	66

Staff position of KVK

Category	Sanctioned	Position	Total	Vacant
Scientist	01	01	01	00
Technical	11	10	10	01
Administration	02	00	00	02
Supporting	02	02	02	00
Total	16	13	13	03



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 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 release of nine improved varieties such as Sreekara, Subhakara, Panchami, Pournami, PLD-2, IISR Thevam, IISR Girimunda, IISR Malabar Excel and IISR Shakthi. FLD programme was undertaken using the released varieties in the farmers' field. 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 for their unique characters. 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.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 with *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* has 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 50 litres/vine 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 most 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 α-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-mancozeb sensitivity of 81 phytophthora isolates was tested and the EC_{50} and EC_{90} values ranged from 0.0002 to 14.4 ppm and 1.1-68.5 ppm, respectively. Among the new chemicals tested i*n 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. 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 with the adoption of scientific packages as compared to 620 kg/ha 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 57.1% and for application of biocontrol agents was 64.2%. The adoption level for application of soil fungicides, fertilisers and pesticides were very low at 21.1%, 7.7% and 7.6 % respectively. *Karshika Sankethika Darshanam* and Media Meet were organized to mobilize mass media support for sharing Agro-Information. Video films on Augmenting black pepper production – a success story (Malayalam, English, Hindi) and success story of a 'Prathiba' grower – post production stage were 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, germplasm bearing unique characters have been registered with NBPGR, New Delhi. The improved varieties such as Appangala 1 IISR Vijetha, IISR Avinash and Appangala 2 have been developed. Coupled with production technologies, these varieties resulted in increasing productivity of cardamom. About 10 high yielding F_1 hybrids were promoted to future coordinated varietal trials.

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 and recN gene sequence based comparison and MLST based comparative genetic analysis further revealed that the strain is 100% similar to the ginger strain of *R. solanacearum*.

Ginger

Germplasm repository at IISR has the largest collections with several exotic collections and high quality accessions. 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 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. Two accessions irradiated with gamma rays showedresistant reaction after three repeated inoculations with *R. solanacearum*. Ginger oil components have been characterized by GC-MS. 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 for N, Rs. 1.30/bed for P and Rs. 0.60/bed 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 testedagainst 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 publication, training programmes and demonstrations. Large scale multiplication and distribution of elite planting material were also undertaken.

Turmeric

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

Molecular genetic fingerprints of sixteen *Curcuma* species using RAPD and ISSR technique 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. zedoria* 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 for N, Rs. 0.40/bed for P and Rs. 0.85/bed 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.

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 Keralashree 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 *Myristica malabarica* continued to be better than other rootstocks for productivity. Green chip budding with orthotropic buds was standardized in nutmeg on *M. 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 *C. 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 olein, 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

The germplasm accessions at the NAGS center are maintained at the Experimental farm, Peruvannamuzhi.The present status of germplasm accessions consists of 1701 local cultivars, 1503 accessions of related taxa and nine exotic types totaling 3213 accessions.

A field genebank with 200 accessions was established during the year at Peruvannamuzhi, besides another 200 accessions at CHES, Chettalli, Karnataka. At present the alternate field gene bank at Chettalli holds 627 cultivar accessions. The Chelavoor field genebank now consists of 223 accessions (Fig. 1).

Fig. 1. Black pepper field genebanks; a. Kozhikode; b. Peruvannamuzhi and c. CHES, Chettalli

A catalogue on black pepper was prepared. The catalogue consists of characterization and evaluation data of 530 accessions. Passport details, morphological and reproductive characters, qualitative and quantitative characters and reaction to biotic and abiotic stresses of each accession along with a photograph of each accession are included in the catalogue (Fig. 2).

Fig. 2. Cover page and sample text page of black pepper catalogue

Germplasm exploration

Germplasm explorations were conducted at Kottayam, Ernakulam, Idukki and Trichur districts of Kerala for collecting cultivar diversity of black pepper. In addition to this, a germplasm collection programme was also carried out in the forests of Gavi and Vallakkadavu regions of Periyar Tiger Reserve, Pathanamthitta, Kerala for collecting wild relatives of black pepper. A total of 193 accessions (134 cultivars and 59 wild accessions) were collected during the year.

A unique putative wild black pepper with persistent stigma resembling Narayakodi but

with ovate berries was also collected from Vallakadavu forest range (Fig. 3).

Fig. 3. *Piper nigrum* with persistent stigma and ovate berries.

Breeding

A replicated yield trial involving 10 improved lines/selections along with two controls laid out in 2012 started yielding. Maximum fresh yield/vine was recorded in Thevam followed by OPKM. However, HP 117 x Thommankody, was found to be an early maturing line, coming to harvest by November (Fig. 4).

Fig. 4. Early maturing line, HP 117 x Thommankodi

Shortlisted black pepper cultivars Arka Coorg Excel, Agali, Chumala, Vadakkan and Kumbackal bush peppers were established for breeding work. Planting of selfed and crossed progenies of *Thekkan* was taken up. Thekkan x Subhakara (9), Subhakara x Thekkan (6), Thekkan (7), Thekkan selfed (7), Subhakara (7) were planted and maintained at Chelavoor farm.

Screening for pollu beetle resistance

Nine of the entries in the yield evaluation trial *viz*., HP 728, HP 1411, HP 780, HP 117 x Thommankodi, Coll.820, Coll.1090, OPKM, Thevam, Sreekara were screened for pollu beetle tolerance under natural infestation.

Sequence analysis of mentor grafted progenies and confirmation of gene transfer from *Piper colubrinum.*

Advanced analysis of the mentor grafted progeny was done with its RAD sequence data and RAD sequences/ transcriptome of *Piper colubrinum* and black pepper. Among the 34 unique nuclear loci specific to *P. colubrinum* found in the mentor grafted progeny, 11 had annotations with plant sequences.

The mentor grafted progeny of Panniyur 1 x *P. colubrinum* alongwith the 'parents' were anatomically characterized. Stem anatomy of the progeny was distinct as compared to the 'parents'.

Molecular biology

Mining and identification of SNPs

The Single Nucleotide Polymorphisms (SNP) from RAD-SEQ data of four accessions were mined using the contigs generated by CLC Bio workbench and Velvet assembler as a skeleton spices reference. The SNPs are mined using the Samtools pipeline. The mined SNPs were filtered according a filtering criteria with SNPs with a sequence coverage of ≥ 4 and with a flanking sequence of ≥ 50 bp were selected for further analysis. A total of 15101 SNPs were found after removing SNPs with coverage less than four.

Variation in SNP between the 24 selected cultivars was studied by Allele Specific PCR by analyzing four polymorphic loci with seven primer pairs. Unique SNP profile have been developed for 14 cultivars out of 24 such as Panniyur 1, 5, 6, and 8, IISR Girimunda, IISR

Malabar Excel, Subhkara, Panchami, Pournami, PLD2, Chumala, Acc. 819, OPKM and Narayakkodi. Furthermore, five different pattern of amplification identified which was shared by two cultivars each *viz*., P2 - Vadakkan, P3 - Arka Coorg Excel, P4 - Agali pepper, P7 - Sreekara and Thevam - Shakthi.

Mining and profiling of EST-SSR markers from transcriptome data

A total 101284 sequences from transcriptome data were analyzed for the presence of SSRs and 9009 sequences exhibited the presence of SSRs. SSR profiles were developed using 16 primer pairs developed based on the simple and complex sequence repeats, including tri, tetra, penta, hexa and hepta repeats with varying product size ranging from 107 to 138 bp. Profiling PAGE analysis helped to distinguish 22 out of 24 varieties tested.

Mining of Antimicrobial peptides (AMP) from *Piper* transcriptome

Similarity search using BLAST was conducted with 273 AMP sequences in the AMP data base revealed 273 AMP sequences similar in *P. colubrinum* and 111 sequences similar in *P. nigrum* the transcriptome. Motif search for identification of cysteine rich AMPs were done using an algorithm for 14 motifs present in all AMPs discovered and 59 sequences with motifs CX{3,30}CX{3}CX{3,30}CX{3,30}CXC and CX{3,5}CX{8,17}CX{4,6}C from *P. nigrum* and 38 sequences with motif CX{3,5}CX{8,17}CX{4,6}C in *P. colubrinum* transcriptomes. Secondary structures of these peptides were also predicted.

Proteomics for AMP discovery

Label free proteomics was done with black pepper challenge inoculated with *P. capsici* using LC-MS identified 24 AMPs having peptide signatures similar to AMPs in the AMP database. These AMPs showed constitutive as well as induced expression in black pepper upon challenge inoculation with *P. capsici*. AMPs falling under different families as cyclotides, defensins, thionins, lipid transfer proteins, snakins and hevein like proteins were identified.

Crop production

Management of virus for yield sustainability

Trials were undertaken for restoring the health and sustaining the yield of virus affected gardens at three estates in Madikeri district of Karnataka. Five treatment combinations were tried *viz*. T1 – FYM + fertilizers as per recommendation, T2 – T1 + micronutrient spray (twice), T3 – T1 + PGPR soil application, T4 – T3 + micronutrient spray (twice) and T5 – control. The vines (var. Panniyur-1) were graded for their virus infection status as mild, moderate and severe based on their visual symptoms and mild and moderate graded vines were selected for imposing different treatments at three locations *viz*., Madapura, Chetalli and Pollibetta.

The improvement in the health of the vines was conspicuous by the application of treatments (FYM, NPK, micronutrients and PGPR) (with a score of 3.10-3.25) as compared to control (2.80). The spike intensity (per 0.5 m^2) was significantly higher under treatments as compared to control. The canopy development was also significantly higher in all the treatments applied with NPK, PGPR and micronutrients as compared to control. The yield was also significantly higher in nutrients and PGPR supplementation as compared to control (1.90 kg/standard) and application of FYM + NPK + PGPR + micronutrients resulted in the highest yield (3.19 kg/standard) followed by application of FYM + NPK + micronutrients (2.91 kg/standard).

Scheduling fertilizer dose for fertigation

A trial was conducted at Laxmi Estate, Hosahalli, Mudigere to quantify the extra nutrient to be supplemented either by soil

application or through foliar over and above the fertigation dosage. Supplementing foliar NPK and micronutrients either alone or in combination has increased the leaf concentration of P, K, Zn and B. Soil supplementation of fertilizers and foliar spray of NPK and micronutrients recorded significantly higher photosynthetic rate and transpiration. Significantly higher dry yield was recorded in NPK + micronutrients (4.73 kg/standard) followed by micronutrients (4.51 kg/standard) supplemented vines with an increase of 26.0% and 20.6% in yield over fertigation alone.

Effect of anti-transpirants spray on gas exchange parameters during summer

Among anti-transpirant treatments (kaolin 1%, kaolin 2%, lime 1.5%, miracle 2 mL/litre and miracle 3 mL/litre), lime 1.5% showed higher stomatal conductance and less transpiration rate compared to control, but maintained photosynthetic rate which was on par with control two weeks after spray.

Impact of harvesting date on yield and gas exchange parameters in the ensuing year

To study impact of early harvest on alternate bearing behaviour of variety Panniyur 1, the crop was harvested early (after maturity) and all the inputs were applied early to study its influence on yield in the ensuing years. The following five dates of harvests were tried *viz.*T1-March 1st week harvest, T2-March 2nd week; T3-March 3rd week; T4-March 4th week and T5-April 1st week. Shade regulation and drip fertigation were followed immediately after the harvest of the crop. In the ensuing year, yield (dry, kg per vine) varied significantly among treatments and T1 showed highest yield (Table 1). The spike length and number of berries per spike also varied significantly among treatments and treatment T1 showed highest spike length,whereas T2 showed highest number of berries per spike. The results indicated that early harvest followed by early input application may lead to better crop in the ensuing year.

Table 1. Influence of time of harvest on yield of black pepper

Treatments	Dry yield (kg)/vine	Spike length (cm)	No. of berries/spike
T1-March 1st week	6.05^{A}	15.20^{A}	70.73^{A}
T2-March 2nd week	6.00^{A}	14.48^{A}	72.30^{A}
T3-March 3rd week	4.12^{B}	15.53^{A}	68.20^{AB}
T4-March 4th week	4.28^{B}	13.08^{A}	67.28^{AB}
T5-April 1st week	4.13^{B}	12.93^{A}	63.03^{B}
Mean	4.92	14.24	68.31
CV (%)	12.97	8.79	4.69
SE (d)	0.40	0.89	2.26
LSD at 1%	1.18	2.70	6.92

Field screening for drought tolerance

Nine previously identified drought tolerant accessions (Accs. 1439, 1622, 807, 4072, 1277, 971, 4226, 4216, 1495 and 1368) along with Subhakara (check) field planted at Chelavoor farm were water stressed for 20 days under control (18.0% soil moisture) as well as 18 days after stress induction (13.4% 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. There was little variation among the genotypes for these parameters under control condition but the values varied significantly among the genotypes under stress condition. In general, Acc. 4226 maintained higher RWC, lower membrane leakage, higher photosynthetic rate and higher chlorophyll fluorescence compared to other genotypes under stress.

Impact of climate change

As a part of mitigation of climate change effect, experiments on pruning (severing) of laterals immediately after harvest and 100 ppm etherel spray as another treatment were taken up to downsize the canopy during peak summer. Etherel treatment (100 ppm) induced severe leaf abscission, thus reducing the transpirational loss. Besides, new leaf and spike production were only about 50-55% of control in the ensuing year but the spike production was improved in the second year which was 90-95% of control. Harvesting, shade regulation and irrigation practices taken up during the month of March recorded higher spike initiation (65-70 spikes/m^2) with more number of berries (70-80 berries/spike) during the month of June which contributed significantly to total yield.

Development of mechanical unit for production of white pepper

A mechanical unit was developed for production of white pepper from green and black pepper. The prototype unit developed for production of white pepper consists of two parts - the fermentation unit and the pulping unit. The trials on production of white pepper were carried out using black pepper (Panniyur 1). The fermentation time required for conversion of green to white pepper was 3 days with daily change in water and black pepper to white pepper was 12 days with alternate days of change in water. Dry recovery of white pepper from green pepper and black pepper was 21.60 % and 65.17%, respectively.

Crop protection

Foot rot and slow decline diseases

Diversity studies in black pepper isolates

New *Phythophthora* isolates of black pepper and cocoa collected from Kozhikode district and four American Type Culture Collections (ATCC) of *Phytophthora tropicalis*, *P. capsici*, *P. palmivora* and *P. meadii* procured were revived and maintained in the National Repository of *Phytophthora*. Presently 440 isolates of *Phytophthora* including ATCC isolates are being maintained in the repository. The morphological and physiological characters of ATCC cultures *P. tropicalis*, *P. meadii* and *P. capsici* were studied and compared with black pepper isolates.

Based on ITS sequences the black pepper isolates of *Phytophthora* included *P. capsici* (44.1%), *P. tropicalis* (51.0%), *P. nicotianae* (2.1%), *P. meadii* (2.1%) and *P. palmivora* (0.7%). ITS phylogeny and MLST analysis of *capsici/tropicalis* groups indicated the presence of two separate subclades within Clade 2, deviating from *P. capsici* and *P. tropicalis*. Morphological studies of *capsici/tropicalis* groups showed the presence of mixed characters deviant from the type description. Preliminary studies based on SSCP analysis also indicated the existence of inter-species hybrids among *Phytophthora* isolates of black pepper.

Host plant resistance

Identification of R genes in Piper colubrinum

Around 1289 candidate R gene homologues were mined from *P. colubrinum* transcriptome

by reverse alignment using amino acid sequences of 42 known R genes. The sequences were functionally annotated and clustered to 91 clusters by h-cd-hit on CD-HIT suite using multiple CD-HIT runs.

Differential expression analysis of Resistance Gene Analogs

To examine the expression variability of *P. nigrum* Resistance Gene Analogs (PnRGAs), the moderately resistant (IISR Shakthi), root resistant (04-P24-1) and susceptible (Subhakara) genotypes were challenge inoculated with *P. capsici* (05-06). Total RNA was extracted from the above genotypes at 0.5, 1, 2, 4, 8, 16, 24, 48 and 72 h post inoculation (hpi) and just before inoculation (0 hpi) and basal level expressions of NBS-LRR PnRGAs were observed. PnRGA13 exhibited no significant change in expression levels. The relative transcript level of PnRGA1, PnRGA8, PnRGA11 and PnRGA24 was higher in IISR Shakthi compared to uninoculated control. The expression of PnRGA2, PnRGA3, PnRGA7, PnRGA8 and PnRGA24 was higher in O4-P24-1. The expression of the entire representative PnRGAs except PnRGA8 was higher in IISR Shakthi compared to Subhakara.

The expression pattern variability of NBS LRR *P. colubrinum* RGAs (PcRGAs) in *P. colubrinum* was analyzed by relative quantification of mRNA transcript in comparison with uninoculated control.Expression of five representative PcRGAs was analyzed in *P. colubrinum* after challenging with *Phytophthora* (Fig. 5).

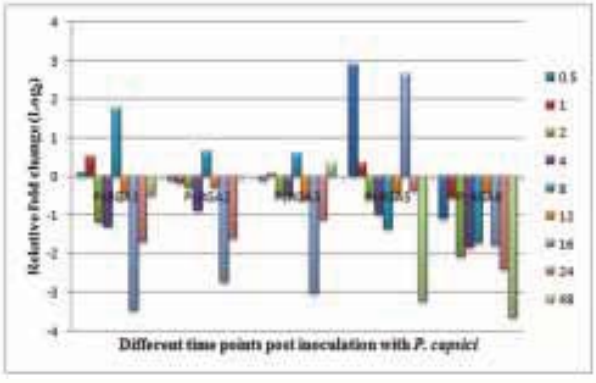


Fig. 5. Relative transcript level of *P. colubrinum* RGAs, PcRGA1, PcRGA2, PcRGA3, PcRGA5 and PcRGA8 in response to *P. capsici in P. colubrinum*

In challenge inoculated *P. colubrinum* leaves, there was a marginally high expression of PcRGA1 (at 0.5 and 1 hpi), PcRGA2 (at 8 hpi), PcRGA3 (at 1, 8 and 48 hpi) compared to uninoculated control. In the case of PcRGA1, maximum fold change recorded was at 8 hpi (3.36) and after 8 hpi expression of PcRGA1 was downregulated.

The expression of NBS LRR *Piper nigrum* RGAs in *P. colubrinum* and *vice versa* was analyzed by relative quantification of mRNA transcripts with mock inoculated control. When expression of 11 PnRGAs was functionally evaluated in *P. colubrinum*, relatively more significant expression of PnRGA1, PnRGA3, PnRGA5, PnRGA7, PnRGA9, PnRGA11 and PnRGA24 was observed in *P. colubrinum* compared to *P. nigrum* (Fig. 6).

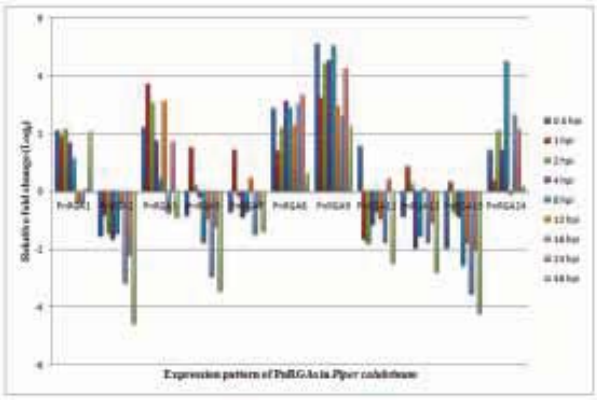


Fig. 6. Relative transcript level of eleven representative PnRGAs in *P. colubrinum* at different time points post inoculation with *P. capsici*

Expression analysis of defense-related proteins in Piper colubrinum

Real time PCR analysis was done for defense-related genes in *P. colubrinum* challenge inoculated with *P. capsici*. Expression of peroxidase (450 folds) and PAL (18 folds) was significantly greater at 24 hpi (Fig. 7). The genes like catechol oxidase (350 folds), cinnamoyl coA reductase (70 folds) and polyphenol oxidase (220 folds) were found to

be expressed maximum at 16 hpi. Lipoxygenase (5.4 folds), chalcone isomerase (2.5 folds), EDS1 (1.85 folds) showed increased expression at early stages of inoculation *i.e.* at 4 hpi. Chitinase II and senescence associated protein genes were downregulated compared to uninoculated control.

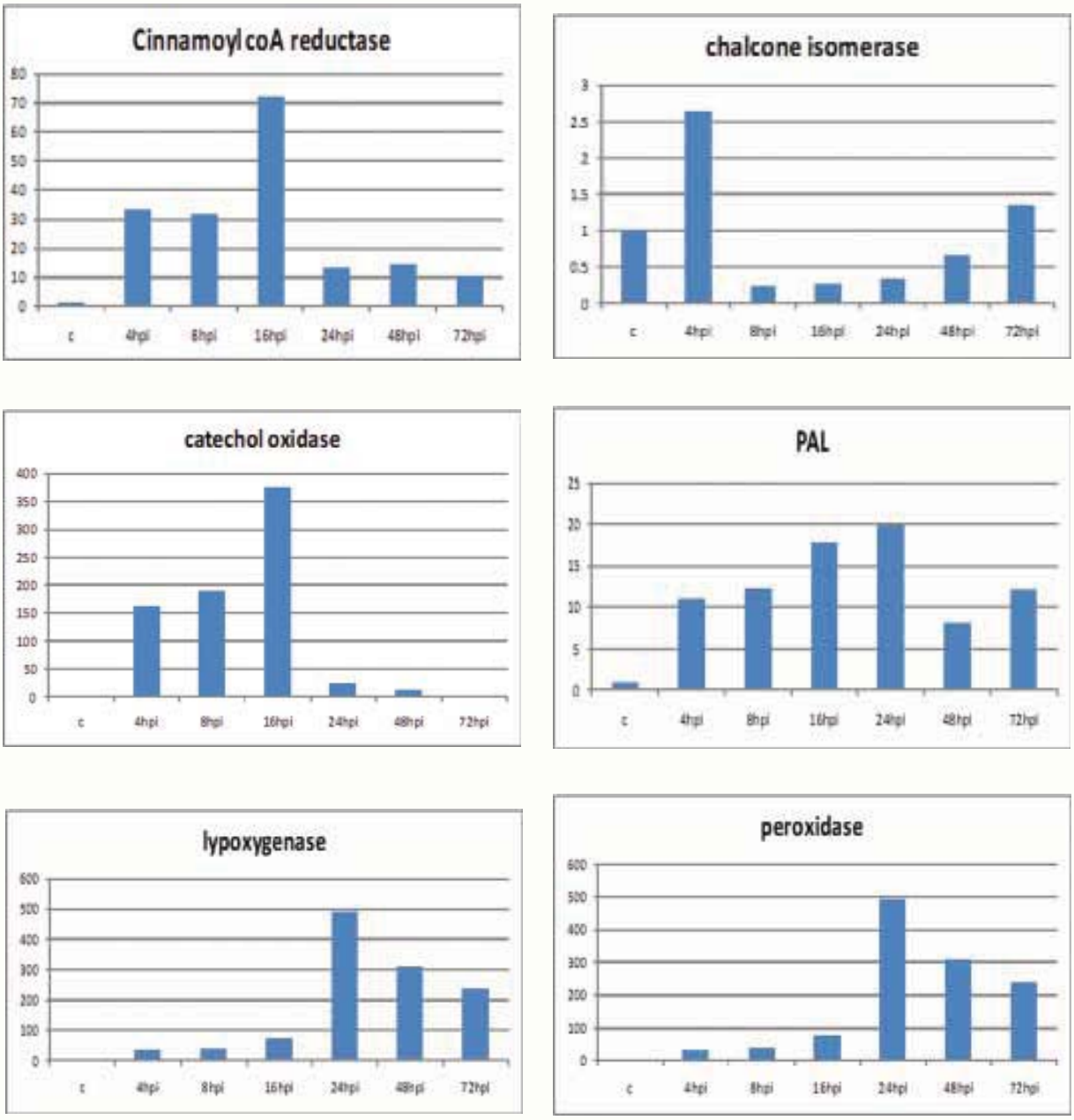


Fig. 7. Relative expression of genes, (a) cinnamoyl CoA reductase, (b) chalcone isomerase, (c) catechol oxidase, (d) PAL, (e) lipoxygenase and (f) peroxidase in black pepper inoculated with *P. capsici*.

Molecular characterization of mapping populations for Phytophthora resistance

Fifty seven genotypes of black pepper along with *Phytophthora* resistant *P. colubrinum*, tolerant lines *viz*, IISR Shakthi, IISR Thevam and P24-04 and susceptible lines - Sreekara and Subhakara were screened for *Phytophthora* resistance using 25 ISSR markers and 15 SSR markers. The dendrogram divided the population into three major clusters. The first cluster was formed by *P. colubrinum* which stood distinct with 32% similarity with rest of the black pepper clusters. The other two major

clusters which comprised of black pepper genotypes shared 80% similarity. The *Phytophthora* tolerant genotypes found a place in the second cluster (Fig. 8).

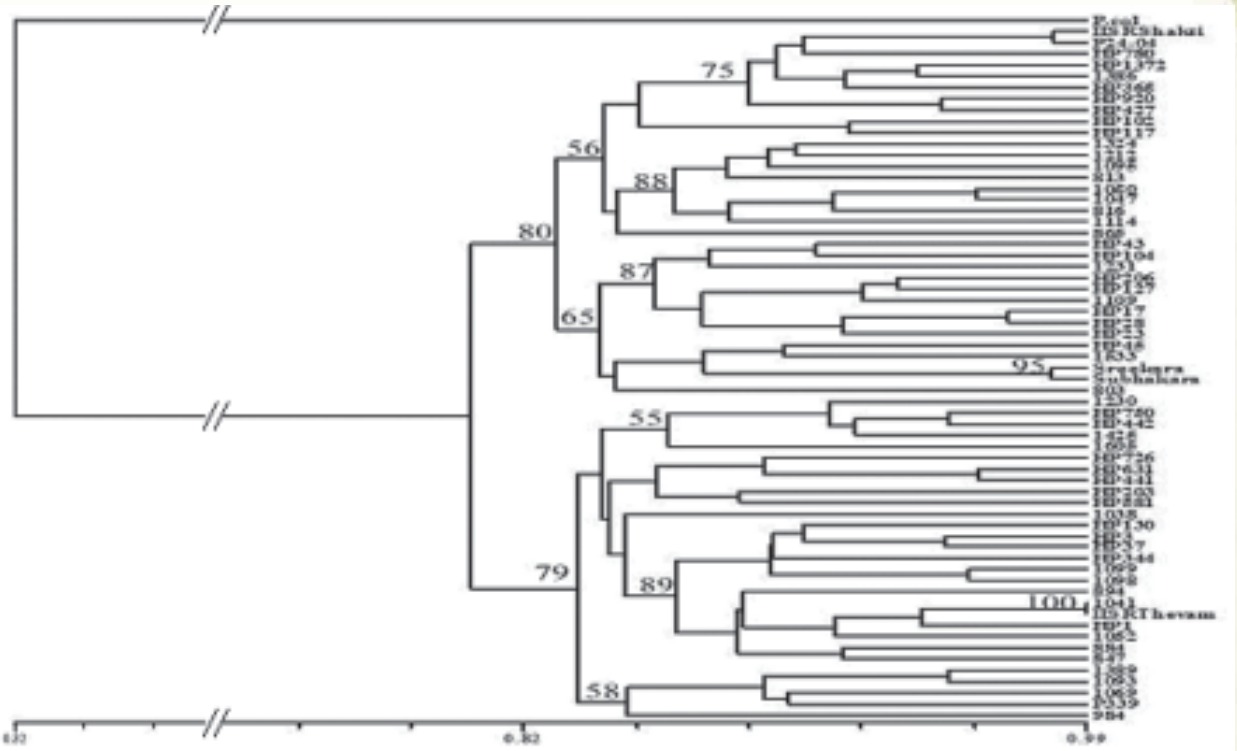


Fig. 8. UPGMA dendrogram depicting diversity and inter-relationships among diverse population of black pepper

Proteomics of defense mechanism in black pepper

Label free proteomics strategy was applied to bring out the protein expression abundance and post translational modifications (PTMs) on tolerant (IISR Shakthi) and susceptible (Subhakara) genotypes. The leaf proteins were extracted from plants inoculated with *P. capsici* at 12 and 24 hpi along with control leaf. LTQ-Orbitrap Discoverer platform was used to fingerprint the quantitative expression of proteins. The peptide peak data obtained was then annotated and relative expression of peptides was analyzed using Hi-3 (Average normalized abundance). In total, 299 proteins were analyzed out of which 84 proteins were found to have above 4 fold to 973 fold increase in expression and 38 of them were found to be upregulated at 24 hpi. In tolerant genotype the pathogen was suppressed by pattern triggered immunity (PTI) which was triggered by receptor like kinases RLKs, RPP13 (R gene). Salycylic acid (SA) mediated SAR was identified during pathogen infection. PR protein (with antifungal activity) production was found to be more in tolerant black pepper.

Management

Effect of secondary metabolites of endophytic fungi on P. capsici

The secondary metabolites extracted from nine different endophytic fungi were tested *in vitro* against *P. capsici.* The maximum mycelial inhibition of 68% was recorded by the isolates BPEF 11 (*Diaporthe* sp.), BPEF83 (*Phomopsis* sp.), BPEF41 (*Annulohypoxylon niten*), BPEF25 and BPEF38 (*Daldinia eschscholtzii*) and the rest of the four isolates showed more than 55% inhibition. The metabolites also inhibited production of *Phytophthora* sporangia on incubating at 25^{O}C for 48 hours under light. When ethyl acetate extracts of fungal metabolites dissolved in dimethylsulfoxide were tested using *Phytophthora* inoculated cut shoots of black pepper, metabolites of seven out of nine isolates (BPEF11, BPEF25, BPEF41,

BPEF72, BPEF73, BPEF81, and BPEF83) showed 90% lesion inhibition.

Evaluation of actinomycetes consortia

Combined application of IISR Act 2 (*Ketosatospora setae*) + IISR Act 5 (*Streptomyces* sp.) and IISR Act 2 + IISR Act 9 (*Streptomyces tauricus*) was found effective in reducing the soil nematode population to an extent of 58-75%.

Field evaluation of strobilurin fungicides

A field trial was conducted at Pulpally and Ambalavayal (Wayanad, Kerala) for evaluating the two strobilurin fungicides - Ergon 44.3% (w/w) [Kresoxim methyl 500 g/L SC] and RIL-070/FI(72WP) which were proved effective under greenhouse conditions. Initial results revealed, there was a reduction of 43.7% in disease incidence when compared to control in case of Ergon while only 6.0% reduction was observed in case of RIL.

Anthracnose disease

Diversity

Nine symptomatological variants (SV 1 to SV 9) were characterized based on the symptoms developed on black pepper leaves, spikes, berries and runner shoots (Table 2 and Fig. 9). Among the symptomatological variants, SV 1,

Table 2. Characterization of symptomatological variants *Colletotrichum gloeosporioides* in black pepper

Variant	Symptomatology
SV 1	Prominent brown to black lesions formed on the leaves with concentric rings. Generally the lesions are surrounded by yellow halo. The symptom is manifested both on younger as well as older leaves.
SV 2	The symptoms initiated as blackish spots which turned brownish grey (central portion) and surrounded by black margin. In later stages, the spots coalesced to give blighted appearance. The spots are usually developed on margins of the leaves, especially on the older leaves.
SV 3	Discrete blackish sunken spots developed on upper surface of the leaves. The spots do not coalesce. Symptoms are normally seen on the younger leaves which later turn brittle in the later stage.
SV 4	Angular blackish lesions on the younger leaves with characteristic shot-hole appearance. The leaves become malformed in the advanced stages.
SV 5	The symptoms are characterized by marginal necrosis. Initially, chlorosis started from the tip of leaves and the affected tissues turned necrotic. Later, the lesion progresses upwards giving a dieback appearance.
SV 6	Sunken dark brown to black spots with characteristic shot-hole at the centre. The spots are surrounded by a prominent yellow halo.
SV 7	Infection on spikes resulted inspike shedding, whereas, infection onimmature berries lead to formation ofbrownish splits.
SV 8	Symptoms are seen on runners with characteristic small, regular, sunken brown to black coloured spots.
SV 9	Discrete spots especially formed on older leaves. The spots are characterized by dull brown margin with grey center. Occasionally minute pin-head sized protrusions are formed in the central area.

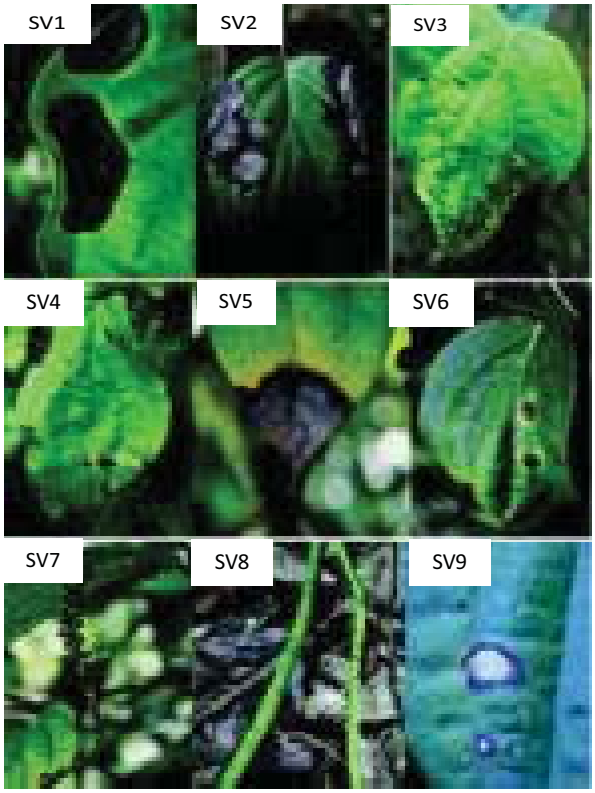


Fig. 9. Symptomatological variants of *Colletotrichum gloeosporioides* in black pepper

SV 2 and SV 3 were observed under nursery conditions of which, SV 3 was found to be the most prominent. SV 5, an uncharacteristic symptom of black pepper anthracnose, was noticed during summer months, especially on the vines under stress conditions.

Management

Evaluation of new fungicide molecules against anthracnose

Among the seven fungicide molecules tested against *C. gloeosporioides*, fenamidone + mancozeb (0.3, 0.2, 0.1, 0.05, and 0.025 %) and carbendazim + mancozeb (0.15, 0.1, 0.05, 0.025 and 0.0125 %) at recommended dose, three lower and one higher concentrations were found to completely inhibit growth of the pathogen under *in vitro* conditions (Table 3).

Table 3. *In vitro* evaluation of fungicides against *C. gloeosporioides* infecting black pepper

Fungicides (F)	Inhibition at different concentrations (%)				
	C1	C2	C3	C4	C5
Fenamidone + mancozeb	100	100	100	100	100
Carbendazim + mancozeb	100	100	100	100	100
Isoprothiolane	84.33	85.53	80.72	81.52	62.64
Carbendazim	100	100	84	84	82
Hexaconazole + zineb	100	100	96.78	91.96	83.93
Tebuconazole	89.95	88.75	87.54	86.74	86.34
Kresoxim-methyl	68.27	36.47	55.41	53.01	50.59
CD (0.01)	F = 1.42 ; C = 1.2 and F x C = 1.2				
CV (%)	1.66				

Fenamidone + mancozeb (C1-0.3, C2-0.2, C3-0.1, C4-0.05, C5-0.025)

Carbendazim + mancozeb, isoprothiolane and carbendazim (C1-0.15, C2-0.1, C3-0.05, C4-0.025, C5-0.0125)

Hexaconazole + zineb (C1-0.45, C2-0.3, C3-0.15, C4-0.075, C5-0.038)

Tebuconazole and kresoxim-methyl (C1-0.075, C2-0.05, C3-0.025, C4-0.0125, C5-0.006)

C2 = recommended dose for all fungicides

NUTMEG

Genetic resources

Farmer participatory surveys were conducted in Trichur, Idukki and Kottayam districts and 18 new germplasm accessions of nutmeg were collected during the year. Unique collections include high yielding types, bold nut type, thick and entire mace types, monoecious types, erect growing types and trees bearing fruits in clusters (Fig. 21).

Fig. 21. (a) Erect canopy nutmeg, (b) bold nut with yellow mace, (c) whole mace with beak

Evaluation of elite lines having low myristicin, elemicin and safrole and high sabinene in nutmeg

Grafts of four short listed elite lines A4-22 (IC-537048); A9-69 (IC- 537218); A9-71 (IC 537220); A9-95 (IC-537244); A9-102 (IC-537251) having low myristicin and high sabinene in nutmeg and mace oils were planted in Chelavoor campus for evaluation. The plants have established well (90%) with flowering and fruit set observed in few plants.

Pruning studies in nutmeg

The pruned nutmeg trees were evaluated for yield parameters. The treatment T3, where the side branches were pruned at 2m width produced significantly high nut dry weight (1.25 kg) and mace (264.64 g) per tree.

Studies on sex expression in nutmeg

Nutmeg is evolving towards monoecy as a means of reproductive assurance. Three types of flowers viz., male (75%), female (19%) and hermaphrodite (6%) are noticed in the monoecious trees studied (Fig 22). Hermaphrodite flowers are reported for the first time in India. All the three types of flowers are borne on the leaf axil as both in cymes and solitary in the same tree. Flower colours of all the three types are light creamy yellow, with thick gamosepalous perianth which bursts as dimerous, trimerous, tetramerous and pentamerous lobes during anthesis. The androecium of staminate flowers have adnate 8 -11 anthers while the gynoecium consists of single ovary with bifid stigma in the pistillate flowers. In case of hermaphrodite flowers, intra flower variability is evident. The androecium of hermaphrodite flowers ranges from 1-5 anthers with either fused filament or free filament or both; some anthers are fused with the gynoecium. Staminodes are also observed besides remnants of the stamen in the developed fruits of hermaphrodite flowers.

The pollen load and pollen viability of the hermaphrodite flowers are found less as compared to the staminate flowers and percentage of pollen viability is 90.77% and 79.74% in male and hermaphrodite flower respectively. Intra flower variability is also observed for pollen load in hermaphrodite flowers. In the population studied, the occurrence of hermaphrodite flower in monoecious tree ranged from 0 - 10 %. Studies on seasonal influence of floral pattern in nutmeg indicated that female

flower production was more in the month of May and June whereas bisexual flower production was more in the month of July and December.

Pistillate Hermaphrodite Staminate

Fig. 22. Different types of flowers in nutmeg

Adulteration detection using DNA bar coding

Four DNA barcoding loci viz., *rbcL, matK, psbA-trnH* and *ITS* were compared to analyse *M. malabarica* adulteration in traded *M. fragrans* mace samples. Amplification and sequencing success, high interspecific than intra specific variation as well as high degree of polymorphism estabilished the potential of *psbA-trnH* as the best barcode over other loci in authentication of *M. fragrans* mace (Fig. 23). Sixty polymorphic sites and the nine indel regions in *psbA-trnH* locus specific to *M. malabarica* were found in three out of the five market samples studied thereby confirming the adulteration of traded *M. fragrans* mace with *M. malabarica.*

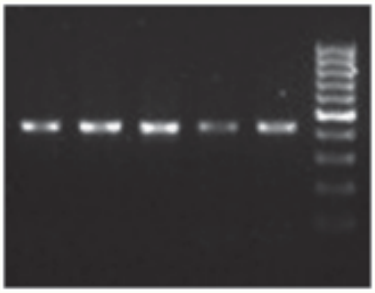


Fig. 23. Amplification of *psbA-trnH* locus in market samples. Lane 1 – market sample 1, lane 2- market sample 2, lane 3- market sample 3, lane 4- market sample 4, lane 5 – market sample 5, lane 6- 100 bp ladder.

Antioxidant activity of *Myristica* species

Petroleum ether and methanol extracts from leaves of *Myristica* species *viz., M. fragrans, M. prainii, M. malabarica* and *M. andamanica,* were tested for antioxidant potential by DPPH free radical scavenging activity, phosphomolybdate assay and Ferric reducing power (FRP) method. Methanol extract of all the species exhibited higher activity compared to the corresponding petroleum ether extracts indicating polar nature of antioxidants. Among the methanol extracts, that of *M. malabarica* showed maximum activity followed by that of *M. fragrans*. Total phenols and flavonoids of the extracts varied between 11-153 mg/g and 82-375 mg/g respectively and showed a positive correlation with antioxidant activity. The phenolic profile of the extracts showed direct relation with the number of phenolic hydroxyl function and antioxidant potential of the extracts.

Characterization of *Phytophthora sp.* infecting nutmeg

Eight *Phytophthora* cultures (13-01 to 13-06, 13-55 and 98-68) were characterized based on morphological, physiological and molecular characters. Majority of the isolates belonged to A1 mating type except 13-06 (A2 mating type). Blast analysis of ITS rDNA sequences, restriction analysis using MSP1 and MLST analysis with mitochondrial and nuclear genes revealed that nutmeg *Phytophthora* isolates were grouped into a separate clade closely related to *P. meadii*. Further through SSCP analysis it was confirmed that, nutmeg isolates were entirely different from *P. meadii* isolates of cardamom and cocoa but closer to coconut *P. meadii*. The per cent identity analysis of nuclear genes revealed that *P. meadii* is the parental species of isolates whereas, analysis of mitochondrial genes showed that most of the isolates have *P. meadii – P. citrophthora* parentage. Based

on the morphological, physiological and molecular characterization, it is hypothesized that the nutmeg isolates could be a hybrid with parentage, *P. citrophthora* x *P. meadii* or *P. capsici* or *P. tropicalis*.

Chemoprofiling of volatiles of clove fruit oil

The study was undertaken to explore the possibility of using essential oil of clove fruits. Fresh and dried clove fruits, upon hydrodistillation yielded 1% and 2% essential oil respectively. Both oils were dominated by eugenol, 2,4,6-trimethoxy acetophenone and t-caryophyllene. The major difference between bud oil and fruit oil was that the fruit oil contained 2,4,6-trimethoxy acetophenone which was not detected in bud oil and eugenyl acetate, which is the second most abundant constituent of bud oil was detected in traces only. The study indicated that 2,4,6-trimethoxy acetophenone can be used as a marker compound to detect adulteration in clove bud oil (clove bud oil adulterated with clove fruit oil).

Developing energy efficient processing technologies for spices

ICAR-IISR has taken the initiative to go green by utilizing renewable solar energy for turmeric curing. A parabolic trough concentrating unit is installed at ICAR-IISR, Experimental Farm at Peruvannamuzhi, Kozhikode for curing of turmeric. The unit has solar thermal collectors with curved parabolic mirrors which concentrates solar radiation on to a central pipe called as the receiver. The receiver is coated with solar selective coating to absorb 90% of the incoming rays and insulated with air jacket to save the collected heat. The collected heat is transferred to the water circulated in the pipe which in turn generates steam. There are 16 nos. of fully enclosed parabolic trough collector modules for concentrating solar energy with an aperture area of 32 m^2 and can generate about 150°C/ 3.5 bar saturated steam in less than half an hour. A micro controller based single axis tracking system with GPS is employed to achieve continuous and automatic tracking. The unit has a cooking vessel of capacity 50 kg turmeric/batch. The initial trial indicated that complete cooking of turmeric could be achieved in 45 min.

Development of a phytochemical database

Spicecom, a database on 665 phyto-chemicals from spices *viz*., ginger, nutmeg, cinnamon and black pepper was developed which enables retrieving data based on botanical name, chemical constituents, biological and pharmacological activity.

QSAR Modeling

QSAR models were generated for predicting antioxidant activity of natural compounds using different methods *viz*., kPLS, PLS and MLR along with different combination of descriptors. Among these kPLS model with semiempirical descriptor showed good correlation with experimental results. Hence it can be used for predicting radical scavenging activity of plant based compounds. Using molecular docking studies, compounds possessing anti-inflammatory, antidiabetic, antidepressant, anti cancer and antifungal activity have been identified.

Antioxidant potential of spice extracts

Black pepper, ginger, cinnamon bark and turmeric were sequentially extracted in soxhlet apparatus using hexane, chloroform and methanol and the antioxidant activity of the extracts was tested by three methods namely, DPPH scavenging activity, phosphomolybdenum assay and ferric reducing power.The results indicated that methanol extract of cinnamon and chloroform extract of turmeric had superior antioxidant potential. It was also observed that total phenols in the extracts had a positive correlation with antioxidant potential. Further different combinations of

cinnamon and turmeric, in different ratios namely, 1:1, 1:2 and 2:1 were prepared and antioxidant potential of combined extracts was tested. Methanol extract of cinnamon:turmeric (2:1) was superior, which will be further studied for its hypoglyceaemic and anti-inflammatory potential. Table 12 illustrate antioxidant

Table 12. Antioxidant potential and total phenolic content of spices

Spice	Extract	Antioxidant potential			Total phenols
		DPPH scavenging activity (IC_{50} value-µg/ml of extract	PM assay MAAE/g of extract	FRP MAAE/g of extract	Mg GAE/g of extract
Black pepper	Hexane	1507.3	0.274	0.283	16.027
	Chloroform	195.7	0.898	0.726	25.970
	Methanol	60.8	0.931	0.737	38.241
Cinnamon	Hexane	689.2	0.857	0.271	33.333
	Chloroform	166.3	1.312	0.372	35.000[e]
	Methanol	11.5	2.341	1.564	244.667
Ginger	Hexane	36.2	0.821	0.343	103.667
	Chloroform	31.3	1.250	0.450	125.000
	Methanol	136.0	0.430	0.200	72.660
Turmeric	Hexane	35.7	1.283	0.378	120.000
	Chloroform	18.2	2.993	1.471	158.667
	Methanol	325.3	0.954	0.406	47.000

Table 13. Antioxidant potential of extracts of spice mixtures

Cinnamon: Turmeric	Solvent	DPPH free radical scavenging activity (IC_{50} µg/ml of extract)	FRAP (MAAE/gram of extract)
1:1	Hexane	600.0	0.918
	Chloroform	26.6	0.594
	Methanol	45.9	0.586
1:2	Hexane	27.3	0.981
	Chloroform	33.8	1.290
	Methanol	25.1	0.818
2:1	Hexane	44.5	0.791
	Chloroform	37.2	1.000
	Methanol	7.2	1.848

potential and total phenolics of spices and Table 13 illustrate antioxidant potential of extracts of spice mixtures.

Delineation of micronutrient deficient areas under spice crops

In order to identify specific micronutrient problems of a particular spice crop/region, district wise crop data (from secondary sources) from each state was generated and compiled for preparation of spice crop boundary maps. The crop boundary maps were then superimposed over the already available micronutrient status maps to generate crop specific micronutrient status maps (Fig. 24).

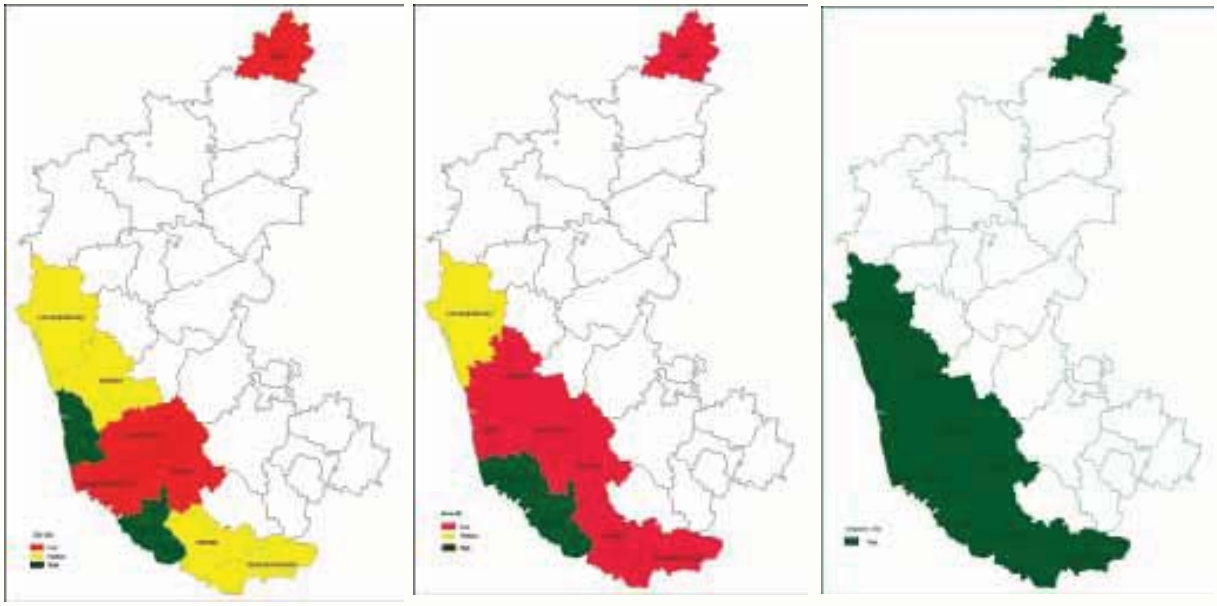


Fig. 24. Status of available Zn (a), B (b) and Mn (c) in ginger growing districts of Karnataka

Isolation and characterization of Zn solubilising bacteria

Several bacterial and fungal strains were isolated from soils collected from virgin forests and cultivated sites under major spice crops. These strains were then characterized for their morphological and biochemical traits and among these nine bacterial and three fungal isolates were shortlisted for further studies on Zn solubilisation. Among these, isolate ZSB1 showed maximum solubilisation efficiency (Fig. 25).

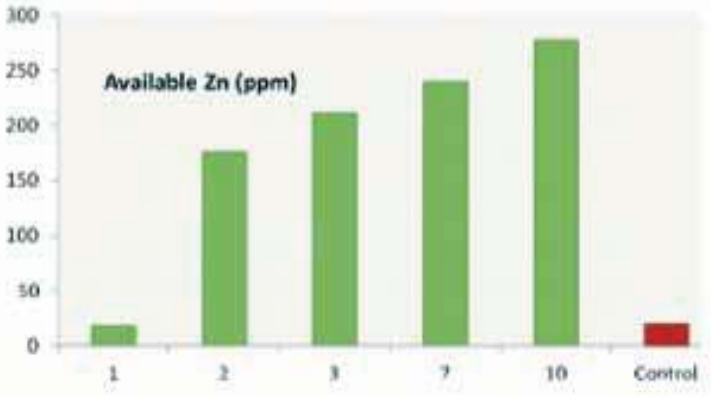


Fig. 25. Zn solubilisation by ZSB1 at different days after inoculation

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 26 locations in Idukki, Wayanad and Kozhikode districts of Kerala. Six entomopathogens and a mermithid nematode were documented from different spice crop pests (*Sinoxylon* spp., *Aspidiotus destructor*, *Aphis craccivora*, *C. punctiferalis* and *Udaspes folus*). The fungus infecting *S. anale* has been identified as *Beauveria bassiana* (IISR-EPF-04) (Fig. 26). The entomopthoralean fungus recorded from *A. craccivora* has been tentatively identified as *Neozygites* sp. (IISR-EPF-12) and that of *A. destructor* identified as *Lecanicillium* sp. (IISR-EPF-13). An NPV (IISR-NPV-03) infecting *Pericallia ricini*, a pest of cardamom was isolated. Further characterization of the NPV based on morphological and molecular characters is in progress. A larval and pupal parasitioid each parasitizing *U. folus* and a mermithid nematode (IISR-MN-03) were recorded during surveys.

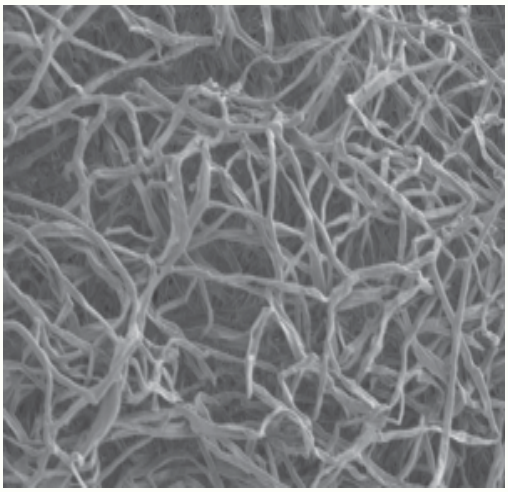


Fig. 26. Ramification of *Beauveria bassiana* mycelia on adult *Sinoxylon anale*

New host of root knot nematode

Root knot nematode associated with Thai green eggplant or yellow-fruit nightshade (*Solanum virginianum*) was collected from cardamom field at IISR Regional Station, Appangala, Kodagu District (Karnataka). *S. virginianum* is a common weed in cardamom plantations (Fig. 27). This nematode was characterized as *M. incognita* using morphology and perineal pattern. This plant appeared to be a new host record of the root-knot nematode, *M. incognita*.

Fig. 27. Root knot nematode infected *Solanum virginianum* root

E TENSION ND IMP CT SSESSMENT

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

The project is implemented under Tribal Sub Plan of XII Plan aiming at livelihood improvement of Tribal communities. The selection of the target areas, collaborating institutions and feasible areas of technology interventions were carried out through collection and analysis of secondary data and participatory need assessment and appraisal methods. The major domains of interventions are demonstration of single sprout transplanting method in ginger and turmeric, establishment of black pepper community nurseries, interventions on irrigation for spices, food crops and vegetables in tribal hamlets, demonstrations of improved varieties of yams and tubers and their popularization as alternative food crops in tribal hamlets, promotion of house hold vegetable farming in hamlets and capacity building programmes on improved cultivation practices of various crops. Programmes are implimented in three north eastern states, Nagaland, Tripura and Assam and tribal hamlets in two districts of Kerala *viz.* Palakkad and Wayanad.

Interventions under North East Hill States programme under XII plan

- Training programme on advances in nursery production and postharvest management in black pepper for the field staff of Amalgamated Plantations Ltd. in collaboration with AICRPS centre, AAU, Kahikuchi – Promotion under Pepper Mithra Programme
- Need assessment workshop at ICAR Research Complex for NEH Region, Regional station, Agartala, Tripura.
- Need Assessment workshop at KVK, South Tripura.
- A naturally ventilated poly house was provided to AICRPS Centre, Nagaland University, Mediziphema for establishing a black pepper and ginger nursery.
- Demonstration of single sprout transplanting method in ginger and turmeric (5 nos) in four KVKs (Dimapur, Whoka, Longleng, Tuensng) and Central Institute of Horticulture, Dimapur.

Interventions under Tribal Sub plan

- Demonstration of improved varieties of turmeric IISR Prathibha (300 kg) in 14 tribal hamlets in Wayanad district, Kerala.
- Demonstration of improved varieties of elephant foot yam – Gajendra (600 kg) and ginger - Varada in 14 tribal hamlets in Wayanad district, Kerala
- Black pepper nursery using serpentine method in naturally ventilated poly house in Attapady Tribal Farming Cooperative Society, Palakkad district, Kerala.
- Demonstration of homestead vegetable gardens in nine tribal hamlets (200 seed packets of released varieties of vegetables by Kerala Agricultural University).
- Training programme on scientific nursery management for the technical staff of Attapady Tribal Farming Cooperative Society, Palakkad district, Kerala.
- Training programe on scientific vegetable cultivation in three tribal hamlets in Wayanad district, Kerala.
- Reclamation of irrigation pond in Kuzhimukku Paniya tribal hamlet, Wayanad district, Kerala.

Fig. 28. Mr. Raman- tribal farmer-Kolipetta, Wyanad with his harvest of IISR Varada ginger

Other transfer of technology progarmmes

Demonstrations

Under Mission for Integrated Development of Horticulture sponsored by the Directorate of Arecanut and Spices Development, eight demonstrations on organic farming, two each in black pepper and turmeric and four in ginger were laid out covering an area of four hectares. Under the project, Area Wide Integrated Pest Management for wilt disease in black pepper sponsored by the Kerala State Planning Board, demonstration plots were established in eight farmers plot at Korangad village in Thamarasserry, Kozhikode district and pre and post monsoon treatments are imposed. Soil samples are collected for biological sample analysis. Diagnostic field visits were organized to 17 plots in Kozhikode district, eight plots each in Wayanad and Idukki districts.

My Village My pride Programme

Under the 'My Village My Pride Programme', 10 wards (villages) in Kattippara Panchayat in Koduvally block of Kozhikode district were selected. The 10 wards cover a total beneficiary family number of about 3000. Five groups of scientists each with five to six members were selected to undertake visits and advisory and other intervention programme. Five diagnostic field visits and farmers meets were organized. A complete bench mark survey for mapping the current agricultural status, socio economic profile and constraints faced in the locality have been undertaken.

Interface

Seven research-extension interface workshops were organized at the ICAR-Indian Institute of Spices Research under the Monthly Technology advisory Services (MTA) programme of Agricultural Technology Management Agency (ATMA), Kozhikode district. Under the Integrated Pepper Research and Development Programme for North Kerala sponsored by the Kerala State Planning Board, three training programmes are organized in which 294 farmers from Kozhikode district, Kerala participated.

Mass contact and social media

ICAR -Indian Institute of spices Research has registered platform in the You tube, the URL being https://www.youtube.com/user/iisrcalicut.As on date there are 44 videos on various aspects of spice cultivation uploaded on this platform. The total viewership of these videos have crossed six lakhs and the viewership for the year under report is 294088. A viedio on BPD unit of the Institute and another one on use of coconut leaf as mulch in ginger have been recently added. During the year, 12 mass contact programmes/exhibitions at national/state/local level were organized.

Economic impact studies

Instability analysis in black pepper

Cuddy-Della Valle instability index (Cuddy and Della Valle, 1978) is used for calculating instability in price parameters. For parameters like area, production, yield, exports etc. where year to year variations are more frequent, the standard deviation of the year on year growth rates was used

as the measure of instability. This will measure instability from an underlying trend for the period studied. In case of area, production and yield instability was higher during the second phase (2002-2013) than the first phase (1991-2001). However, on the export import scenario the instability was less during the later phase than the first phase. The results are furnished in Table 14.

Table 14. Instabilty index in black pepper

Particulars	Period I (1991-01)	Period II (2002-13)	Overall period
Area	0.12	0.15	0.14
Production	0.14	0.20	0.17
Yield	0.06	0.25	0.18
Export quantity	0.42	0.31	0.36
Export value	0.50	0.44	0.46
Export unit value	0.31	0.19	0.25
Import quantity	0.47	0.35	0.41
Import value	0.69	0.29	0.51
Import unit value	0.36	0.28	0.32

Trade competitiveness in black pepper

Revealed Comparative Advantage was used to measure the trend in competitiveness of black pepper exports from India. RCA was worked out for various periods beginning form 1988. There was a study decline in computed RCA during the period for the export of black pepper from India (Table 15).

Table 15. Revealed comparative advantage for black pepper exports from India

Year	RCA	RSCA
1988-90	26.83	0.90
1991-95	18.86	0.89
1996-00	23.41	0.91
2001-05	7.99	0.77
2006-10	7.31	0.74
2011-14	4.61	0.64

Cost of cultivation of turmeric in Karnataka under intensive management

The worked out cost of cultivation through a small sample survey is provided in Table 16. The results of analysis of returns on

Table 16. Cost of cultivation of turmeric in Karnataka

Particulars	Cost (Rs/ha)	Share (%)
Land preparation (one disc ploughing, 1-2 rotavator and bed preparation)	11000	4.2
Cost of planting material	90000	34.4
Fertilizers and manures	35000	13.4
Labour charges		
Planting and basal fertilizer application	20000	
Fertilizer application –top dressing	7000	
Weeding –Three times	22000	
Earthing up	12000	
Harvesting, cleaning and packing	20000	
Total labour charges	81000	30.9
Drip system (life span of 5 years)	15000	5.7
Plant protection Chemicals	10000	3.8
Cost of packing materials	20000	7.6
Total cost of cultivation	262,000	100
Add 10 % management charges	288200	

turmeric cultivation indicated that the CB ratio is 1:2.61, at assumed whole sale price of turmeric at Rs. 25 per kg.

Varietal spread

Fig. 29. Prathibha plot of at Zahirabad.

Prathibha turmeric variety is spinning success across the country. Mr. Ramaprasad Reddy an IT professional turned farmer of

Fig. 30. Mr. K.C. Joseph with his Varada ginger harvest

Zahirabad,Telengana is reaping good success with the variety (Fig. 29).

A small farmer Mr. Mr. K.C. Joseph, from Venappara, Kozhikode obtained 1:40 from IISR ginger variety, Varada in his 0.50 acre plot (Fig 30).

Integrated black pepper research and development in North Kerala districts

Four hundred and thirty 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. Three trainings on soil health management, black pepper production technology and disease management were given to 420 farmers. Twenty four FLDs on improved technologies and 20 participatory nurseries that in four

a

b

Fig 31. (a.) Demonstration on released varieties at farmers plot: Mr. Thomas, Kallanode, Koorachundu; (b.) Training farmers in nusery practices at KVK

panchayats of Kozhikode district during last year were continued. In nurseries 500-980 cuttings were produced and sold by the farmers through participatory mode (Fig 31).

Enhancing the economic viability of coconut based land use systems

Soil (profile) and leaf samples (370 samples each) were collected from experimental and demonstration plots of coconut, pepper (in Naduvannur and Arikulam panchayats of Kozhikode) and nutmeg (at Mookanur panchayat of Ernakulam). Experimental plots of coconut had low OC, P, C, Mg, Cu, Zn and B and high Al content in the soil profile. Similarly black pepper soils showed high P, low K, B and Mo and that of nutmeg soil showed very low K, low Cu, B, Zn and Al and high P. Based on these fertility levels, site specific nutrient doses (fertilizers, dolomite) were applied.

The leaf analysis of coconut index leaves, black pepper and nutmeg showed lower K in coconut and nutmeg leaves. Site specific application of amendments and nutrients helped in increasing the black pepper yield (1.55 dry kg/plot) as compared to the farmers practice (1.01 dry kg/plot) recording an increase of 33-68% at various demonstration plots. Launching and awareness seminar of the project and soil health campaign were conducted at the identified panchayats benefitting 140 farmers.

Area wide integrated pest management for wilt diseases

The AWIPM programme was launched at Muthappanpuzha in Kozhikode District. Five demonstration plots and two nurseries were initiated at Anakkampoil and Muthappanpuzha during the period. IISR released varieties *viz.* Sreekara, Subhakara, Thevam, Malabar Exel, Girimunda, Panchami and Pournami were planted in nine farmers' plots at Thekkumthottam in Thamarasserry Panchayat. Promising biocontrol agents including endophytic bacteria, PGPR and Actinomycetes along with existing biocontrol agents are being demonstrated along with new plantings. Soil samples were analysed and health cards were issued to 71 farmers in Rajakkad (Idukki District), Aadichira (Wayanad District), Muthappanpuzha and Thamaraserry (Kozhikode District). One nursery was established in Omasserry under AWIPM where four released varieties viz. Thevam, Shakti, Girimunda and Malabar excel are being multiplied. More than 3500 rooted cuttings were produced in the nursery in nine months from 100 nucleus plants. Two more nurseries were initiated in Muthappanpuzha and Anakkampoyil where all the seven released varieties are being multiplied. Training programmes were also organized for farmers at Rajakkad (Idukki), Pulpally (Wayanad) and Thamarasserry (Kozhikode).

Empowerment of rural women and youth in Kozhikode district through ornamental fish culture applying biotechnologies

Twenty five beneficiaries have been selected, who are residing within 25 Km radius of KVK. The beneficiaries have been given five day training on various aspects of freshwater ornamental fish culture which includes breeding, culture, diseases and water quality management, marketing of fishes etc. Trainings were conducted on 24.11.15, 4.1.16 and from 9.3.16 to 11.3.16. The beneficiaries were given skill development training on production of various accessories for aquarium, aquarium tank, top and fish feed. An exposure visit for the beneficiaries was organised to spring aqua farm, Adivaram, Kozhikode on 5.1.16. A baseline socio economic survey of the beneficiaries has been carried out. Inputs for starting up the units have been distributed to the beneficiaries. Four units have started marketing fishes produced from their unit. The production is yet to come up in full swing in 13 farms due to unusual water scarcity faced in the area. A fully equipped marketing unit has been

established at KVK to assist farmers in marketing fishes and accessories. Equipments for fish feed production unit such as pulveriser (5 kg capacity), flour kneading machine (10 kg capacity), cooker (60 L capacity) have been procured.

Agriculture technology information centre

The quality and responsiveness of agricultural extension system is a critical component in raising agricultural productivity. The Agricultural Technology Information Centre (ATIC) has been able to sustain the high level of professional expertise in catering to the needs of spice farmers by leveraging the advances in communication technology and through effective coordination with other institutional partners. The wide range of activities undertaken for transfer of technology and dissemination of information include on campus and off campus training programmes, exposure visit to farmer groups, sensitizing personnel from line departments, participation in mass contact programmes, targeted training programmes and input distribution for vulnerable groups etc. The visitor advisory services of the centre were availed by more than six thousand stakeholders. The e-communication channels for client contact and service delivery have made ATIC more accessible to the farmers from all over the country. More than 600 e-mail advisories have been issued during the last year.

Organization of need based training programmes for stakeholders remain one of the most critical intervention in the efforts for technology dissemination. Seventeen training programmes of various duration were organized during 2015-16. These training programmes, including on-campus and off-campus locations, were supported through different schemes/institutions for the benefit of farmers, officials and other stakeholders. Apart from this, three paid training programmes, customized to suit specific client requirement, were also conducted.

Sale of technology inputs

The sales counter at ATIC also caters to the need of the farming community in providing access to good quality inputs for agriculture including planting materials, bio control agents like *Trichoderma,* crop specific micro nutrients etc. Apart from physical inputs, services like soil testing also are popular among the farmers. The total sales revenue generated was Rs. 1228226.00 (Rupees twelve lakhs twenty eight thousand two hundred and twenty six only).

Participation in mass contact programmes

The technological advances in spice cultivation were popularized through participation in several mass contact programmes like farmer fairs and exhibitions during 2015-16. This has helped the institute in strategical deployment and dissemination of the improved technologies across major spice growing regions and non-traditional regions. The exhibition stall of the institute functioned for 71 exhibition days spread over 14 venues (Locations in Kerala, Tamil Nadu and Karnataka) during the year. The exhibitions were chosen to reach out to priority stakeholder groups like marginal farmers, rural youth, women, tribals etc. (Fig. 32 - 35).

Fig. 32. Sri K P Mohanan, Agriculture minister, Government of Kerala visiting exhibition stall during Organic Agriculture Summit at Angamaly, Kerala

Fig. 33. Visitors at ICAR IISR Stall during Krishi Mela at ICAR -CPCRI, Kasargod

Fig. 34. Participants of Training and exposure on improved technologies for spices production sponsored by HOFED, Lucknow, Uttar Pradesh

Fig. 35. Farmers from North East states visiting ICAR IISR

KRISHI VIGYAN KENDRA

Training programmes

During 2015 - 16, KVK has conducted 106 training programmes for practicing farmers, farm women, rural youth and extension functionaries in the disciplines of agronomy, horticulture, animal sciences, home science, fisheries, plant protection, soil science and allied fields. It includes eleven sponsored trainings, five paid trainings, and two vocational On Job trainings. A total of 4005 trainees were benefited out of the programmes.

On Farm Testing

During the period seven OFTs were conducted by KVK. OFT on performance evaluation of IISR micro nutrient mix on yield of black pepper showed average pepper yield of 620 Kg/ha with B:C ratio of 2.48 which is significantly higher than farmers practice followed by recommended cultural practice of pepper. Other on farm trials in progress are.

- Performance evaluation of grafted black pepper (Long term continuing)
- Assessment of organics for whitefly management in solanaceous vegetables and okra
- Fertility management in dairy cattle
- Use of carotenoid rich feed for freshwater ornamental fish culture
- Management of wild boars
- Performance evaluation of brinjal varieties.

Front Line Demonstration

- During the period nine FLDs were organized. The three FLDs on ginger *viz.*, demonstration of pro-tray technique of ginger, demonstration of use of PGPR encapsulated bio-capsules for management of soft rot of ginger and demonstration of IISR Power mix for higher yield and quality in ginger were successfully organized in 30 farmers fields. The other FLDs in progress are
- Culture of freshwater fishes using formulated floating feed.
- Demonstration on utilization of Kasthuri turmeric (*Curcuma aromatica*) for the production of herbal cosmetics.
- Demonstration on integrated management of Tanjore wilt of coconut (Long term continuing).
- Demonstration of column method of propagation of black pepper.
- Demonstration of soil application of banana micro-nutrient mixture viz. AYAR in nendran banana for higher yield.
- Formulation of homemade ration for livestock.

Revolving Fund Programme

The Kendra has a strong revolving fund programme to generate income for productive uses. Along with maintenance demonstration units at KVK, Peruvannamuzhi, the Kendra also produced quality seeds and planting materials of spices and vegetable seedlings, layer chicks, goats, biocontrol agents, micronutrient mixtures, vermicompost, mushroom spawn and ornamental fishes and made available to public at affordable rates. By these activities an amount of Rs. 42.37 Lakhs has been realized through sale of planting materials, chicks, bioproducts, training fees and the activities of animal health centre.

Goatery and hatchery unit

A goat rearing unit comprising of 26 goats, including a broiler goat unit with four animals, is functioning at KVK (Fig. 36). Farmers were provided with training, insemination services and veterinary help. A hatchery unit with capacity to hatch 15000 chicks per batch is also functioning at KVK. Layer chicks (Aseel cross, Kaveri, Kalinga Brown) of different maturity (1-45 days) were supplied to the farmers from this unit.

Fig. 36. A view of the ICAR-KVK goatery unit

Special programmes

Seminar on Attracting and Retaining Youth in Agriculture (ARYA - 2015)

An awareness seminar on ARYA (Attracting and Retaining Youth in Agriculture) was organized on 16th September 2015 at ICAR-Krishi Vigyan Kendra, Peruvannamuzhi (Fig. 37) as a part of Swasraya Bharat 2015 of Swadeshi Science Movement, Kerala intended to attract and retain youth in agriculture, in spite of various challenges due to socio-economic factors, including profitability in agricultural pursuits. A total of 150 participants including students from 14 schools, teachers and young agri-entrepreneurs attended the programme.

Fig. 37. Inaugural function of ARYA 2015

Workshop on Soil health management

As part of World Soil Day celebrations, a workshop-cum-training on 'Soil Health Management' was organized at ICAR-KVK, Kozhikode (Fig. 38). Detailed classes on importance of soil fertility, its management and nutrient deficiency reclamation methods, Soil-Plant-Animal Relationship and the importance of soil testing and procedure of soil sample collection for soil nutrient analysis were conducted. A student-farmers interaction was also held during the programme and 125 Soil Health Cards were distributed to farmers.

Fig. 38. World soil day –Soil health card distribution

Pre *rabi* awareness seminar on paddy cultivation

To promote paddy cultivation in Kerala, a pre-rabi district level awareness seminar on 'problems and prospects of paddy cultivation' was conducted under the sponsorship of Agricultural Technology Application Research Institute, Bengaluru. The interactive seminar included lectures on rice agronomic practices, pest and disease management, nutrient management, medicinal and scented rice varieties and mechanization in paddy. A farmer- scientist

interactive session was also conducted during the seminar to clarify the problems faced by farmers in paddy cultivation (Fig. 39).

Fig. 39. Inauguration of the pre rabi awareness campaign

Residential training on planting material production/Spices Production training

Ten days residential training was organized to women members of Harithasree group of Baluserry block. They were trained on nursery establishment, seedling production, propagation methods, pest and disease management of spices, vegetables, plantation crops and ornamentals production with hands-on practical classes. They were also exposed to government nurseries at State Agriculture farm, Koothali, Agriculture Research Station, Anakayam and private nurseries. Apart from this, two MIDH sponsored trainings on spices production was also organized at KVK. About 200 farmers participated in these trainings (Fig. 40).

Fig. 40. Participants of MIDH training

Technology week

Technology week "Paddavum Padavum" was organized at KVK Peruvannamuzhi in collaboration with Agriculture Technology Management Agency (ATMA), Kozhikode from 29 February to 2 March 2016 (Fig. 41). The programmes covered seminars on various aspects of agriculture and allied sectors such as organic farming, spice production technology, dairy management, ornamental fish culture fruits and vegetable processing. On 1st March 2016 a seminar on "Scientific production and processing of spices" under the sponsorship of Mission on Integrated Development of Horticulture (MIDH) was held with the focus varieties, production technology, pest and disease management and post-harvest technology of black pepper, turmeric and ginger. A farmer scientist interface was also organised. The main attraction of the technology week was an exhibition set up at KVK premises showcasing the recent innovative technologies in agriculture and allied fields.

Fig. 41. Inaugural function of Technology week, 'Patavum Padavum'

Integrated Farming system day

A model Integrated Farming System (IFS) functioning at KVK, Peruvannamuzhi, comprising of upland rice (Vaisakh); tubers like cassava (Sree Padmanabha), elephant foot yam, colocasia, dioscorea; fruit crops like banana, citrus; spices black pepper,

ginger and turmeric; vegetables such as cucurbits, amaranthus, curry leaf, cowpea, brinjal, lady's finger, ivy gourd alongwith milch animals and fishes has sparked interest among farmers, youth and women. The Integrated Farming System day was observed on 29th September, 2015 at KVK and many farmers attended the programe. Stem cuttings of the cassava variety Sree Padmanabha were distributed to farmers on the occasion.

Fig. 42. Integrated farming system day function at ICAR-KVK

Diary unit at Chelavoor campus

As a part of network project on organic farming lead by Indian Institute of Farming System Research (IIFSR), Modipuram a farming system unit with spices (turmeric), milch animals, fodder crops (hybrid Napier grass, CO-3, CO-4, Congo signal grasses and DHN-6) as well as vegetables was started at Chelavoor Campus. The diary unit established with the technical collaboration of ICAR-KVK, Peruvannamuzhi, comprises of two Jersy cross bred cows and a desi breed (Kasaragod dwarf) (Fig. 43).

Fig. 43. Kasaragod dwarf cow and calf in the diary unit

Success stories/rewards

Mr. Mathew Sebastian, the farmer partner of ICAR-IISR in evolving the nutmeg variety 'Keralasree' bagged the IARI Innovative Farmer Award 2015. He received the award from Sri. Radha Mohan Singh, Union Minister of Agriculture and Farmer's Welfare in the Krishi Unnati Mela held at IARI, New Delhi during March 2016 (Fig. 44). Mr. Mathew Sebastian was nominated by ICAR-KVK, Peruvannamuzhi.

Fig. 44. Mr. Mathew Sebastian receiving the Award from the Union Minister of Agriculture and Farmer's Welfare, Shri. Radha Mohan Singh

The success story of the ginger woman, Mrs. Omana Devasia of Chempanoda, Kozhikode promoted by the KVK is featured in the Home page of ICAR (Fig. 45).

Fig. 45. Screen shot of ICAR home page featuring KVK success story

ALL INDIA COORDINATED RESEARCH PROJECT ON SPICES (AICRPS)

Genetic resources

A unique black pepper accession having extra bold berries and another with oval shaped berries resembling Karivilanchi were collected from Lower Palani hills of Tamil Nadu. Fifteen accessions of large cardamom were collected from East and West districts of Sikkim and Siang districts of Arunachal Pradesh. Among the clove accessions at Pechiparai, SA-3 recorded the highest dry yield of 5.50 kg/tree compared to local check, 3.00 kg/tree. Among the nutmeg accessions, MF- 4 recorded maximum number of fruits (1150 fruits / tree), single fruit weight (108.0 g) and mace yield (440.50 g/ tree). In cinnamon, CV-5 recorded maximum plant height (6.69 m), stem girth (29.10 cm), leaf yield (8.90 kg/ plant) and dry bark yield (625.00 g/plant) compared to local check. Among 173 ginger germplasm accessions evaluated at Pottangi, Zo-9-1 recorded maximum yield (18.8 kg/3 m^2) followed by Phiringia (16.57 kg/3 m^2) and Tura local (11.0 kg/3 m^2).

Among 55 ginger genotypes were analyzed for quality at Solan, the essential oil content varied from 0.72 (%) (Varada) to 1.67 (%) (SG-857). The high yielding genotype, SG-26-04 (Giriganga) was found superior for dry matter, essential oil, oleoresin and crude fibre contents. Among 40 turmeric genotypes analyzed, dry recovery (%) and curcumin (%) ranged between 15.52% (Zeera) to 24.76% (BDJR-1144) and 1.53% (ST-315) to 6.30% (PCT-14), respectively.

Crop improvement

Five high yielding varieties of spices were recommended for release in XXVI AICRP on Spices workshop held at ICAR-IISR, Kozhikode, Kerala. One coriander variety-LCC 219 (Susthira) from Horticultural Research Station (Dr. YSRHU), Guntur with high yield, suitable to rainfed and irrigated conditions with high essential oil content was recommended for release in Andhra Pradesh, Telangana and Tamil Nadu. Two fennel varieties Ajmer Fennel-2 (AF-2) developed by ICAR-NRCSS, Ajmer with high essential oil content and moderate resistance to *Ramularia* blight was recommended for release at national level and RF-157 developed by Sri Karan Narendra Agricultural University, Jobner, Rajasthan with high yield potential and better seed quality was recommended for release in Rajasthan, Gujarat and Haryana. Two fenugreek varieties, RMt-354 with high yield potential and moderate resistance to powdery mildew and downy mildew and Narendra Methi 2 (NDM 69) developed by Sri Karan Narendra Agriculture University, Jobner, Rajasthan and Narendra Dev University of Agriculture and Technology, Kumarganj respectively were also recommended for release in the workshop.

During the year 2015, black pepper genotypes PRS 64, PRS 154 and PRS 137 were the top yielders at Panniyur. The PRS 64 ranked first with 4.29 kg green berry yield and 1480 spikes/vine. Among the hybrids, PRS 160 and PRS 161 were found to be promising with mean green berry yield of 4.35 kg/vine and 3.99 kg/vine respectively. In CVT for turmeric at Pottangi, NDH-98 (24.2 t/ha) recorded maximum yield with yield advantages of 56.5 % than the national check variety Prathibha (15.5 t/ha). In Pasighat also, NDH-98 recorded maximum yield (22.64 t/ ha). In CVT for ginger SE-8640 (8.5 t/ ha) found to be superior with a yield advantages of 20.2 % compared to national check, Varada (7.1 t/ha).

Crop production

In an experiment at Pampadumpara, application of dolomite @ 2 kg/plant was found to be the best treatment with highest wet (2667.427 g/plant) and dry capsule (941

g/plant) yield in cardamom. In Pundibari, soil application of boron (as borax) @ 25 kg/ha recorded maximum yield (11.13 kg/3m^2 and 22.45 t/ha, which was also statistically on par with foliar spray of boron (as borax) @ 0.5% after 60 and 90 days of planting (10.59 kg/3m^2 and 21.36 t/ha). Higher yield of turmeric was recorded in the treatment of soil application of iron (as Fe_2SO_4) @ 25 kg ha^{-1} (9.87 kg/3m^2 and 19.90 t/ha).

Crop protection

In a trial for biological control of slow decline in black pepper at Panniyur, intensity of disease was minimum (7.5%) in the treatment *Trichoderma viride* + Neem cake @ 2 kg/vine. Similar result was recorded in case of *Pochonia chlamydosporia* multiplied in partially decomposed farm yard manure and applied @ 2 kg/vine and drenched with *P. fluorescens* @ 2%. In a trial for management of bacterial wilt in ginger at Pottangi, least disease incidence (8.6%) and high fresh rhizome yield (17.4t/ha) was recorded in rhizome treatment, mancozeb @ 3g/l + carbendazim@ 1g/l + streptocycline @ 1g/l and foliar spray at 45DAS and 90DAS.

Forty entries of coriander from Hisar, Kumarganj, Guntur and Dholi were screened against powdery mildew disease under natural condition at Jagudan, minimum disease intensity was noticed in DH-261 (13.3%), while the maximum disease intensity was recorded in DH-278 (34.8%). Also, 18 entries of cumin were screened against blight and powdery mildew diseases. Minimum blight disease was noticed in GC-3 (5.7 %) followed by GC-4 (10.1 %), while the maximum disease intensity was recorded in CUM-30 (59.9 %). In case of powdery mildew, minimum disease intensity was noticed in JC-2010-1 (3.5 %) and the maximum disease intensity was recorded in CUM-26 (10.2 %). Among 10 entries of fenugreek screened against powdery mildew, minimum incidence was noticed in JFg -80 (5.0 %), whereas the maximum was recorded in GM-2 (16.2 %). Seven new generation fungicides were evaluated at Jagudan to manage powdery mildew in coriander. Minimum incidence was observed in hexaconazole 0.1% spraying which was on par with propiconazole 0.1%, wettable sulphur 0.2% and tebuconazole 0.1%.

BIOINFORMATICS

Development and maintenance of databases

Two new databases, SpiceComDB and PiperPepDB, were developed during the period. SpiceCom comprises of plant based compounds and their bioactivity. It allows the user to search using compound name, plant name as well as based on activity. Facility to download compounds individually as well as in batch mode is provided. Literature information will be incorporated. PiperPepDB is a database of experimentally MS/MS generated peptides from black pepper. Another database on plant viruses of India, Plant Virus DB, was launched. It includes information on 139 plant viruses from Indian subcontinent such as their taxonomy, host range, symptoms, transmission, references etc.Provision for comparing and downloading sequences is also built in. Radobase, Phytoweb and Sequence Repository of IISR were updated during the period.

Support to Bioinformatics data analysis

- Comparative genomics, orthology and phyletic patterns of *Phytophthora* species infesting black pepper in India
- Comparative genomics of *Ralstonia* isolates from India
- Molecular characterization of a novel type III polyketide synthase, CLPKS11 showing positive correlation with curcumin content
- SNP marker association analysis for agronomic trait in turmeric by DDRAD sequencing of *C. longa*
- Characterization of *Phytophthora* spp. causing outbreaks of leaf and nut fall of nutmeg in Kerala
- Incompatible interactions of *P. colubrinum* with *P. capsici*: Insights from gene expression studies
- Identification and *in silico* characterization of putative resistance genes in black pepper and related species
- Phylogenetic analysis of nutmeg and cinnamon
- Quality assessment and assembly transcriptomes of *C. amada* and *Z. officinale* inoculated with *R. solanacearum*
- SRA Submission of transcriptomes of *C. amada, C. longa, Z. officinale, P. nigrum* and *P. colubrinum*

Collaboration and support to other agencies

- NIT, Kozhikode - Primer designing and homology modelling of human myeloperoxidase
- ICAR-SBI, Coimbatore - Predicted protein families from ORFs for Sugarcane ESTs and classification using Blast2GO; Secretome analysis of *Colletotrichum falcatum's* RNA SEQ data, prediction of signal peptides; Blast and Blast2GO analysis of *Colletotrichum falcatum's* novel transcripts and grouping based on their classifications
- ICAR-IARI, New Delhi; ICAR-CPRI, Shimla, ICAR-IIHR, Bengaluru & ICAR-CCARI, Goa -Whole genome analysis of *R. solanacearum*
- ICAR-CIBA, Chennai - Genome assembly and annotation of *P. aeruginosa* and *Vibrio harveyi*

NATIONAL INFORMATICS CENTRE FOR SPICES

Subscription of resources

Arranged subscription for Nematology abstracts, Review of Plant Pathology and Review of Agricultural Entomology from CABI. A statistical data base 'Indiastat.com' was subscribed for easy access to statistical information. Continued subscription of 32 Indian journals, nine foreign journals. Two hundred and forty gratis publications and 10 priced publications were added to stock during the period.

Library services

Library continued to be a part of CeRA, the e-journal consortium of ICAR and catered to 75 requests from various CeRA members. During the reporting period 540 users availed the library facilities while 560000 information retrieval searches were made using the EBSCO interface.

E-services

The library website, Spice Bibliography, OPAC, Spice-books, DSpice etc. were updated withnewly added information resources. Twelve issues of the Agrititbits, the agricultural news service, were brought out. The institutional digital repository DSpice was also updated.

AGRICULTURAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

AKMU facilitates the IT and ICT related activities of the institute and ensures uninterrupted internet connectivity to all divisions/sections and VPN connectivity to IISR Regional station, IISR Experimental Farm and Krishi Vigyan Kendra. AKMU is also taking care of network security aspects, regular updation of institute website, displaying circulars and other materials in the website and intranet portal. During the period the websites of AICRPS, ISS , SpicE-Library and Intranet portal were redesigned and a new website was developed for SYMSAC VIII. The maintenance of SpicE-mail, webserver, etc., were done. The Personnel Management Information System Network of ICAR (PERMISnet II) and Project Information & Management System of ICAR (PIMS-ICAR) were updated. Necessary action were taken for ICAR email id to all staff members and also assisted for using FMS/MIS of ICAR. The repair and maintenance of computers and its accessories of various divisions, audio visual support to various activities were also facilitated through AKMU. Apart from this AKMU assists in analyzing and interpreting geographical data using ArcGIS & DIVA GIS and statistical analysis of scientific data using SAS and other statistical software.

RESEARCH PUBLICATIONS

1. Chuan-Rui Zhang, Ettannil Jayashree, Paramasivam Suresh Kumar & Muraleedharan G Nair 2015 Antioxidant and antiinflammatory compounds in nutmeg (*Myristica fragrans*) pericarp as determined by *in vitro* assays. Nat. Product Commun. 10: 1399–1402.

2. Cissin J, Reena N, Suseela Bhai R, Eapen SJ, Nirmal Babu K, & Anandaraj M 2015. Development and characterization of microsatellite markers from expressed sequence tags for analyzing genetic diversity among *Phytophthora* isolates from black pepper. International Journal of Innovative Horticulture 4(1): 34-40.

3. John Zachariah T & Leela N K 2015 Curcumin or Curcuminoids: Industrial and medicinal potential. Food & Foods Ingredients J. Jpn. 220: 309–317.

4. Kandiannan K, Anandaraj M, Prasath D, John Zachariah T, Krishnamurthy K S & Srinivasan V 2015 Evaluation of short and tall true turmeric (*Curcuma longa*) varieties for growth, yield and stability. Indian J. Agric. Sci. 85: 718–720.

5. Kandiannan K, Chandaragiri K K & Anandaraj M 2015 Models to elucidate crop-weather association in turmeric (*Curcuma longa* L.). Ital. J. Agromet. 20: 49–58.

6. Kandiannan K, Prasath D & Sasikumar B 2015 Biennial harvest reduces rhizome multiplication rate and provide no yield advantage in ginger (*Z. officinale* R.). J. Spices Arom. Crops 25: 79–83.

7. Mathew P A, Krishnamoorthy B, Rema J, John Zachariah T & Sasikumar B 2015 IISR-Keralashree- A high yielding and high quality nutmeg (*M. fragrans* H.). J. Spices Arom. Crops 25: 56–59.

8. Muthamil Selvan, Thankamani C K, Annamalai S J K & Jayashree E 2015 Design and development of power operated continuous-run potting machine for seedling-nursery. Indian J. Agric. Sci. 85: 817–820.

9. Nair R R 2016 Variation in pollen fertility and chromosome number among germplasm collections of ginger (*Zingiber officinale* Rosc.). Caryologia 69: 73–81.

10. Neelam S, Kumar A, Vibhuti M, Agisha V N & Eapen S J 2016 *Pseudomonas putida* BP25 alters root phenotype and triggers salicylic acid signaling as a feedback loop in regulating endophytic colonization in *Arabidopsis thaliana*. Physiol. Mol. Plant Pathol. 93: 99–111. doi:10.1016/j.pmpp.2016.01.008

11. Parvathy V A, Swetha V P, Sheeja T E & Sasikumar B 2015 Detection of plant-based adulterants in turmeric powder using DNA barcoding. Pharm. Biol. DOI: 10.3109/13880209.2015.1005756.

12. Pervez R & Eapen SJ 2015. Distribution of plant parasitic nematodes associated with black pepper rhizosphere from Idukki district (Kerala), India. Annals of Plant Protection Sciences 23(1): 192-193.

13. Pervez R, Eapen SJ, Devasahayam S & Jacob TK 2015. Effect of temperature on infectivity and multiplication of entomopathogenic nematodes against shoot borer infesting ginger. Journal of Biological Control 29(4): 171-176.

14. Pervez R, Eapen SJ, Jacob TK, Hamza S & Srinivasan V 2015. Diversity and community analysis of nematodes associated with black pepper rhizosphere from Idukki District (Kerala), Indian J.Nematology 45(2): 23-29.

15. Pradeep B, Manoj P S & Lijo Thomas 2016 Role of institutional extension efforts in spreading grassroot innovations: A study of ornamental fish culture in Kerala. Indian Res. J. Extn. Edu. 16: 134–138.

16. Rosana O B, Eapen S J & Krishna P B 2016 Cloning and characterization of genes encoding two detoxifying enzymes, glutathione s-transferase and carboxyl-esterase, from burrowing nematode (*Radopholus similis*). Intl. J. Parasitol. Res. 8: 173–183.

17. Sangeeth KP & Suseela Bhai R 2015.Integrated plant nutrient system – with special emphasis on mineral nutriton and biofertilizers for black pepper and cardamom – A review. Critical Reviews in Microbiology doi: 10.3109/1040841X.2014.958433.

18. Sasi S, Revathy KA & Bhat AI 2015. Rapid identification of transgenic black pepper using loop-mediated isothermal amplification (LAMP) and real-time LAMP assays. J. Plant Biochem. & Biotech. 24: 466-469.

19. Senthil Kumar C M, Jacob T K, Devasahayam S, Sharon D'Silva, Jinsha J & Rajna S 2015 Occurrence and characterization of a tetrahedral nucleopolyhedrovirus from Spilarctia obliqua (Walker). J. Invertebr. Pathol. 132: 135–141.

20. Sheeja T E, K Deepa, R Santhi & Sasikumar B 2015 Comparative transcriptome analysis of two species of Curcuma contrasting in a high value compound curcumin: insights into genetic basis and regulation of biosynthesis. Plant Mol. Biol. Rep. 33: 1825–1836. DOI: 10.1007/s11105-015-0878-6.

21. Srinivasan V, Thankamani C K, Dinesh R, Kandiannan K, Zachariah T J, Leela N K, Hamza S, Shajina O & Ansha O 2016 Nutrient management systems in turmeric: Effects on soil quality, rhizome yield and quality. Ind. Crops Prod. 85: 241–250.

22. Sruthi D & John Zachariah T 2015 Chemo profiling, *in vitro* antioxidant activity and cytotoxicity of essential oil from selected piper species. Intl. J. Adv. Pharm. Res. 6: 284–295.

23. Thankamani C K, Srinivasan V, Kandiannan K & Krishnamurthy K S 2014 Intercropping vegetables and pulses in black pepper (*Piper nigrum* L.). J. Med. Arom. Plant Sci. 36: 34–37.

24. Umadevi P & Anandaraj M 2015 An efficient protein extraction method for proteomic analysis of black pepper (*Piper nigrum* L.) and generation of protein map using nano LC-LTQ Orbitrap mass spectrometry. Plant Omics 8: 500–507.

25. Vibhuti M, Agisha V N, Neelam S, Aditi K, Vibina V, Subaharan K, Suseelabhai R, Eapen S J & Kumar A 2016 Genotyping and identification of broad spectrum antimicrobial volatiles in black pepper root endophytic biocontrol agent, *Bacillus megaterium* BP17. Biol. Cont. 92: 66–76.

26. Vijesh Kumar IP, Johnson George K & Anandaraj M 2016. Real –Time Quantitative RT-PCR of some defense response genes in *Piper colubrinum* challenge inoculated with *Phytophthora capsici*. Int. J. Agri. Sci. and Res. 6:69-78.

27. Vijesh Kumar IP, Johnson George K, Rosana OB & Anandaraj M 2015. Quantitative RT-PCR analysis of *Phytophthora* specific genes expressed during *Phytophthora capsici-Piper colubrinum* interaction. Int. J. Biotech. Res. 2:1-8.

HUMAN RESOURCE DEVELOPMENT

Trainings conducted

A training program on 'Bioinformatics for whole genome sequencing' was organized from 27-30 January 2016. There were 15 participants from various ICAR/CSIR institutions and universities. Faculty included experts from M/s Bionivid, Bengaluru and IISR. The training program was inaugurated by Dr. T. Janakiram, ADG (Hort.), ICAR, New Delhi and the keynote address was given by Dr. K.A. Abdul Nazeer, Head, Department of Computer Science & Engineering, NIT, Kozhikode (Fig. 46).

Fig. 46. Faculty members and trainees of national training on Bioinformatics for whole genome sequencing

One day training on skill enhancement for the skilled supporting staff (SSS) was organized at ICAR-IISR, Regional Station, Appangala, Karnataka on 14.03.2016.

Second one day training on functional skill development organized for the skilled supporting staff (SSS) was organized at ICAR-IISR on 18.03.2016.

Trainings attended

Name of the official	Training programme	Date	Organization
Ms. S. Aarthi	Interactive co-learning workshop on philosophy, methods and ethics in science	03-05 Nov. 2015	CMFRI RC, Vizhinjam
Dr. C.N. Biju	International summer school on plant disease epidemiology	30 Mar. to 3 Apr. 2015	IGKV, Raipur, Chhattisgarh
Mr. D. Chethan	Noting and drafting	09-10 Nov. 2015	ISTM, New Delhi
Dr. S. Hamza	Competence enhancement training programme for technical officers of ICAR	14-23 Dec. 2015	ICAR-NAARM, Hyderabad
Dr. T.K. Jacob	Decoding the non-coding	15-20 Feb. 2016	Central University, Kasaragod
Mr. P.T. Jayaprakash	Noting and drafting	09-10 Nov. 2015	ISTM, New Delhi
Mr. K. Jayarajan	4th NKN workshop	21-22 Jan. 2016	JNTU, Hyderabad

Dr. E. Jayashree Dr. T.E. Sheeja	Managing technology value chains	22-26 Feb. 2016	ASCI, Hyderabad
Mr. K.G. Jegadeesan	Management development programme on accrual accounting in autonomous bodies	22-27 June 2015	NIFM, Faridabad
Dr. K. Kandiannan	Role of scientists in natural resources and environment management	8-12 Feb. 2016	IIFM, Bhopal
Dr. N.K. Leela	Advancement of analytical instruments in modern science	29 Sep. 2015	University of Calicut, Malappuram
Dr. Lijo Thomas	Analytical techniques for decision making in agriculture	16 July to 05 Aug. 2015	ICAR-NIAEPR, New Delhi
Dr. P.S. Manoj	Annual review workshop of KVK	20-23 May 2015	UAHS, Shimoga
Mr. P. Muraleedharan	Public procurement	11-16 May 2015	NIFM, Faridabad
Dr. K. Nirmal Babu	Management development programme on leadership development	30 Nov. to 12 Dec. 2015	ICAR-NAARM, Hyderabad
Ms. N. Prasannakumari	Joint hindi workshop	21 April 2015	ZSI, Kozhikode
Dr. D. Prasath	Competency enhancement training workshop for HRD nodal officers of ICAR Indo-German joint DUS workshop	10-12 Feb. 2016 23-24 Nov. 2015	ICAR-NAARM, Hyderabad PPV & FRA, New Delhi
Mr. P.K. Rahul	Noting and drafting	09-10 Nov. 2015	ISTM, New Delhi
Ms. P.V. Sali	Managing creativity and innovation	15-17 Feb. 2016	ASCI, Hyderabad
Dr. C.M. Senthil Kumar	Agri Bussiness Incubation sensitization workshop	21-22 Mar. 2016	ICAR-NAARM, Hyderabad
Ms. P. Umadevi	Mass spectrometry based quantitative proteomics for beginners	01-04 Feb. 2016	Institute of Bioinformatics, Bengaluru
Skilled Supporting Staff (9)	Skill enhancement training programme	14 March 2016	ICAR-IISR RS, Appangala
Skilled Supporting Staff (7)	Skill enhancement training programme	18 March 2016	ICAR-IISR, Kozhikode

ITM BPD UNIT

The year 2015-16 was a very vibrant year for ICAR-IISR as far as technology commercialization is concerned. During the year ITM-BPD Unit facilitated the non exclusive licensing of five varieties and three product based technologies. Nutmeg variety, "IISR Keralashree" is the first variety of its kind developed through a farmer's participatory research approach. The progressive farmer Mr. Mathew Sebastian, Malappuram, Kerala who was involved in developing the variety was provided with benefit sharing with ICAR-IISR on equal terms. The variety was licensed to another progressive farmer (Fig. 47), Mr. Venugopal SJ of Karnataka, for large scale commercial production and marketing. One of the elite ginger varieties, "IISR Mahima" was licensed to Mr. S. Shashikant Patil, Medak District, Telangana. Owing to the consistent performance of the high curcumin turmeric variety, IISR Prathibha, one of the licensees, Mr. Abdul Nabeel, has renewed the license for the second term. ITM-BPD Unit, also issued three licenses to Mr. Jigar Dipakbhai Patel, Ahmadabad, Gujarat for the commercialization of turmeric varieties, IISR Prathibha and IISR Alleppey Supreme and ginger variety, IISR Rejatha.

As far as the product based technologies are concerned, the novel method for delivery of PGPR viz., "Biocapsule Technology" has attracted many biofertilizer manufacturing companies and ICAR-IISR has signed a non-exclusive agreement for commercialization of the same during January 2016 with Codagu Agritech, Karnataka (Fig. 48). The same company has also availed the technology of "Microbial consortium for black pepper", a simple and effective technology for enhanced root growth, yield and disease suppression in black pepper suitable both for field and nursery and *Trichoderma harzianum*. Another private firm from Kottayam, Kerala, M/s. Agri Life Biotech have also availed the license for commercial production of *Trichoderma harzianum*.

The Spice Processing Unit at Peruvannamuzhi, Farm came into full fledged operation during this year. The unit houses 21 equipments for processing of black pepper, white pepper and manufacture of curry powders and masala powders. Four license agreements were signed with clients this year for utilizing the facilities. The first agreement was with M/s SUBICSHA, the Coconut Producer's company, which is composed of 532 women self help groups. M/s Abhiruchi Food Products, a unit of Kudumbasree, a cluster of women self help groups and two private entrepreneurs, M/s Maaloos Pure Food Mix and M/s Cookway foods, Kozhikode are the other clients. The production of various curry powders like turmeric, coriander, chilli, chicken masala, garam masala, rasam mix etc. are the major products. M/s SUBICSHA and M/s Abhiruchi have already launched their product in the market on 1 January 2016 and 16 February 2016, respectively (Fig. 49 and 50) and other companies will be launching their products soon.

ITM-BPD Unit has generated Rs. 9.48 lakhs through non-exclusive licensing of ICAR-IISR technologies and ITM-BPD membership fee. Testing of manures/ fertilizers/bioagents for quality assessment contributed Rs. 7.88 lakhs to the institute revenue. Hence the total income generated through various activities is Rs. 17.36 lakhs.

Establishment of Agri-Business Incubation (ABI) Centre at ICAR-IISR

ICAR, New Delhi has sanctioned a new project for establishment of "Agri-Business Incubation (ABI) Center" under XIIth Plan Scheme for National Agriculture Innovation Fund (NAIF) at ICAR-IISR, Kozhikode.

Under this new project, a total of 79.15 lakh has been sanctioned. ICAR-IISR is planning to establish a Food Processing Facility especially to encourage entrepreneurship development among rural women and youth under this project.

Fig. 47. Signing of MOU with Mr. Mathew Sebastian and Mr. Venugopal SJ

Fig. 48. Signing of MoU with Codagu Agritech, Karnataka

Fig. 49. The launch ceremony of 'SUBICSHA Spice Powders'

Fig. 50. Dr. M. Anandaraj, Director, ICAR-IISR Kozhikode launching Abhiruchi Spice products

HINDI CELL

Official Language Implementation Committee meeting

The Official Language Implementation Committee (OLIC) met once in every quarter; first on 22nd June 2015; second on 16th September 2015; third on 3rd December 2015 and fourth on 19th March 2016 under the chairmanship of Dr. M. Anandaraj, Director and reviewed the official language implementation activities of the institute.

Workshops conducted

Four Hindi workshops were organized at ICAR-IISR, Kozhikode for popularizing official language. First on "Noting and drafting", lecture delivered by Mr. K. V. Mahendaran, Manager (OL), State Bank of India, Kozhikode on 17th June 2015, second on "Noting and drafting", lecture delivered by Mrs. S. Maya, Manager (OL) Vijaya Bank, Zonal Office, Kozhikode on 16th September 2015, third on "Noting and drafting", lecture delivered by Mr. K. V. Mahendaran, Manager (OL), State Bank of India, Kozhikode on 21st December 2015 and fourth on "Noting and drafting", lecture delivered by Mr. K. Ravi, Secretary, TOLIC and Manager (OL) State Bank of Travancore, Kozhikode on 10th March 2016.

Hindi day and Hindi Week celebration

Hindi Day was celebrated on 14th September 2015 and Hindi week from 14th September to 19th September 20154. Hindi week inauguration was held on 14thSeptember 2015 under the president ship of Dr. M. Anandaraj, Director. 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 19th September 2015. Ms. Amandeep Kaur, IFS, Divisional Forest Officer, Kozhikode was the chief guest. Institute official language magazine Masaloon Ki Mehak was released on this occasion.

Fig. 51. Hindi week valedictory function and release of OL magazine Masoolon ki Mehak

TOLIC activity

Dr. S. Devasahayam, Head, Division of Crop Protection and Dr. Rashid Pervez, Senior Scientist and Hindi Officer attended the half yearly TOLIC meeting at IIM, Kozhikode on 28th April 2015.

Dr. Rashid Pervez, Ms. Prasannakumari, and Mr. K. G. Jegadeesan attended Rajbhasha seminar conducted by Town Official Language Implementation Committee, Kozhikode at Hotel Malabar Palace, Kozhikode on 10th August 2015.

Dr. Rashid Pervez attended Hindi workshop on OL rules, Hindi software and Noting and drafting at Zoological Survey of India, Kozhikode on 15th March 2016.

Dr. Rashid Pervez and Ms. N. Prasannakumari attended the half yearly and sub-committee TOLIC meeting on 15th June; 2nd August; 13th November and 17th December 2015.

Publications

Following publications were published during 2015-16

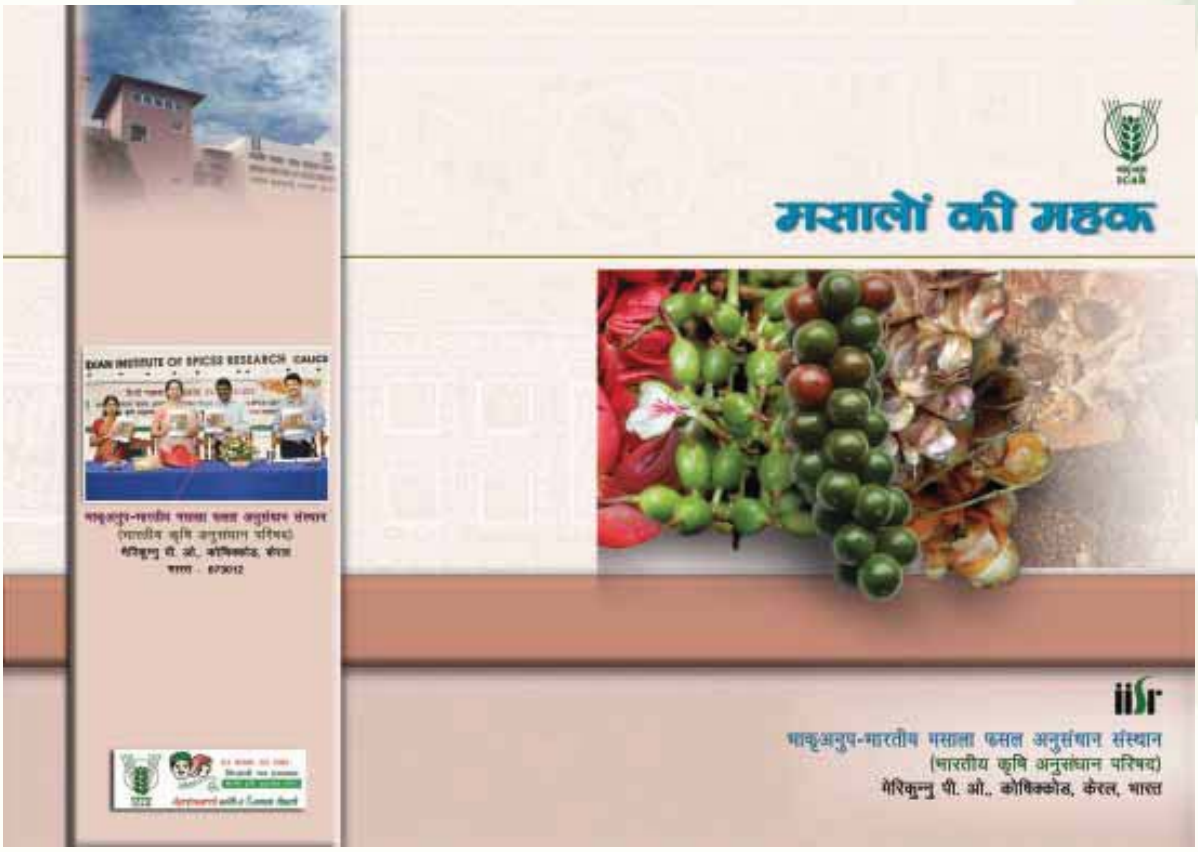
- Annual report (2014-15), Page 100 + iv
- Anusandhan ke mukhya ansh (2014-15), Page 28 + iv
- Executive summary of annual report of the institute and AICRPS (Spices)
- Masala Samachar (four issues)
- Masaloon ki Mehak (OL magazine), Page 81 + iv
- Bulletins (Adrak), Page 22 + iv
- Bulletins (Haldi), Page 20 + iv
- 16 scientific popular hindi articles publish in various journals/magazines.

OL Reports

Quarterly and annual reports on official language activities of the institute 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 institute submitted to Department of Official Language, Ministry of Home Affair, Govt. of India. The half yearly report on Official Language implementation have been 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.



MAJOR EVENTS

Environment day	5 June 2015, ICAR-IISR, Kozhikode
Seminar on Attracting and Retaining Youth in Agriculture	16 September 2015, ICAR-KVK, Peruvannamuzhi 01 October 2015, ICAR-IISR, Kozhikode
Hindi Week	15-19 September 2015, ICAR-IISR, Kozhikode
Vigilance awareness week	26 – 31 October 2015, ICAR-IISR, Kozhikode
XXVI Workshop of ICAR- All India Coordinated Research Project on Spices	5-7 October 2015, ICAR-IISR, Kozhikode
Swasraya Bharat 2015, in collaboration with Swadeshi Science Movement, Kerala	15-21 October 2015, Swapna Nagari, Kozhikode
World Soil Day 2015 Kendra, Peruvannamuzhi	05 December 2015, ICAR-Krishi Vigyan
National symposium on spices and aromatic crops (SYMSAC VIII)	16-18 December 2015, TNAU, Coimbatore, Tamil Nadu
National Science Day	26 Feb. 2016, ICAR-IISR, Kozhikode
International Womens Day	08 March 2016, ICAR-IISR, Kozhikode
Interactive meeting on spices: farmers rights and varietal protection	26 March 2016, ICAR-IISR, Kozhikode

Fig. 52. a. Inauguration of ARYA seminar
b. Sri. N T Sajan, Deputy Conservator of Forests delivering the environment day lecture;

RESEARCH ADVISORY COMMITTEE

Name	Address	Position
Dr. K.V. Peter	Ex-Vice Chancellor, KAU, Thrissur & Director, World Noni Research Foundation, Chennai - 600096	Chairman
Dr. M.N. Venugopal	Door No.11, Block -3, Rangarao colony, Vasu Layout Ramakrishna Nagar, Mysore-22	Member
Dr. M. R. Sudharshan	Ex-Director (Research) Spices Board,222, 9th Main RoadSrinagara, Bengaluru - 560050	Member
Dr. K. K. Sharma	National Coordinator, AINP on Pesticide Residues, IARI, LBS Building, New Delhi-110 012	Member
Sh. Philip Kuruvilla	Indian Products (P) Ltd, Door No.V/705, Gujarati Road, Mattancherry 682 002, Kochi	Member
Dr. R. Viswanathan	Professor (Agric. Processing), Anbil Dharmalingam Agrl. College and Res. Inst., Navalur Kuttappattu, Ramji Nagar P.O., Thiruchirappalli - 620 009 (TN).	Member
Dr. T. Janakiram,	ADG (Hort-II), KAB-IIICAR, New Delhi - 110012	Ex-officio Member
Dr. M. Anandaraj	Director ICAR-Indian Institute of Spices Research, PB No.1701, Marikunnu PO, Kozhikode - 673 012	Ex-officio Member
Dr. R. Dinesh	Principal Scientist (Soil Science), ICAR-IISR, Kozhikode - 673012	Member Secretary

The following recommendations were made by the RAC:

- Prior permission need to be obtained from the council for printing of spices germplasm catalogue as well as posting it on the public domain
- More funding for conservation and maintenance of germplasm needs to be envisaged.
- Plant volatiles influencing resistance of black pepper lines to pollu beetle need to be studied.
- The anti-cancer property of curcuminoids and its derivatives need to be explored.
- For better profiling of spice extracts the use of Super Critical Fluid Extraction need to be studied.
- Separate Food Safety Cell may be created in the Institute to address Food Safety and Supply Chain Management issues in spices.
- 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.
- NABL accreditation of IISR laboratories may be attempted.

INSTITUTE MANAGEMENT COMMITTEE

Name	Address	Position
Dr. M. Anandaraj	Director ICAR-Indian Institute of Spices Research, Marikunnu P.O, Kozhikode - 673 012	Chairman
Dr. Viswanathan R	Head, Plant Protection, ICAR- Sugarcane Breeding Institute, Coimbatore - 641 007, Tamil Nadu	Member
Dr. V. Niral	Principal Scientist, ICAR- Central Plantation Crops Research Institute, Kudlu P.O, Kasaragod - 671 124	Member
Dr. K. Kandiannan	Principal Scientist, ICAR- Indian Institute of Spices Research, Marikunnu P.O, Kozhikode - 673 012	Member
Dr. P.K. Asokan	Principal Scientist & Scientist - In-Charge, Calicut Research Centre of CMFRI, West Hill P.O, Calicut - 673 005	Member
Assistant Director General (H)-II	Indian Council of Agricultural Research, Krishi Anusandhan Bhavan - II, Pusa, New Delhi - 110 001	Member
Mr. M. Radhakrishnan	Finance and Accounts Officer, ICAR-IISR, Kozhikode	Member
Mr. K.V. Pillai	Administrative Officer, ICAR- Indian Institute of Spices Research, Marikunnu P.O, Kozhikode - 673 012	Member Secretary

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]
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. S. Devasahayam & Ms. S. Aarthi]
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 (2007-2016) [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. XXXII (813): Expression profiling and allele mining of genes induced under water-deficit stress in black pepper (*Piper nigrum* L.) (2012-2016) [Dr. Johnson K. George, Dr. K.S. Krishnamurthy & Ms. P. Umadevi]
6. Gen. XXXV (813): Genetic improvement in turmeric through seedling selection and hybridization (2013-2020) [Dr. R. Ramakrishnan Nair & Ms. S. Aarthi]
7. Biotech. XII (813): Mining of DNA markers and genes from expressed sequence tags of *Curcumalonga* (2012-2016) [Dr. T.E. Sheeja & Dr. B. Sasikumar]
8. ICAR-CIB 1. Mining and validation of candidate gene markers and screening on 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)]

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]
2. Phy. XI (813): Source sink relationship, endogenous hormone levels and their relationship with rhizome development

in ginger and turmeric (2011-2016) [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 (2011-2016) [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 & 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. S. Hamza)

6. AGR. XXXI (813). Development of fertigation schedule for better productivity in black pepper (2015-18) (Dr. CK Thankamani and Dr. K Kandiannan)

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 (2013-2016) [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 (2011-2016) [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. Biochem. VIII (813): Evaluation of spice extracts for anticancer effect in relation to telomerase activity (2012-2016) [Dr. N.K. Leela, Dr. T. John Zachariah & Dr. K. Sujathan (RCC, Thiruvananthapuram)]

4. 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)

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 (2012-2016) [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 (2012-2016) [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 (2008-2016) [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 (2012-2016) [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. DBT-CP6: Genome mining of spice associated endophytic bacteria for natural products (2011-2016) [Dr. Santhosh J. Eapen & Dr. R. Suseela Bhai]
5. Outreach Programme on Fungal Foliar Diseases (2009-2017) [Dr. C.N. Biju, Dr. R. Praveena & Mohammed Faisal Peeran]

Project IX: Development of diagnostic kits and integrated management 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) (2008-2016) [Dr. A. Ishwara Bhat, Dr. T.K. Jacob, Dr. K.V. Saji, Dr. K.S. Krishnamurthy & Ms. P. Umadevi]

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. M. Anandaraj	Director (upto 31.3.2016)
Dr. T. John Zachariah	Head, Crop Production & PHT
Dr. K. Nirmal Babu	Project coordinator (Spices)
Dr. B. Sasikumar	Head, Crop Improvement & Biotechnology
Dr. Santhosh J. Eapen	Head, Crop Protection
Dr. S. Devasahayam	Principal Scientist (Plant Pathology)
Dr. T.K. Jacob	Principal Scientist (Entomology)
Dr. J. Rema	Principal Scientist (Horticulture)
Dr. Johnson K. George	Principal Scientist (Gen. & Cytogenetics)
Dr. C.K. Thankamani	Principal Scientist (Agronomy)
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	Senior Scientist (Nematology)
Dr. D. Prasath	Senior Scientist (Horticulture)
Dr. E. Jayashree	Senior Scientist (AS & PE)
Dr. C.M. Senthilkumar	Senior Scientist (Agri. Entomology)
Dr. C.N. Biju	Scientist (Plant Pathology)
Dr. Lijo Thomas	Scientist (Agri. Economics)
Dr. C. Sarathambal	Scientist (Plant Microbiology) (w.e.f. 09.12.2015)
Dr. Awadesh Kumar	Scientist (Plant Biochemistry) (upto 30.04.2015)

Dr. Prativa Lakhotia	Scientist (Spices, Plantation, Medicinal & Aromatic Plants) (upto 30.05.2015)
Dr. R. Praveena	Scientist (Plant Pathology)
Ms. P. Umadevi	Scientist (Biotechnology)
Ms. Aarthi S	Scientist (Spices Plantation Medicinal & Aromatic Plants)
Ms. Akshitha H J	Scientist (Spices Plantation Medicinal & Aromatic Plants)
Ms. Sivaranjani R	Scientist (Plant Biochemistry) (w.e.f. 08.10.2015)
Mr. Mohamed Nizar	Scientist (Plant Biochemistry) (w.e.f. 11.12.2015)

Technical Officers

Dr. Hamza Srambikkal	Chief Technical Officer (Lab)
Dr. Utpala Parthasarathy	Chief Technical Officer (upto 29.02.2016)
Mr. M P Ramesh Kumar	Chief Technical Officer (w.e.f. 10.08.2015)
Mr. K. Jayarajan	Sr. Technical Officer (Stat.)
Dr. Sushamadevi CK	Sr. Technical Officer (upto 31.05.2015)
Ms. N. Prasannakumari	Sr. Technical Officer (Hindi Translator)
Mr. K.T. Muhammed	Technical Officer (Farm)
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. M Radhakrishnan	Finance & Accounts Officer
Ms. P.V. Sali	Private Secretary
Mr. K.G. Jegadeesan	Astt. Finance & Accounts Officer
Mr. R.N. Subramanian	Astt. Administrative Officer
Mr. P Sundaran	Astt. Administrative Officer

IISR Experimental Farm, Peruvannamuzhi

Technical Officers

Mr. Abubackerkoya VK	Chief Technical Officer (upto 30.11.2015)
Mrs. E. Radha	Asst. Chief Technical Officer (T 7-8)
Mr. E S Sujeesh	Sr. Technical Officer
Mr. K. Kumaran	Technical Officer (upto 30.11.2015)

Krishi Vigyan Kendra

Scientific

Dr. P Ratha Krishnan	Programme Coordinator (w.e.f. 19.08.2015)

Technical Officers

Mr. 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 T6 (Fisheries)
Ms. A. Deepthi	Subject Matter Specialist T6 (Home Science)
Mrs. K K Aiswariya	Subject Matter Specialist T6 (Plant Protection)

IISR Regional Station, Appangala, Karnataka

Scientific

Dr. S.J. Ankegowda	Principal Scientist (Plant Physiology)
Dr Alagupalamuthirsolai	Scientist (Plant physiology) (w.e.f. 15.06.2015)
Dr. Rajna S	Scientist (Agricultural Entomology) (upto 25.04.2015)
Dr. Sharon Aravind	Scientist (Spices Plantation & Aromatic Plants)
Mr. Narendra Chaudhary	Scientist (Spices Plantation & Aromatic Plants)
Dr. Mohammed Faisal Peeran	Scientist (Plant Pathology) (w.e.f. 13.04.2015)

Administrative

Mr. P. Muraleedharan	Asst. Administrative Officer

Technical

Sri. K Ananda	Technical Officer

WEATHER DATA

Experimental Farm, Peruvannamuzhi

Months	Rainfall		Temperature (°C)		Relative Humidity (%)	
	Total Rainfall (mm)	Rainy days	Max. (Mean)	Min. (Mean)	Max. (Mean)	Min. (Mean)
January	0.0	0	33.48	21.12	91	53
February	13.0	2	35.32	21.07	88	47
March	157.0	6	34.95	23.09	92	51
April	147.0	15	34.63	23.68	91	62
May	386.8	17	33.31	23.28	89	66
June	1114.4	24	30.86	23.15	94	75
July	836.4	27	30.43	23.7	95	80
August	549.4	22	30.35	23.76	94	80
September	416.0	19	32.05	24.10	94	71
October	282.4	16	32.35	24.33	93	71
November	211.4	12	32.48	23.4	93	68
December	129.4	4	34.11	23.03	90	62
Total/mean	4243.2	164	32.86	23.14	92	66

Regional station, Appangala, Madikeri

Months	Rainfall		Temperature (°C)		Relative Humidity (%)	
	Total Rainfall (mm)	Rainy days	Max. (Mean)	Min. (Mean)	Max. (Mean)	Min. (Mean)
January	0.0	0	28.02	13.13	96	88
February	0.0	0	30.20	13.70	97	89
March	13.5	2	31.70	16.90	96	92
April	121.6	10	31.36	18.51	94	85
May	241.9	14	29.17	18.40	95	84
June	1135.0	20	25.50	18.04	95	88
July	522.2	24	25.40	18.50	94	91
August	350.9	23	26.20	18.10	95	93
September	531.7	13	26.80	17.72	86	82
October	94.3	7	25.90	18.20	88	83
November	532.0	4	26.10	17.70	91	90
December	5.9	1	28.20	16.90	91	82
Total/mean	3549	118	27.88	17.15	93	87

RECOGNITIONS

Rajbhasha Shield Award

The award was granted to IISR for significant contribution to Hindi correspondence, organizing Hindi workshops, OLIC meetings, publications like Annual Report, Masala Samachar, Research Highlights, official language magazine Masloon Ki Mehak, Popular articles and extension bulletin in Hindi and OL implementation during 2014-15.

Masloon Ki Mehak (best official language magazine award)

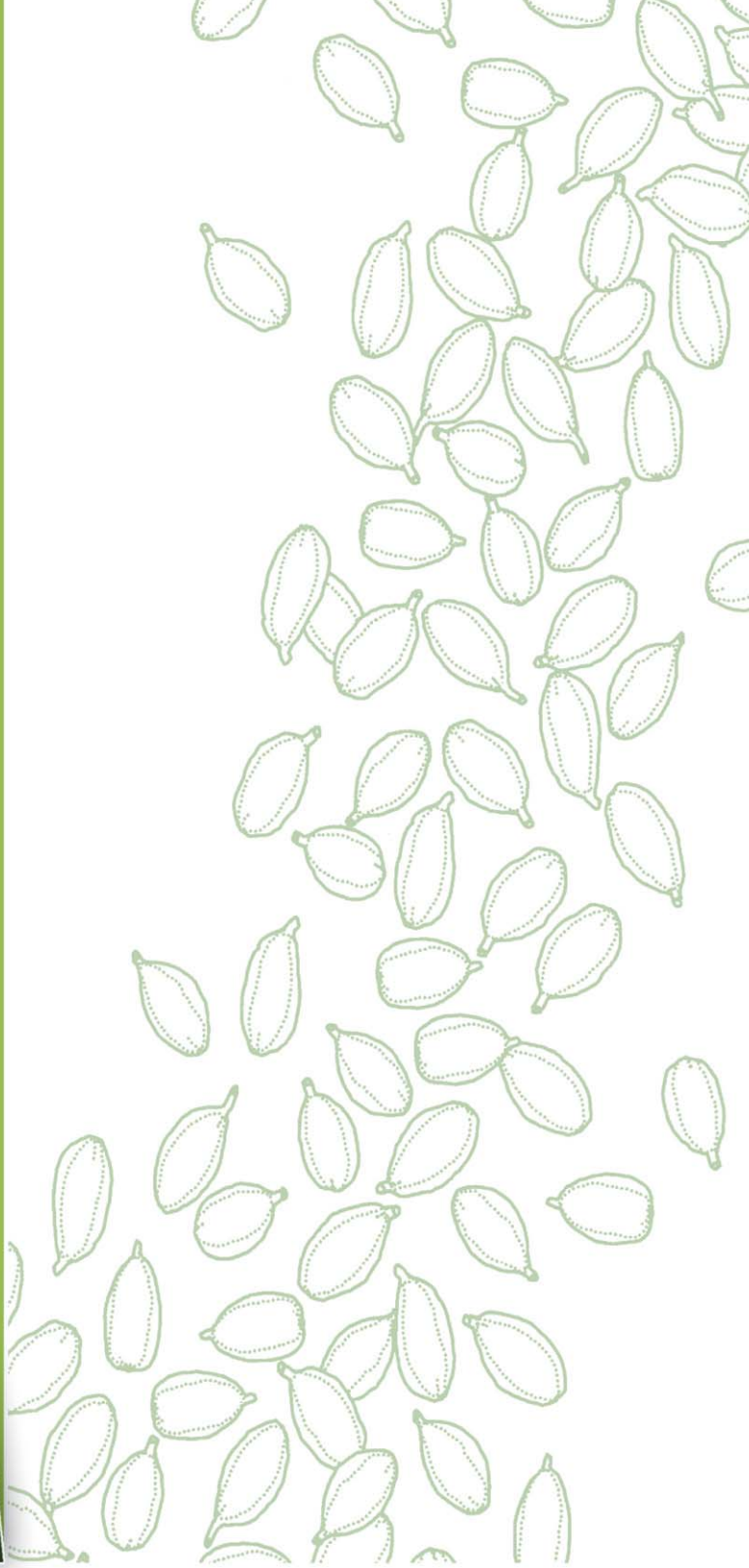
Best OL magazine award was granted for official language magazine Masloon Ki Mehak, among the 76 central government organizations and members of the TOLIC, Kozhikode.

Dr. JS Pruthi best paper award 2013 (awarded in 2015)

TE Sheeja, C Sabeesh, OV Shabna, RS Shalini and B Krishnamoorthy. Genetic diversity analysis of *Myristica* and related genes using RAPD and ISSR markers, Journal of Spices and Aromatic crops, 22, 2013, 38-46

Fellow of Indian Society for Spices

Jayashree E, Prasath D and Utpala Parthasarathy were nominated as Fellow of Indian Society for Spices, Kozhikode, Kerala.



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