अनुसंधान के मुख्य अंश
Research Highlights
2018-19


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भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान, कोषिक्कोड

ICAR-Indian Institute of Spices Research

Kozhikode

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भाकृअनुप - 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 - 673012, Kerala, India

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PREFACE

The Institute was blessed with the visits of Dr. Trilochan Mohapatra, Secretary, DARE and Director General, Indian Council of Agricultural Research and also Dr. A. K. Singh, Deputy Director General (Horticultural Science), ICAR. All the programmes of the institute are aimed at doubling the farmer's income through increased productivity, development of climate resilient spice varieties and clean and pesticide-free spices safe for consumption through various approaches. Recognising the potential for channelizing CSR funds, two private firms in Telangana, Verity Pvt. Ltd. and Apollo Hospitals are being provided with technical support and guidance for creative use of CSR funds in spice farming initiatives. The institute in a move to support tribal welfare, organized a workshop in collaboration with AICRPS on Processing and value addition in spices in Telangana and four turmeric boilers and four turmeric polishers were distributed among tribal FPOs involved in turmeric cultivation. Institute and AICRPS together organized a seminar on Spices production technologies in Pottangi, Koraput, a pure tribal hamlet for the benefit of tribal farmers during which mother garden of spices was established at HARS, Pottangi and allspice saplings which can cover one hectare area was provided to establish a mother garden, first of its kind in the country. The institute is very committed to develop spice hubs in North East. All the initiatives by the Government to promote spices in North East are well attended by the Institute. A project on survey, identification and characterization of unique ginger and turmeric landraces endemic to North Eastern Region (NER) of India has also been initiated. The Institute took up Swachhta, Hindi and Vigilance programmes with great passion and commitment.

The Institute was awarded Ganesh Sankar Vidyarthi Hindi Krishi Patrika Puraskar 2018 (second prize). AICRP on Spices won the prestigious Chaudhary Devi Lal outstanding AICRP award for the best AICRP for the year 2017-18. Dr. R. Dinesh, Principal Scientist received NAAS Recognition award in Soil, Water and Environmental Sciences for the year 2018. Dr. E. Jayashree, Principal Scientist received the Commendation Medal Award 2018 of Indian Society of Agricultural Engineers. Dr. V. Srinivasan received H. S. Mehta Memorial Best Young Scientist award. Dr. D. Prasath, Principal Scientist was awarded the Fellow of Horticultural Society of India. Many of our scientists won best paper awards in various seminars. Our ITM-BPD unit signed thirteen license agreements for technology commercialization/services during 2018-19.

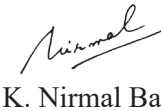
In terms of research achievements, one unique germplasm accession of black pepper with ~30 cm spike length was registered with ICAR-NBPGR, New Delhi. Effective technology for controlling bacterial wilt in ginger was developed and demonstrated efficiently in eight AICRP centres. In turmeric, seed set observed in inbreds offer great potential in developing hybrids with desirable traits. A promising black pepper hybrid with high yield and promising drought tolerant black pepper and cardamom genotypes are under multilocation testing. Diagnostic tools for black pepper plants infected with endogenous and episomal forms of *Piper yellow mottle virus* have been developed. Climate analogues sites for small cardamom and large cardamom were identified using CCAFS climate analogues tool which helps in area expansion for increasing production and export. Organic management of cardamom with sustainable yield with minimum pesticide residue

has been developed. The institute has developed solar dryer with high efficiency for curing turmeric. Three entomopathogenic fungi were documented from insects associated with spice crops which helps in deriving biocontrol strategies. Study on rain induced natural calamity estimates indicated crop loss in terms of expected production loss at state level over previous year in spices at 25138 tonnes (12541.1 million INR).

XXIX AICRPS workshop was held at Dr YSPUH & F, Solan. Eleven varieties with traits such as climate resilient and stem gall resistant coriander, high quality nutmeg, high curcumin turmeric, high quality coriander *etc.* suitable for different agro-ecological zones were recommended for release during the workshop. ICAR-IISR KVK organized live telecast of Pradhan Mantri Kisan Samman Nidhi inauguration by Hon'ble PM for the benefit of 1500 farmers. KVK also organized Technology week (*Tharrum Thalirum*) for the benefit of about 800 farmers. ICAR-IISR organized a district level seminar on Good agricultural practices for clean and safe spices on 22 December 2018 which was inaugurated by Dr. Trilochan Mohapatra, Director General, ICAR. The institute continued to develop and support seed villages for certified seed production of turmeric in Andhra Pradesh and Telengana. ICAR-IISR and the Department of Horticulture, Government of Telangana jointly organized a consultative meeting to formulate a strategy for productivity enhancement of turmeric and its value chain development. The Institute distributed soil health cards to farmers based on soil test results. Quality and disease-free nucleus planting material of spices were distributed to farmers from different regions of the country. Two national facilities which were established during the last year *viz*. Pesticide Residue Lab and Value Chain Incubation Facility for processing of spices have started functioning.

The present production and export levels of spices indicate that we need to produce more to be competitive in global market. This requires united efforts and committed work from the spices sector as a whole (research, development, industry, farmers and the field functionaries) which can bring back the lost glory.

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



K. Nirmal Babu

Kozhikode

15 June 2019

BLACK PEPPER

Genetic resources

Germplasm explorations were conducted to Nagaland (Mokokchung, Tuensang and Mon districts) and Andaman and Nicobar Islands in collaboration with ICAR-NBPGR, Shillong, Meghalaya and ICAR-NBPGR, Thrissur, Kerala, respectively. Forty accessions of black pepper were collected from the forests of Nagaland and 17 accessions from Andaman and Nicobar Islands. Five new *Piper* species *viz. P. boehmeriaefolium, P. makruense, P. pothiforme, P. rhytidocarpum* and *P. diffusum* from Nagaland and two new species (*P. pedicellatum* and *P. clypeatum*) from Andaman and Nicobar Islands were added to the black pepper germplasm repository.

P. makruense

P. pedicellatum

P. clypeatum

Fig. 1. *Piper* spp. collected during exploration trip

Germplasm registration

A black pepper accession from the germplasm (IC-0619910) was registered with NBPGR for its unique character of having very long spike (29.3 cm).

Breeding

Yield evaluation

Among the nine promising lines, hybrid HP 117 x Thommankodi recorded highest fresh yield of 8.90 kg per standard with 32.5% dry recovery followed by IISR Thevam (5.1 kg per standard with 31.2% dry recovery). HP 117 x Thommankodi had the longest spike length of 21 cm and HP 780 had the highest dry recovery of 37.5%.

Fig. 2. HP 117 x Thommankodi in field

Portable black pepper

Generally black pepper vine is trailed on live or dead standard. A stationary vine lacks horizontal mobility. A portable vine is a novelty that adds easy maintenance and it serves a purpose of display and adds aesthetic value in exhibitions and best suited for urban horticulture. Portable black pepper can be raised in big containers with PVC pipe or bamboo as standard compacted with coir rope. Orthotropic shoots are the ideal material to raise portable vines as they will have uniform canopy from the base to the top.

Fig. 3. A snap of portable black pepper vine

Peptide based functional markers to tag *Phytophthora* resistance in black pepper

Peptides with high (R) and low (S) quantitative expression (10 peptides) against *Phytophthora* infection from the *Phytophthora* tolerant variety IISR Shakthi was taken to analyze its association to *Phytophthora* resistance in two groups *viz*., tolerant and susceptible. Five peptides based primers were screened in 26 black pepper genotypes. Pep 5 discriminated Narayakodi from all the other genotypes. This primer can be used to select the progenies under Narayakodi background in the hybridization programme. Though the approach is aimed at *Phytophthora* resistance tagging, the initial results suggested that it may be helpful in peptide barcoding of genotypes.

Estimation of piperamides in *Piper* species

Estimation of piperamides (piperlongumine, piperlonguminine and piperine) based on a modified method of reverse phase high performance liquid chromatography (RP-HPLC) was done in the berries collected from different *Piper* species. Piperlonguminine and piperine were detected in four species analyzed whereas piperlongumine, a potential and novel anticancer agent was detected only in *P. longum* and *P. sarmentosum.*

RNA sequencing

Nanopore sequencing and error correction of the data with Illumina data (Hiseq) was performed using RNA samples isolated from the berries of *Piper nigrum* and *P. longum* for better delineation of genes especially those involved in biosynthesis of secondary metabolites. Genes encoding proteins involved in terpenoid precursor mevalonate (MVA) and methylerythritol phosphate (MEP) pathways were found in *Piper* transcriptomes. Major genes involved in the synthesis of class I and class II terpenes were also found in the transcriptomes. *Alpha-guaine 2- oxidase*, the key gene in the biosynthesis of rotundone, an oxygenated sesquiterpene was also discovered in black

pepper. Major genes involved in piperidine alkaloid biosynthesis were also discovered from the transcriptome data.

Plant health management

Differential induction of peroxidase in black pepper inoculated with *Phytophthora* isolates

Peroxidase activity was assessed in 11 black pepper accessions including seven released varieties with the *Phytophthora* resistant line, 04-P24, as the check to assess whether peroxidase production can be taken as a biochemical marker for screening plants for resistance to *Phytophthora* infection. Results indicated that peroxidase activity can be used as a biochemical marker for screening black pepper plants against *Phytophthora*.

Diversity studies on *Colletotrichum* spp.

Different isolates of *Colletotrichum* inciting leaf blight in black pepper representing Kerala and Karnataka were morphologically characterized wherein considerable variability was observed with respect to colony, conidial as well as appressorial characters and their dimensions. *In planta* pathogenicity studies indicated that three isolates could infect Panniyur 1 (susceptible host), inducing prominent yellow halo. While, *in vitro* studies showed that infection could occur within 72 hours after inoculation leading to the formation of acervulus initials. Initial studies on molecular identification with two isolates indicated that the ITS region was 100% similar to *C. gloeosporioides, C. aenigma* and *C. siamense.* The β-tubulin gene region was 100% similar to *C. gloeosporioides* and *C. fructicola.*

Characterization of *Pythium* species associated with black pepper yellowing

Study on 92 soil and 12 root samples from different regions of Kerala and Karnataka revealed presence of *Pythium* in 87 soil samples (94.5%) and eight root samples (67%). These isolates were characterized morphologically which yielded *Pythium* species with three distinct colony morphologies *viz*. cottony, chrysanthemum and chrysanthemum with cottony aerial mycelium. They produced torulated/globose sporangia having different growth rate on different media and can grow at a pH range of 4.5 to 10.0 and a temperature range of 15-37ºC. Out of these, 10 isolates were tested for their pathogenicity and all were found pathogenic to black pepper. Molecular characterization of these isolates indicated the presence of three species *viz*. *Pythium deliense, P. cucurbitacearum* and an unidentified *Pythium* sp.

Differentiation of black pepper plants infected with endogenous and episomal PYMoV

A combination of polymerase chain reaction (PCR) and reverse transcription (RT) PCR based assay was developed for differentiation of black pepper plants infected with endogenous and episomal forms of *Piper yellow mottle virus.*

P. deliense *P. cucurbitacearum* *Pythium* sp.

Fig. 4. Colony morphology of three species of *Pythium* infecting black pepper

Characterization of pararetroviruses

Occurrence of pararetroviruses namely, *Piper DNA virus 1* (PDV-1) and PDV-2, were detected in 20 varieties of black pepper through PCR using five virus specific primer pairs. The specificity of the PCR product was confirmed by directly sequencing PCR products.

Field evaluation of promising bacterial and actinomycete consortia against foot rot and slow decline diseases

The field trial with promising combinations of bioagents was continued for the third year in farmer's plots in Kozhikode district of Kerala. All the treatments were found to be better than the control in yield as well as suppression of soil-borne pathogens. However, treatment with *Pseudomonas putida* and *Bacillus megaterium* (Bp25 + Bp17) with 1% Bordeaux mixture spray was comparatively superior to other treatments.

Area wide integrated pest management of black pepper wilt diseases

No disease incidence was noticed in any plots treated with *Trichoderma harzianum* + *Pochonia chlamydosporia*, Bordeaux + copper oxy chloride + carbosulfan and metalaxyl-mancozeb + carbosulfan when compared to nearby farmer's plots. Two black pepper nurseries were established under this project by adopting technologies for production of healthy disease-free planting material.

CARDAMOM

Genetic resources

A total of 621 cardamom germplasm accessions are being maintained at National Active Germplasm Site (NAGS), Appangala, Karnataka which consists of 423 accessions from Appangala; 101 accessions from Pampadumpara; 41 accessions from Mudigere and 56 from Sakaleshapura.

Oil and oleoresin estimation of 24 germplasm accessions were done during this year. Oil content ranged from 5.10 % (IC 349466) – 7.15 % (IC 349478) and oleoresin content ranged from 4.49 % (IC 547212) – 6.05 % (IC 349335).

Breeding

PET III consisting of 23 inter-varietal F_1 hybrids was evaluated for yield and reaction to pest and diseases. From the pooled data of three years, nine superior hybrids were shortlisted and capsule characters of shortlisted hybrids were recorded. Among the nine shortlisted hybrids-ICRI 4 × IISR Vijetha was having highest fresh (1090 g) as well as dry yield (236 g) of capsules per plant. Capsules of ICRI 4 × IISR Vijetha (14) were globose, bold (11.06 mm) and pale green in colour

Fig. 5. Capsule characters of ICRI 4 × IISR Vijetha (14)

Organic farming

Significantly higher organic carbon, N, P, Ca, Mg, Fe and Zn availability was recorded in organic and integrated management system as compared to chemical management system. Among the organic nutrient sources, neem cake (NC) + vermi compost (VC) combined application recorded 1.3 kg dry capsules per plot (of 12 plants) followed by farm yard manure (FYM) + NC (0.85 kg/plot) and VC (0.81 kg/plot). Integrated management yielded significantly higher fresh capsule yield (1.48 kg/plot) followed by chemical management (1.3 kg/plot) and organic management (0.9 kg/plot). With the application of spinosad and *Lecanicillium* and spinosad with *Trichoderma* and *Pochonia*, no major incidence of rhizome rot and <5% incidence of thrips damage on capsules was observed.

Identification of climate analogues sites for small and large cardamom

Identification of climate analogues sites for small cardamom and large cardamom was carried out using CCAFS climate analogues tool. For identification of climate analogues sites, efficient producing zones were identified based on relative yield index and relative spread index. These efficient zones were used as reference sites for identifying the climate analogues sites under changing future climate using CCAFS climate analogues tool. Accordingly, for small cardamom, 236 taluks located in 104 districts and for large cardamom, 234 taluks located in 112 districts were identified as climate analogues sites considering their future climate under changing climate scenario.

Screening of cardamom hybrid against thrips and shoot borer

Progenies of seven cardamom hybrids were screened for natural incidence of capsule

borer and thrips. The incidence of thrips and borers on capsules of selected progenies of the hybrids ranged from 2.17-8.64% and 2.55-7.48%, respectively.

Characterization of nucleorhabdovirus associated with cardamom plants infected with vein clearing disease

The study for the first time reports association of a nucleorhabdovirus with vein clearing (*kokke kandu*) disease of cardamom. The causal virus was successfully transmitted onto healthy cardamom using the aphid, *Pentalonia caladii*. The identity of the causal virus was established based on sRNA sequencing and subsequent verification of the same through RT-PCR, cloning and sequencing. The sequenced region showed identities with nucleorhabdoviruses in the nucleocapsid (N), phosphoprotein (P), movement protein (P3), matrix protein (M), glycoprotein (G) and polymerase (L) genes ranging from 30-62% indicating that the virus associated with vein clearing disease of cardamom is a nucleorhabdovirus.

GINGER

Genetic resources

Six hundred and sixty eight ginger accessions are being maintained in the field gene bank. The ginger germplasm conservatory was enriched with 27 ginger accessions, eight *Zingiber* spp. and 30 related genera collected from Nagaland, Manipur and Andaman and Nicobar Islands.

Fig. 6. *Etlingera fenzlii* collected and added to the germplasm repository

Characterization

Development of novel EST-SSR markers

Mining of ginger transcriptome data resulted in 16790 Simple Sequence Repeats (SSRs) and were identified as potential molecular markers in the unigenes. Also, 4597 SSRs were identified in coding region of the sequences. Based on the SSR-containing gene sequences, 25 primer pairs were randomly selected and synthesized and used for assessment of polymorphism. Six primer pairs were polymorphic and revealed polymorphism among 43 ginger collections.

Yield evaluation

The experiment (AICRPS CVT) was conducted during 2015-2018 at ICAR-IISR Experimental Farm, Peruvannamuzhi, Kerala with seven different entries and a national check IISR Varada. Among the ginger accessions, maximum yield (pooled) was recorded in Acc. 247 (20.69 t/ha) followed by Rio-de-Janeiro (17.75 t/ha) and SE 8681 (15.81 t/ha).

Mutation breeding

Ten M_1V_5 and 102 (M_1V_{11}) mutants have been maintained. Three potential mutants identified against *Pythium* sp. (V 0.5/2, R 0.8/1 and R 1.25/4) and three potential mutants against *Ralstonia pseudosolanacearum* (HP 0.5/2, HP 0.5/15 and M 0.5/1) were multiplied.

Induction of polyploidy

The rhizome buds of IISR Mahima were submerged in different concentrations of colchicine (0.025, 0.050, 0.075, and 0.1 %) solution for 48 h to induce polyploids. Maximum sprouting was recorded in 0.025% colchicine. All the successful plants (15) have been established for further studies.

Microrhizome production

Microrhizome of ginger varieties (Athira, IISR Mahima, IISR Varada) and turmeric varieties (Sona, Suranjana, Varna) were subcultured and 3000 plantlets of ginger and 1500 turmeric were raised in protrays and are being hardened in polybags under nursery.

Nutrient mineralization dynamics of crop residues

Nutrient mineralization dynamics of commonly used crop residue mulches (*Gliricidia, Ailanthus* and mixed leaves) with and without FYM and rhizosphere priming was studied in ginger. The rate of NO_3-N mineralization from crop residues applied was found to be significantly higher in the treatments with ginger over treatments without ginger, indicating the positives of rhizosphere priming effect. Highest NO_3-N and NH_4-N release was found in *Gliricidia* mulch. Almost 10 times higher net P release was observed between with FYM and without FYM treatment. The FYM priming increased the dry matter production of ginger by 48% and by 88%, 100% and 75% the N, P and K uptake, respectively as compared to without FYM.

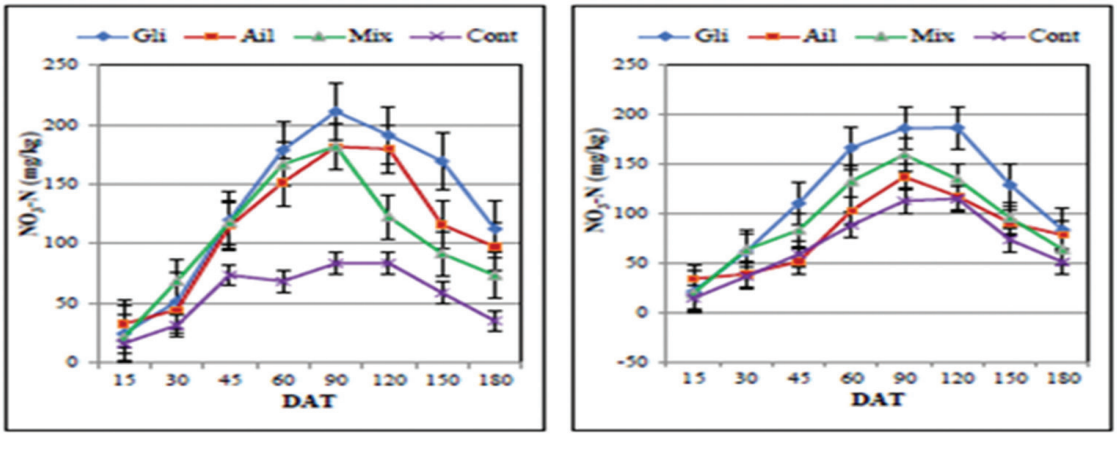


Fig. 7. Changes in NO_3-N availability due to application of mulches (a) with FYM; (b) without FYM

Infection mechanisms of *Bipolaris rostrata* on ginger

Studies on infection mechanisms of *Bipolaris rostrata* on ginger showed that conidia inoculated on the surface of ginger leaves germinated, produced germ tubes from both the poles of conidia. From the tip of these germ tubes, uni- and multi lobed appressoria ranging between 9.02-15.34 × 4.12–10.57 µm were formed. From these, infective hyphae entered the tissues either directly through the epidermal cells or through the stomatal opening. Light brown lesions appearing on the surface of leaves are due to the growth of secondary hyphae inside the epidermal cells.

Pink pigmented *Methylobacterium* against major pathogens of ginger

A novel phyllosphere associated pink-pigmented, Gram negative, motile rod shaped bacterium (GPPFM13) was short listed from 60 PPFMs. *In vitro* assay against pathogens of ginger *viz*. *Macrophomina phaseolina, Sclerotium rolfsii, Pythium myriotylum, Colletotrichum gloeosporioides* and *Fusarium oxysporum* showed inhibitory effect in the range of 40 – 75%. The mineral solubility index, IAA production and production of mycolitic enzymes and siderophores were studied. *In planta* evaluation showed better rhizome and root formation when the bacterium was applied as a foliar spray along with soil drenching. The isolate (GPPFM13) is identified as a species of *Methylobacterium* by MDH (mxaF) gene analysis and showed 96% similarity to *M. platani* and *M. inners*.

Fig. 8. Formation of appressoria by *Bipolaris rostrata*

Physiological and biochemical changes in ginger - *Bipolaris* interaction

Physiological and biochemical changes occurring during the ginger - *Bipolaris rostrata* interaction were studied under glasshouse conditions. Biochemical parameters like chlorophyll and protein were found to decrease whereas electrolyte leakage increased in artificially inoculated ginger plants compared to the control.

Development of a suitable formulation for *Bacillus licheniformis*

For developing a suitable formulation of *Bacillus licheniformis* GAP107, a potential biocontrol agent against bacterial wilt

of ginger, two different carriers such as charcoal and talc were tested in comparison with the broth culture. All the formulations enhanced the soil properties such as organic carbon, nitrogen, phosphorus and potassium content. Application of charcoal formulation at the time of planting as rhizome priming (seed coating) and as soil application at 45, 60 and 90 days, significantly reduced the disease incidence and increased the plant height, number of tillers and rhizome development.

Fungitoxic activity of silicates on *Pythium myriotylum* and soft rot of ginger

Effect of solid and liquid forms of sodium and potassium silicate and sodium meta silicate was tested on the growth of *P. myriotylum* under *in vitro* conditions. Sodium meta silicate suppressed the fungal growth at 70 mM whereas sodium and potassium silicate restricted the mycelial growth at 3% concentration. *In planta* studies showed an overall increase in growth rate of plant as compared to control. Challenge inoculated plants with silicate molecules showed a decrease in disease incidence as compared to the control. Among the treatments, potassium silicate was found to be very effective in increasing the overall growth of the plant and limiting the disease incidence.

FLD on IDM of bacterial wilt in ginger

Frontline demonstrations on management of bacterial wilt in ginger were undertaken in nine AICRP centres and one farmer's plot in Karnataka. In each location, soil drenching with 3% calcium chloride, seed priming and soil drenching with *Bacillus licheniformis* were evaluated in solarized and non-solarized plots and compared with recommended PoP of each centre. The germination and establishment of the plants were significantly superior in solarized plots amended with both calcium chloride and *Bacillus licheniformis.* In general, solarized plots showed significant improvement in growth and yield when compared with non-solarized plots.

Fig. 9. FLD on soil solarization to control bacterial wilt of ginger in field

Characterization of the viruses belonging to the family, Closteroviridae and Tombusviridae associated with chlorotic fleck disease of ginger

The present study for the first time reports association of two distinct viruses, one belonging to the genus, *Ampelovirus* (Family Closteroviridae) and the other distinct species belonging to an undescribed new genus belonging to the family Tombusviridae with chlorotic fleck disease affected ginger. The identity of the causal virus was established

based on sRNA sequencing and subsequent verification of the same through RT-PCR, cloning and sequencing.

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 11 *Curcuma longa* and six *Curcuma* spp. from Nagaland and Andaman and Nicobar Islands.

Characterization

Characterization of 150 turmeric accessions was carried out based on 12 quantitative and 10 qualitative characters.

Evolving extra long and bold turmeric lines

Twelve accessions of Salem Local (Erode and Salem district of Tamil Nadu) and four accessions of Mydukur (Andhra Pradesh) were collected and multiplied. Also, open pollinated seeds of 31 turmeric accessions from germplasm were collected and raised seedling progenies to evolve extra long turmeric genotypes. Germination was found to be staggered, 63 seeds germinated, seventeen seedlings were transplanted.

Evaluation of hybrids and seedlings

Replicated trial of three seedlings and three hybrids at Chelavoor recorded yield of 11.3 kg. fresh rhizomes per 3 m^2 bed in SLP 359/2 and 10.36 kg in SLP 65/12. All the three hybrids and one seedling recorded yield below 10 kg. Of the four first generation selfed progenies of Acc. No. 65 (2n=63), two flowered during 2018-2019. Among these one had distorted floral morphology and all the seven flowers produced were female, having ovary and a short style with stigma compared to the bisexual flowers in normal turmeric plants.

Performance evaluation of solar drier developed by ICAR-IISR

The solar dryer developed by ICAR-IISR, Kozhikode was evaluated and it was observed that drying time for turmeric was slightly higher for solar dryer as it is multilayer drying compared to sun drying which single layer is drying. Drying of sliced turmeric was completed in 7 days in both solar drying and sun drying. There was no significant change in the dry recovery and the final moisture content of turmeric cured by different methods. Quality evaluation showed that the retention of primary metabolites was higher in solar dryer dried turmeric compared to sun dried turmeric. Curcumin content was maximum (4.61%) for solar dryer dried sliced turmeric.

Survey for plant parasitic nematodes of turmeric

High incidence of root knot nematodes were observed in samples collected from turmeric growing areas of Coimbatore, Erode, Salem and Villupuram districts of Tamil Nadu and random samples collected from Kerala, Karnataka and North East. Burrowing and lesion nematodes were also present. Other nematodes of common occurrence were *Rotylenchulus reniformis, Hoplolaimus* sp. and *Helicotylenchus* sp. The lesion nematodes (*Pratylenchus* spp.) were observed

in Alandur and Thannerpanthal region of Coimbatore District, Bhavanisagar and Gobichettipalayam region of Erode District, Shimoga in Karnataka and Nagaland in North East region. *Pythium* was isolated from some of the rhizome samples collected from Tamil Nadu.

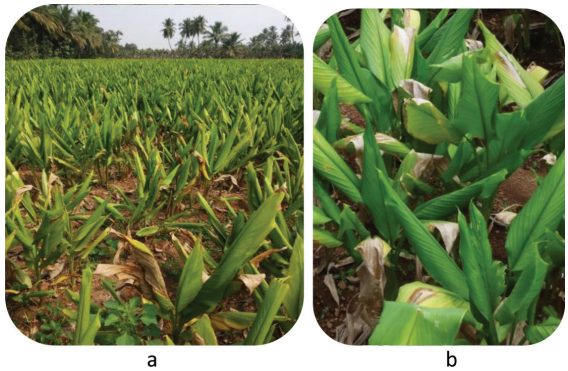


Fig. 10. Field symptoms of nematode infestation in turmeric. (a) Root knot nematode and (b) Lesion nematode.

GINGER & TURMERIC

Mermithid parasitism of shoot borer (*Conogethes punctiferalis*)

Mermithid nematode parasitism reached epizootic levels in *Conogethes punctiferalis* exceeding 50% mortality in host insect populations and the parasitism ranged from 18.2 to 80.6% and 17.9 to 66.7% in *C. punctiferalis* collected from ginger and turmeric, respectively. The level of host parasitism by the mermithid was positively correlated with rainfall and negatively influenced by maximum temperature. The pairwise Kimura 2-parameter (K2P) distance revealed that the closest taxon to the study nematode was an undescribed mermithid species reported to infect slugs with a K2P distance of 0.009. The results provide a basis for using this nematode as a biocontrol agent for developing integrated pest management strategies against *C. punctiferalis.*

Fig. 11. Mermithid nematode infesting turmeric shoot borer

Dose optimization of insecticides

Three insecticides (spinosad, flubendiamide, chlorantraniliprole), which were found effective in earlier trials and also a treatment with spraying of chlorantraniliprole and spinosad alternatively were tested under field conditions at ICAR-IISR Experimental Farm, Peruvannamuzhi for dose optimization against shoot borer infesting ginger and turmeric for the second consecutive year. All the insecticides were very effective in the management of the pest even at the lowest dose (0.3 ml/ litre of water) tested. The treatment of spraying chlorantraniliprole and spinosad alternatively was also equally effective in controlling the insect. A botanical formulation developed by a farmer was also found to be effective in controlling the pest.

Evaluation of antagonists against pathogens of ginger and turmeric

Two strains of *Trichoderma viz., Trichoderma erinaceum* (IISR AP1) and *T. atroviridae*

(IISR TL 1) were found effective against *Pythium myriotylum, P. aphanidermatum* and *Fusarium oxysporum* under *in vitro* conditions. Three strains of bacteria *viz., Pseudomonas* sp. and *Bacillus* sp. were found to inhibit the growth of *Bipolaris rostrata, Colletotrichum gloeosporioides* and *C. capsici.*

VANILLA

Genetic resources

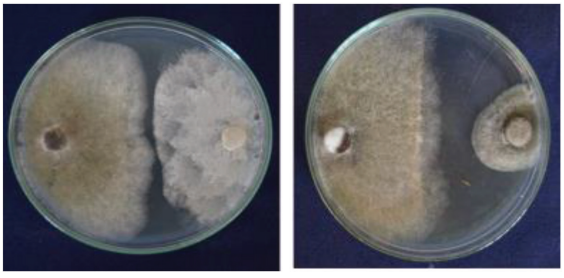
Sixty five *Vanilla planifolia* and eleven V*anilla* spp. are being maintained in the polyhouse. The germplasm conservatory was enriched with six *Vanilla* spp. collected from Assam and Andaman Islands.

Fig. 12. *V. andamanica* collected from Andamans

Biological control of vanilla pathogens

Among five *Chaetomium* spp, FVREP4 showed 56.88% and 83.73% inhibition over control of *Phytophthora meadii* and *Colletotrichum gloeosporioides*, respectively. It also produced siderophores (iron chelation), cellulase and hydrolysed starch.

On screening 31 bacterial microbes against *P. meadii,* four isolates *viz*., VSEN7, VSEN8, VREP2 and VAREN4 showed more than 50% inhibition and three isolates (VLEN2, VLEN3 and VSEP3) showed more than 50% inhibition to *C. gloeosporioides*. None of them were effective against *S. rolfsii.*



Against P. meadii *Against C. gleosoporioides*

Fig. 13. *In vitro* antagonistic activity of *Chaetomium* FVREP4 against pathogens of vanilla

TREE SPICES

Genetic resources

Nutmeg

Various islands of South Andaman, Middle Andaman, Great Nicobar and Little Nicobar were surveyed and collected three accessions of *Myristica andamanica*, two accessions of *Horsfieldia* spp. and four accessions of *Knema* spp. Two accessions of *Myristica andamanica* and one accession each of *Horsfieldia* and *Knema* species were also collected from ICAR-NBPGR, Thrissur.

Cinnamon

Three cinnamon accessions from Andaman Islands, three accessions of *C. camphora*

from Dehradun and a wild species of cinnamon from Nicobar were collected and added to the germplasm. Six accessions of *Cinnamomum* spp. were collected from NEH region also.

Garcinia

Garcinia nervosa, G. cowa, G. kydia, G. dhanikhariensis and an unidentified species were collected from various islands of Andaman and Nicobar. Three high yielding accessions of *G. indica* were obtained from ICAR-NBPGR Regional Station, Thrissur. Two exotic species of *Garcinia viz. G. schomburgkiana* and *G. kola* were collected from farmer's field. 7 accessions were collected from NEH region also (*G. lancifolia, G. pedunculata, G. kydia* and *G. cowa*).

Fig. 14. *Garcinia nervosa* collected from Andamans

SPICE CROPS

Production of nucleus planting materials of improved varieties

Improved varieties of black pepper were distributed to 581 farmers and 70000 cuttings were sold from main campus and 12000 from Regional Station. Around 4 tons of ginger and 6 tons of turmeric seed material were produced and distributed. About 2885 suckers and 475 seedlings of cardamom were multiplied and distributed from Regional Station, Appangala. Five hundred nutmeg grafts of IISR Viswashree were produced from Experimental Farm, Peruvannamuzhi.

DNA fingerprinting and barcoding in spices

Identified polymorphic DNA marker for distinguishing Vietnam black pepper from Sri Lankan black pepper based on samples provided by DRI (MZU) and DASD, Kozhikode, Kerala. A total of 41 samples from DRI (MZU), FSSAI, Chennai and DC (customs), Muzaffarpur and two samples each from Synthite Industries Ltd. and Unique Spices Indian Ltd. were analyzed. Fingerprinting facility was extended to AICRPS Centres for varietal release of five turmeric, three ginger, three fenugreek and four coriander samples.

DUS testing facility

The DUS testing centre has been established at ICAR-IISR, Kozhikode by the PPV&FRA, New Delhi. During the year, preliminary on-site observations on the farmer's varieties of black pepper (3 nos.) and small cardamom (6 nos.) were taken up and the data submitted to PPV&FRA for further processing. Also, completed DUS test for seven ginger and 19 turmeric candidate varieties.

Surveillance and documentation of pests and diseases of spices

As a part of surveillance programme, spice plantations were surveyed for the incidence of pests/diseases in Karnataka and Kerala. Twenty isolates of *Phytophthora* representing black pepper and nutmeg were collected during the surveys conducted in Kerala. Damages due to scales (3-5%) and marginal gall thrips (2-10%) in black pepper, thrips (8-10%) and shoot borer (15-20%) in cardamom, shoot borer (15-20%) in ginger and leaf miner (15-20%) and leaf gall damage (5-10%) in cinnamon were observed in different gardens of Kodagu, Karnataka. Plant parasitic nematodes *viz*., *Meloidogyne incognita, Radopholus similis* and *Helicotylenchus* were found associated with vines exhibiting declining symptoms.

Entomopathogens and other natural enemies of spice crops

Three entomopathogenic fungi (IISR-EPF-19, IISR-EPF-20) were documented from insects associated with spice crops, *Basilepta* sp. infesting cardamom and *Saissetia nigra* infesting nutmeg. The entomopathogenic fungus infecting *Basilepta* sp. has been identified as *Beauveria* sp. based on morphological studies. The entomopathogenic fungus infecting an unknown caterpillar infesting ginger (IISR-EPF-17) has been identified as *Nomuraea rileyi* based on molecular studies. An infected *Conogethes punctiferalis* of unknown etiology was also recorded.

Studies on *Pochonia chlamydosporia*

The growth promoting and antagonistic properties of the nematophagous fungus, *Pochonia chlamydosporia*, was studied under *in vitro* conditions. The fungus produces siderophores, ammonia and ably solubilizes zinc and phosphate. Total suppression of *Phytophthora* and *Pythium* was noticed in dual plate assays.

Transcriptomics of *Radopholus similis*

The transcriptome of *R. similis* was sequenced by Illumina sequencing and *de novo* assembled and annotated. A total of 62312 unigenes (73.09%), ranging in size from 201– 10747 bp with a mean contig size of 1046 bp, were obtained. The assembled contigs were functionally annotated and protein domains were predicted. Out of these, 1116 excretory/secretory (ES) proteins were predicted and functionally annotated.

Effect of spice essential oils on *Aspergillus* spp.

Allspice leaf essential oil at 0.04% concentration completely inhibited *Aspergillus flavus* (IISRaf1), the mycotoxin producing fungus, within seven days of incubation by the poisoned food technique. Significant reduction in radial growth and biomass of *A. flavus* was also noticed with allspice leaf essential oils ranging from 0.02 to 0.03%.

Fig. 15. Thin layer chromatography with agar overlay assay of leaf oil against *A. flavus*

BIOINFORMATICS CENTRE

The SpiceCom database developed by the Centre was launched by Hon. DG, ICAR, New Delhi. Initiated development of a web application for managing the details of farmers (SpiceFarm) and a DSS tool with images for symptoms of various diseases of plants. A short-term training on 'Bioinformatics for metagenome data analysis' was conducted from 19-22 March 2019 with the support of Department of Genomic Science, Central University of Kerala, Kasaragod.

ECONOMICS AND IMPACT ASSESSMENT

Valuation of technology impact: A study on curcumin enhancement in turmeric

Using a logical framework of domestic production scenario, curcumin content and extent of varietal spread of high curcumin varieties, the approximate monetary value of higher curcumin consumption was worked out. The magnitude of the annual value of the monetary benefits (Rs. 22591 million INR) indicate the levels of returns which are often unheeded while measuring the returns from investments in agricultural research.

Value of germplasm conservation

Agricultural research is considered to be one of the public goods. In an exercise aimed at measuring the benefits from conservation of germplasm resources at ICAR-IISR Experimental Farm, the total direct investment incurred at the experimental farm from 1986-87 to 2017-18 (32 years) at 2011-12 prices was worked out (635.36 million INR). A simplified hedonic pricing model for valuing gains from the agricultural research. At five per cent share in pure crop research effect, the average yearly incremental production in these four crops attributable to germplasm conservation efforts during the last decade was valued at 1159 million INR.

Natural calamity in Kerala: impact on spice crops

A study on impact of the rain induced natural calamity was designed with an objective to gain a quick understanding of the ground level situation for primary producers of spice crops. To implement time bound intervention strategies for calamity mitigation, a simplified strategy was adopted in the sampling used for data collection. A total of 60 village panchayats across 27 Community Development Blocks were covered under the extensive survey. The ground truth collected from the extensive field surveys were used to firm up the data from agricultural department to arrive at the production impact of the natural calamity. The initial estimates of crop loss in terms of expected production deficit at state level over previous year amounts to 25138 tonnes (12541.1 million Rupees).

ICAR-ALL INDIA COORDINATED RESEARCH PROJECT ON SPICES

The XXIX Workshop of ICAR-All India Coordinated Research Project on Spices was held during 4-6 October 2018 at Dr. Y. S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh. The workshop was inaugurated by Dr. Hari C. Sharma, Hon'ble Vice Chancellor, Dr. YSPUH & F, Solan on 4 October 2018. In his inaugural address he opined that advanced biotechnological tools may be utilized for crop improvement and to enhance secondary metabolite content in spices. Dr. K. Nirmal Babu, Director, ICAR-IISR & Project Coordinator (AICRP on Spices), Kozhikode highlighted the importance of spices in Indian economy and research accomplishments made in spices. Dr. Gopal Lal, Director, ICAR-NRC for Seed Spices, Ajmer and Dr. Rakesh Gupta, Dean, College of Horticulture, Dr. YSPUH & F, Solan were the Guests of Honour and offered felicitations. During the inaugural session the "Best AICRPS Centre Award 2017-18" was presented to Pepper Research Station, Panniyur (KAU), Kerala. Thirteen booklets/pamphlets on spice production technologies from different AICRPS centres were released during the occasion. Varieties covering different spice crops such as ginger, turmeric, nutmeg, coriander and fenugreek suitable for different growing regions were recommended for release during the workshop. Six different technologies covering black pepper, cardamom, coriander and fennel were also recommended during the occasion.

Fig. 16. (a) Inaguration of the workshop (b) Presentation of Best AICRPS centre award to PRS, Panniyur

KRISHI VIGYAN KENDRA

KVK conducted total 84 trainings covering agriculture and allied fields benefiting 3057 farmers, rural youth, extension functionaries and students. It includes, two OJTs for sixty two students, paid training on Breeding and culture of ornamental fishes, Horticorp's bee keeping trainings. Training for 45 Kutumbasree members on planting material production and nursery establishment funded by District Kutumbasree unit, Kozhikode; Friends of coconut training funded

by CDB and one month Gardeners training funded by SHM were also organized. As mass awareness programmes, District level seminar on "Scientific cultivation of tapioca" in association with ICAR-CTCRI, Trivandrum; world soil day, seminar on soil health; workshop on "After flood management of soil and plants" for extension functionaries of ATMA & Department of Agriculture, Kozhikode; Productivity week seminar on "Tropical tubers cultivation"; live telecast of Pradhan Mantri Kisan Samman Nidhi inauguration by Hon'ble PM were organized for the benefit of 1500 farmers.

KVK also organized Technology week – 2019 (*Tharrum Thalirum*) for the benefit of about 800 farmers. Expert lectures were delivered by KVK staff on 'Doubling farmer's income' during Kisan Kalyan Divas organized by ATMA in all the 12 blocks of Kozhikode on 2 May 2018. Fourteen Front Line Demonstrations and five On Farm Trials on technology assessment and refinement in 149 farmer's fields were carried out in Naduvannur and Ulleri Panchayats. Among these, technologies on seed production of Pragati turmeric, Varada ginger, Kasturi turmeric, Estrus synchronization and fixed time breeding in goat, cows, FFS on apiary and value added products using honey were received very well by the stakeholders.

Fig. 17. Training class on honey production

INSTITUTE TECHNOLOGY MANAGEMENT-BUSINESS PLANNING AND DEVELOPMENT (ITM-BPD) UNIT

The ITM-BPD unit expanded its activities during the year. Thirteen new licenses for different technologies were issued during the year out of which six were for ginger and turmeric varieties, four for micronutrient technology and one each for seed coating, mobile app based instant analysis of turmeric quality and *Trichoderma.* Total revenue generated technology commercialization was 18.50 lakhs and Rs. 12.47 lakhs was earned through sale of planting materials, spices and other products during the year. The unit organized visit of Dr. Saji Gopinath who heads Kerala Startup Mission. He addressed scientists and discussed about the future collaboration of ICAR-IISR with KSUM and signing of MoA. The unit also organized a farmer interface meeting on "Facilitating direct marketing by spice

farmers and developing an incubation model" on 27 March 2019 at ICAR-IISR. Sri. S S Nagesh, Chief-Agriculture, Kerala State Planning Board was the chief guest on the occassion.

Fig. 18. Signing of MoA between ADA, Parasite Breeding Station, Kozhikode and ICAR-IISR for licensing '*Trichoderma harzianum'*

HINDI CELL

Institute was awarded Ganesh Sankar Vidyarthi Hindi Krishi Patrika Puraskar 2018 (second prize).The Official Language Implementation Committee (OLIC) of the institute met four times during the year. Four Hindi workshops on noting and drafting were conducted during 2018-19. Hindi week was celebrated from 14 – 22 September 2018 with various competitions like Hindi word power, caption writing, Hindi reporter, Hindi noting and drafting, pick and speak, Hindi song *etc*. The valedictory function of the Hindi Week was held on 22 September, 2018. Mr. Jitendra Gupta, Post Master General, Kozhikode was the Chief Guest of the function. Dr. Trilochan Mohapatra, Director General, ICAR released institute's Official Language Magazine *"Masaloon Ki Mehak"* 2018 on 22 December 2018 during the Institute visit.

Fig. 19. Release of Masaloon ki Mehak

MAJOR EVENTS

Workshop on Processing and value addition in spices

As a part of tribal empowerment initiative, ICAR-IISR organized a workshop on spice processing and value addition on 7 June, 2018 at Horticultural Research Station (AICRPS centre), Chinthapalle, Telangana. Four turmeric polishers and four turmeric boilers were distributed among four leading tribal Farmer Producer Organizations involved in turmeric cultivation and value addition. Along with tribal farmers, representatives from Tata trust, Vijayavahini Charitable Foundation, Girijan Cooperative Corporation, Gramin Vikas Kendra, and Society for Elimination of Rural Poverty, Government of Andhra Pradesh took part in the deliberations.

Fig. 20. A turmeric boiling unit being handed over to representatives of FPO in Chintappalle, Telangana

Consultative meeting on turmeric

ICAR-IISR and the Department of Horticulture, Government of Telangana jointly organized a consultative meeting to formulate strategies for enhancing the productivity of turmeric in the state with a strong focus on value chain development. The meeting was held at Centre of Excellence, Jeedimetla, Hyderabad on 5 June 2018. The deliberations were lead by Sri. L. Venkatram Reddy, Director Horticulture and Dr. K. Nirmal Babu, Director, ICAR-IISR. Progressive turmeric farmers from across Telangana and representatives from spice industry attended the event. The consultative meeting designed a strategic road map for the turmeric economy of the state.

International training programme on Value addition in spices

ICAR-IISR conducted Feed The Future-India Triangular Training (FTF-ITT), an International training programe on 'Value Addition in Spices' during 15-29 May 2018. The programe was sponsored by Project Management Unit (PMU) of National Institute of Agricultural Extension Management (MANAGE), Rajendranagar, Hyderabad; USAID India and Ministry of External Affairs (MEA), Govt. of India. Twenty two executive trainees from five partner countries; Uganda (5), Kenya (6), Malawi (5), Liberia (3) and Myanmar (3) attended the training programme.

Fig. 21. Trainees of FFT–ITT training programme

District level seminar on Good agricultural practices for clean and safe spices

As a part of its efforts to spread the awareness on Good agricultural practices, ICAR -IISR organized a district level seminar on Good Agricultural Practices for clean and safe spices on 22 December 2018. The seminar was inaugurated by Dr. Trilochan Mohapatra, Secretary, Department of Agricultural Research and Education and Director General, ICAR. More than 200 farmers attended the seminar. Dr. T. Janakiram, ADG (HS-II) and Sri. Suresh Chandel, Member, Governing Body, ICAR, were also present during the occasion. As part of the seminar, an exhibition was organized showcasing the technological advancements and varietal wealth in spices along with the current

developments in post-harvest processing and value addition in spices. The seminar included technical sessions on soil management practices for production of clean and safe spices and crop management practices for spice based farming systems.

Fig. 22. (a) Inauguration of the seminar on Good agricultural practices for clean and safe spices by Dr. T. Mohapatra, DG, ICAR at ICAR-IISR, Kozhikode (b) Inauguration of the exhibition

Swachhta activities

The Swachhta Pakhwada campaign at ICAR-IISR, Kozhikode was inaugurated by Dr. K. Nirmal Babu, Director during which, the Swachhta pledge was administered. To spread the message of clean environment, health and to highlight the significance of Swacch Bharat Mission to the general public, banners highlighting significance of Swachhta were displayed in public premises and awareness rally with participation of farmers were organized. The staff of ICAR-IISR Regional Station, Appangala organized cleanliness and sanitation drives in the villages adopted under *Mera Gaon Mera Gaurav.* The personnel of ICAR-IISR KVK, Peruvannamuzhi organized cleanliness campaign at Naduvannur Panchayat, Kozhikode and provided on the spot solution besides demonstrating farm waste recycling and methods for coir pith composting. On 22 December, the Swachhta programme at ICAR-IISR Headquarters was inaugurated by Dr. Trilochan Mohapatra, Director General, ICAR.

Fig. 23. Swachhta activities conducted at various centres of ICAR-IISR

AWARDS

Institute was awarded Ganesh Sankar Vidyarthi Hindi Krishi Patrika Puraskar 2018 (second prize). Dr. Rashid Pervez, former Principal Scientist and Hindi Officer received the award from ICAR, New Delhi on 16 July 2018.

AICRP on spices has won the prestigious Chaudhary Devi Lal outstanding AICRP award for the best AICRP for the year 2017-18. Pepper Research Station, Panniyur under Kerala Agricultural University has been awarded as the Best Centre under AICRPS.

Dr R. Dinesh received NAAS Recognition Award in Soil, Water and Environmental Sciences for the year 2018.

Dr E. Jayashree received the Commendation Medal Award - 2018 of Indian Society of Agricultural Engineers.

Dr V. Srinivasan received HS Mehta Memorial Best Young Scientist Award-2018

Dr D. Prasath was awarded the Fellow of Horticultural Society of India during January 2019.

Dr. M. S. Shivakumar, Dr M. Alagupalamuthirsolai and Dr V. Srinivasan won best oral presentation awards in different national seminars.

Dr. Rashid Pervez, former Principal Scientist and Hindi Officer receiving the award

1. *Piper pedicellatum*, 2. *Etlingera fenzlii*
3. *Piper clypeatum*, 4. *Piper makruense*
5. *Garcinia nervosa*, 6. Mermithid nematode infesting turmeric shoot borer

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