EMERGING PRODUCTION TECHNOLOGIES ON SPICES FROM IISR, CALICUT

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Intensive research on spices in the country was initiated with the establishment of a regional station of Central Plantation Crops Research institute (CPCRI) at Calicut, 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. The Cardamom Research Center at Appangala was subsequently merged with it to intensify research on spices. The NRCS was further upgraded to the present Indian Institute of Spices Research (IISR) during 1986.

Black pepper (*Piper nigrum*), cardamom (*Elettaria cardamomum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), cinnamon (*Cinnamomum verum*), cassia (*C. cassia*), vanilla (*Vanilla planifolia*), nutmeg (*Myristica fragrans*), garcinia (*Garcinia gummi- gutta*), clove (*Syzygium aromaticum*), allspice (*Pimenta dioica*) and paprika (*Capsicum annuum*) are the mandate crops of IISR. The current developments in spices research at IISR and recommendations of nutrients, pest and disease management for major spice crops are mentioned below.

1. Black pepper (*Piper nigrum*, L.)

Germplasm collection and conservation

Black pepper originated in the Western Ghats. The Indian Institute of Spices Research has played a key role in collection and conservation of genetic resources of spices, which include cultivated, wild and endangered species. The institute holds the world's largest collection of black pepper germplasm. The collections include 2300 black pepper accessions besides more than 1400 hybrids and 150 open pollinated progenies of black pepper. The valuable collections in the spice gene bank include endangered spices like *Piper barberi, P. hapnium, P. silentvalleyensis* and other wild spices like *P. mullesua, P. thomsonii, P. peepuloides* etc. The germplasm has been characterized for yield, quality and resistance to pests, diseases and drought. Molecular characterization of germplasm is in progress.

Crop improvement

Various improved varieties that had a great impact in increasing the production and productivity of black pepper in the country have been developed. Four high yielding and high quality varieties of black pepper, Sreekara (2677 kg dry/ha), Subhakara (2352 kg dry/ha), Pournami (2333 kg dry/ha), and Panchami (2828 kg dry/ha) were released, among which Pournami is tolerant to root knot nematode. Four more varieties of black pepper *viz.*, IISR Shakthi, tolerant to phytophthora and yielding 2253 kg dry/ha, IISR Thevam, field tolerant to phytophthora and yielding 2481 kg dry/ha, IISR Girimunda, a hybrid for high elevation (2880 kg dry/ha) and IISR Malabar Excel, another hybrid for high elevation (1440 kg dry/ha) have been proposed for release (Table 1).

Biotic and abiotic stresses are the major production constraints. Foot rot, slow decline and 'pollu' beetle in black pepper are some of the major stresses. Successful efforts have been made to locate resistant gene sources. This has led to the identification of some field resistant/tolerant lines. These resistant gene sources are being utilized in conventional and molecular breeding programmes. *Piper colubrinum* with multiple resistances to *P. capsici*, *R.similis*, *M. incognita* and 'pollu beetle' is a good rootstock. About 78% success was observed with double graft method of pepper on *P. colubrinum* and the field performance of these grafts are highly encouraging.

Nutrient management

Integrated nutrient management including organic farming technologies have been standardized in black pepper. Besides, fertilizer schedules and foliar diagnostic norms for assessing nutrient balance and yield for obtaining higher yields for black pepper have been standardized. A fertilizer dose of 140:55:270 g of NPK/ vine/year for laterite soils has been recommended for black pepper.

Rapid multiplication of nucleus planting material

In view of the increasing demand of quality planting materials of spices, rapid methods for propagation for large-scale production of planting materials and high production technologies for black pepper have been developed and popularized in farmers' fields. Using split bamboos for rapid vegetative multiplication of single nodes of black pepper, a multiplication rate of 1:40 has been achieved. However, this method was found to promote diseases and hence another efficient method viz., serpentine method was developed. A multiplication ratio of 1: 60 single node rooted cuttings could be achieved by adopting the new serpentine method. About 3.5 lakh rooted cuttings of improved varieties of black pepper were produced and distributed by IISR in the last 5 years.

Value addition

Identifying varieties or accessions among the germplasm for rich oil, oleoresin and pungent principles is a major priority for value addition. In pepper the parameters of interest are grades of black pepper berries, bulk density, green pepper products, white pepper, oil, oleoresin and piperine content. Some of the high quality varieties identified are Kottanadan, Kumbhakodi, Balankotta, Sreekara, Subhakara, Jeerakamundi and Malabar Excel. Importance was also given to develop processing techniques, harvesting tools and techniques, which add value to the primary products. Techniques have been standardized to prepare white pepper from red berries and pepper in brine from tender berries. Panniyur-1 and Balankotta are the cultivars found good for preparing white pepper.

Pest and disease management

Besides, new pests and diseases are also threatening the black pepper plantations. The most serious among these are root infestation by mealy bugs, 'stunt' and 'phyllody' disease of black pepper. *Phytophthora* foot rot and slow decline in black pepper still remain a major threat. The pollu beetle (*Longitarsus nigripennis*) is the most destructive insect pest of black pepper especially in the plains and midlands. An integrated strategy was developed for management of this beetle. This involves regulation of shade and spraying of quinalphos 0.05% during July and October or spraying of quinalphos 0.05% during July followed by 3-4 sprays of Neemgold 0.06% during August-October.

Phytophthora foot rot caused by *Phytophthora capsici* is the most serious disease affecting black pepper. An integrated management strategy involving cultural practices, chemical and biological control and use of resistant variety has been developed.

The cuttings in the nursery should be raised in sterilized potting mixture fortified with biocontrol agents such as VAM (100 cc/kg), *Trichoderma harzianum* (1 g/kg) and *Pseudomonas fluorescence* (1 g/kg). Phyto-sanitation and shade regulation in the plantation are important. Application of *Trichoderma harzianum* and *Pseudomonas fluorescens* (50 g/vine) twice a year during May-June and August-September is recommended. In diseased gardens, foliar spray with potassium phosphonate 0.03% or Ridomil mancozeb 0.125% during May-June and August-September is to be adopted. A cost effective package has been developed combining both neem products and insecticides. Aqueous leaf extracts of *Chromolaena odorata*, *Strychnos nuxvomica*, garlic, mustard, *Piper colubrinum* and allspice leaves are found to be inhibitory for *P.casici* at various phases of life cycle under *in-vitro* conditions. A black pepper variety, IISR-Shakthi, which is resistant to the pathogen, has been recommended for release.

Slow decline is also a major disease of black pepper and occurs due to feeder root damage by the nematodes *Radopholus similis* and *Meloidogyne incognita* and also *P. capsici*. Pathogen-free rooted cuttings raised in sterilized nursery mixture fortified with biocontrol agents should be used for planting in the field. Severely affected vines should be removed from the plantation. Biocontrol agents like *Pochonia chlamydosporia* or *Trichoderma harzianum* (50 g/vine) can be applied during May-June and September-October. In severely infested gardens nematicides such as phorate 10 G @ or carbofuran 3 G should be applied during May-June and September–October. In areas severely infested with root knot nematodes, the resistant variety Pournami may be planted. Methodology for the large scale multiplication of biocontrol agents on agricultural waste like coffee pulp and organic materials like sorghum seeds have been standardized. For the production of disease free quality planting materials in the nursery soil solarization and incorporation of biocontrol agents like *Trichoderma*, VAM etc were found to be very effective (Table 2).

A DAS-ELISA based procedure has been standardized for indexing black pepper for viruses and species-specific primers were developed for identification of *R. similis*. A method for simultaneous isolation of RNA and DNA from infected black pepper plants and multiplex PCR for simultaneous detection of CMV and badnavirus in a single reaction has been standardized.

During the last 27 years, intensive research was carried out for controlling the major diseases of spices and technologies were formulated. The plant protection technologies developed at IISR are given in Table 3. A Repository of biocontrol agents of bacteria, fungi and nematodes affecting spice crops has been established at IISR to conserve, characterize and document the variability and potential of biocontrol agents. Large scale multiplication of biocontrol agents for distribution to farmers is also being undertaken. Cultures of biocontrol agents are also being provided to entrepreneurs for multiplication. Emphasis is now being given for developing rapid diagnostic techniques for detection of pathogens, developing resistant varieties through conventional and molecular approaches, and developing consortia of biocontrol agents for management of various pests of pathogens.

2. Ginger and Turmeric

Crop improvement

Several putative wild types of ginger and high curcumin types of turmeric have been collected and conserved in the *ex-situ* gene bank. The institute presently has 665 ginger and 924 turmeric accessions. Emphasis was given to evolve varieties through selection and breeding for high yield, quality and resistance to biotic and abiotic stresses. So far IISR has released 5 turmeric and 3 ginger varieties. Three ginger varieties with high yield and quality, Varada (22.7 t fresh/ha), Rejatha (22.4 t fresh/ha), and Mahima (23.2 t fresh/ha) were released. Five high curcumin and high yielding turmeric varieties namely Suvarna (17.4 t fresh/ha), Sudarsana (28.8 t fresh/ha), Suguna (29.3 t fresh/ha), Prabha (37.5 t fresh/ha) and Prathibha (39.1 t fresh/ha) were also released. Besides two more varieties namely IISR Kedaram (34.5 t fresh/ha) and IISR Alleppey Supreme (35.4 t fresh/ha) have been proposed for release (Table 1). Biotechnological tools involving micro propagation protocols have been standardized and are used in rapid clonal multiplication of ginger and turmeric. Direct regeneration of plantlets from pseudostem of ginger has been achieved through tissue culture. Besides, 'synseed' technology and production of micro tubers in ginger and turmeric have become handy for production of disease-free planting material.

Crop production

Several agronomic practices for have been standardized for ginger and turmeric. This includes INM schedules, organic methods of cultivation, irrigation schedules and targeted yield production technologies. Main components of organic farming such as recycling of organic residues and vermi composting have been taken up. Biofertilizer programmes using *Azospirillum*, P-solubilizing bacteria and fungi and also Vesicular Arbuscular Mycorrhiza (VAM) have been initiated and the initial results are encouraging.

The nutritional requirement of improved varieties of ginger was standardized to meet the major, secondary and micro nutrient requirements. Under IPNM, dosage of organic amendments *viz.*, neem cake, groundnut cake and gingely cake (1 to 2.5 t/ha) for improving the physicochemical properties of soil and increasing the yield and quality of ginger was standardized. As the major spice growing soils are acidic, better source (rock phosphate) and

dose of application of P on incubation with FYM (10 t ha^{-1}) was standardized for ginger (25 kg P_2O_5 ha^{-1}) to improve the agronomic efficiency of applied P. The optimum zinc fertilizer dose for getting maximum rhizome yield was found to be 6 kg ha^{-1}.

In ginger, critical concentrations for soil and foliar zinc levels to obtain profitable yield were calculated by graphical method of Cate and Nelson (1965) and found to be 2.1 mg kg^{-1} for soil (Fig. 1) and 27 mg kg^{-1} for foliar concentrations. These critical levels when verified by Mitscherlich model at 90% sufficiency level were higher than that of graphical method and found to be 3.4 mg kg^{-1} and 37 mg kg^{-1} respectively for soil and leaf concentrations. The investigation on nutrient requirement for targeted production of ginger shows that in the targets with 10, 15 and 20 kg fresh yield/3 m^2 the mean yield recorded is 11.04, 11.93 and 12.2 kg/3 m^2 respectively. The deviation from the fixed targets was calculated to be +10.4, -20.4 and -39.0% respectively, stating that at targets level of 15 kg/bed, we could achieve up to 80% of the targets fixed. At 10 kg /3 m^2 target, the yield exceeded the target fixed.The nutritional requirement of improved varieties of turmeric was standardized to meet the major, secondary and micro nutrient requirements. Recommendation on lime requirement and NPK requirement under chemical (60: 50: 120 kg N, P_2O_5 and K_2O ha^{-1}) and integrated nutrition methods were recommended. Under IPNM, dosage of organic amendments *viz.*, neem cake, groundnut cake and gingely cake (1 to 2.5 t/ha) for improving the physicochemical properties of soil, increasing the yield and quality of turmeric was standardized. As the major spice growing soils are acidic, better source (rock phosphate) and dose of application of P on incubation with FYM (10 t ha^{-1}) was standardized for turmeric (25 kg P_2O_5 ha^{-1}), to improve the agronomic efficiency of applied P. The investigation on nutrient requirement for targeted production of turmeric showed that in the targets with 15, 20 and 25 kg fresh yield/3 m^2, the mean yield recorded are 26, 24.2 and 26.6 kg/3 m^2 respectively. The deviation from the fixed targets was calculated to be +73, +21 and +6.3% respectively, stating that at all targets levels the rhizome yield exceeded the target fixed.

Value addition

Among the parameters that define ginger quality, thrust was given to crude fibre content, oil and oleoresin. Among the traditional varieties, Rio-de-Janeiro, Gurubathani etc. contain more than 6% fibre. Maran, Himachal etc. contain 5-6% fibre. New varieties like Varada, Mahima, Rejatha etc. are relatively low fibre types. High fibre types are more ideal for oleoresin extraction. Many accessions with 3% fibre were identified. Techniques have been standardized for fresh ginger products like salted ginger, ginger based jam, squash etc.

Studies on the biosynthesis of curcuminoids were initiated to assay, localize and characterize the key enzymes involved in the biosynthetic pathway and to identify the precursors and intermediates during biosynthesis. The primary rate-limiting enzyme initiating the biosynthesis of curcuminoids was found to be Phenylalanine Ammonia Lyase (PAL). Higher levels of PAL were indicated in the early germination phase, suggesting the formation of phenolic precursors. The role of phenylalanine as the starting material for the biosynthesis was also confirmed through tracer studies.

Priority was also given to identify turmeric accessions with high curcumin. In the industrial point of view turmeric with more than 5.5% curcumin are highly desirable. Many accessions with more than 6% curcumin were identified. Curcumin content varies with location. Some of the high curcumin lines identified are Suguna, Sudarshana, Prabha, Prathibha, IISR Alleppey supreme etc. Planting turmeric in May and harvesting in November yield 30% more curcumin compared to harvesting at full maturity. However, there will be slight reduction in yield.

Pest and disease management

Pests and diseases have remained as bottlenecks in hampering productivity of ginger and turmeric. Among the pests, shoot borer (*Conogethes punctiferalis*) is the most serious insect pest of ginger. An integrated schedule including pruning of freshly infested shoots at fortnightly intervals during July–August and spraying malathion (0.1%) at monthly intervals during September– October was found to be effective in controlling the pest infestation on ginger. Another major pest, rhizome scale (*Aspidiella hartii*) infests rhizomes of ginger and turmeric in storage. Storage of seed rhizomes in dried leaves of *Strychnos nux-vomica* + sawdust in 1:1 proportion helps in keeping the seed rhizomes free of scale infestation. In case the infestations are severe, dipping of seed rhizomes in quinalphos 0.075% before storage may be essential.

Soft rot caused by *Pythium* spp is the most destructive disease of ginger and turmeric. Seed rhizomes are to be selected from disease-free gardens, and stored suitably. Cultural practices such as selection of well-drained soils for planting is important. Application of *Trichoderma harzianum* (50 g/bed) at the time of planting and after 45 days was found to help in preventing the disease. Removal of diseased clumps and drenching the affected and surrounding beds with copper oxychloride 0.2% checks the spread of the disease.

Bacterial wilt caused by *Ralstonia solanacearum* is also a serious soil and seed-borne disease affecting ginger. Selection of seed rhizomes from disease-free gardens, and planting in well-drained soils has been found to minimize the occurrence of this disease. Besides, solarization of seed rhizomes on a sunny day soon before planting to attain a temperature of 46-48°C in the rhizomes for about 30 min has been found to be effective in disinfecting the rhizomes. BT (*Bacillus thuringiensis*) formulations are found effective against stem borer of ginger and turmeric. *Pasteuria penetrans, Paecilomyces lilacinens* and *Verticillium chlamydosperium* are effective in controlling root knot and burrowing nematodes.

3. Cardamom

Germplasm collection and conservation

Collection and conservation of cardamom germplasm is a major mandate of IISR. The *ex-situ* genebank of the institute is augmented regularly by undertaking collection programmes from the primary and secondary centres of origin. Multi branch type of cardamom and natural 'katte' resistant lines of cardamom have been collected and conserved in the *ex-situ* gene bank. The *ex-situ* gene bank presently consists of 439 collections, hybrids and disease resistant selections of cardamom.

Varieties

Emphasis was given to evolve varieties through selection and breeding for high yield, quality and resistance to biotic and abiotic stresses. So far IISR has released 3 cardamom varieties (Table 1). Suvasini, a high yielding variety suitable for high density planting (745 kg dry/ha), Avinash, a variety resistant to rhizome rot disease (847 kg dry/ha) and Vijetha, a variety resistant to *katte* disease (643 kg dry/ha) have been released.

Crop production

High production Technologies (HPT) developed through high yielding varieties and effective crop management practices in cardamom has achieved about 200% increase in yield. In cardamom it is proved that through HPT programme 460 kg/ha can be produced against 116kg/ha under average management.

Drip irrigation or sprinkler irrigation once in 12 days recorded significantly higher number of clumps, more number of leaves per tiller and panicles per plant. No significant variation was observed in soil moisture content between irrigation treatments. Drip irrigation @ 8 L plant^{-1} daily from January 15th onwards recorded higher yield (575 kg ha^{-1}) followed by sprinkler irrigation once in 12 days (395 kg ha^{-1}). I was also found that trench system of planting is superior over pit system of planting with less run off (10.8mm) and soil loss (66.34 kg ha^{-1}).

Efforts are on to screen the cardamom germplasm collections and to characterize the drought tolerant cultivars based on identified parameters. Studies revealed that plant height, number of tillers, dry weight of leaves, stem and root were reduced under water stress conditions. Relative water content decreased and membrane leakage increased under stress treatment. Mysore types were found to be susceptible to moisture stress compared to Malabar and Vazhukka.

Pest and disease management

Cardamom thrips (*Sciothrips cardamomi*) are widespread and destructive pests of cardamom damaging shoots, panicles and capsules. Pruning of leaf sheaths during February–March, regulation of shade and removal of other herbaceous host plants around the plantation reduces the pest population in the field. Insecticides such as quinalphos 0.025%, fenthion 0.05% and phosalone 0.05% and 5–7 rounds of sprays along with the cultural operations were found to be effective against thrips.

Katte disease caused by virus is the most important disease of cardamom. Roguing of disease affected clumps and replanting with katte resistant variety such as IISR-Vijetha is recommended. Soil borne diseases such as plant parasitic nematodes, rhizome rot and damping off could be controlled by integrated approach (Tables 2 & 3). 'Katte' clinics were set up to appraise the farming community on the management of 'Katte' disease. Rhizome rot disease of cardamom caused by *Pythium vexans* and *Rhizoctonia* sp. can be managed by phytosanitation, providing adequate drainage, application of *Trichoderma harzianum* (50 g/clump) twice a year during May-June and September-October and planting of the resistant variety IISR-Avinash.

Tree spices

Presently IISR has 484 nutmeg, 225 clove, 408 cinnamon including cassia, 116 garcinia and 180 allspice accessions. Epicotyl grafting and top working in nutmeg, and air layering and rooted cuttings of cinnamon, cassia and allspice are some of the novel propagation methods standardized in tree spices.

Two high quality cinnamon varieties, IISR Navashree (250 kg dry/ha) and IISR Nithyashree (250 kg dry/ha) and a nutmeg variety, IISR Viswashree (3122 kg dry seed/ ha and 480 kg mace/ha at 8th year) were also released (Table 1). Four high yielding high quality cassia accessions have been identified for release.

Bark oil, leaf oil, cinnamaldehyde and eugenol oil, bark oleoresin etc. are the quality constituents in cinnamon. In *Cinnamomum cassia* both leaf and bark oil contain more than 80% cinnamaldehyde and trace of eugenol. Clove bud, leaf and stem yield oil. The oil of all three fractions contains eugenol as the main constituent. In nutmeg both nut and mace is used for extracting oil. Both contain about 13 to 16% oil. Major constituents in the oil are sabinene, myrcene, limonene, myristicin, elemicin and safrole. Among the nutmeg accessions at IISR, myristicin content ranged from 3.6 to 4.5% in nutmeg oil and 1.0 to 36% in mace oil. Myristicin is an established hallucinogenic principle.

Future thrusts

Despite the significant achievements made on various aspects, there are gaps, which deserve our attention. New research programmes for increasing the production and productivity by increasing the area of cultivation, identifying new prospective areas and using high yielding and high quality planting materials are to be intensified. Concerted efforts need to be made for value addition and product diversification.

Increasing productivity of spices through development of varieties with resistance to biotic and abiotic stresses and Integrated Plant Nutrient Management (IPNM) techniques suited to different agro-ecological situations in the country is another important are which needs attention. Non-traditional area expansion based on soil suitability studies should be given priority. There is a very good scope for bringing the tea and coffee estates under pepper production since about one third of the shade trees in the estates are planted with pepper. It is estimated that tea estates in Wayanad and other areas in North East can also accommodate more than 2 million standards for pepper. Therefore, ideal varieties suitable for this region have to be identified.

Another key area that needs emphasis is the production of organic spices as there is an increasing potential for organically produced spices in the global market. The annual growth rate of organic spice market is around 20%. Increasing the productivity of spices by exploiting hybrid vigor (pepper, cardamom and seed spices), characterization of germplasm for better economic traits and molecular profiling of the existing germplasm and identification of useful genes for further exploitation of important spices needs focus.

Table 1. Improved varieties of major spices developed by IISR

Sl. No.	Crop	Varieties	Total	Yield
1	Black pepper	Sreekara, Subhakara, Panchami, Pournami, PLD-2, Thevam,* Girimunda*, Malabar Excel*, Sakthi*	8	1417 – 2947 kg/ha
2	cardamom	Suvasini, Avinash, Vijetha	3	643-848 kg/ha
3	Ginger	Varada, Rejatha, Mahima	3	22.4- 23.2 t/ha
4	Turmeric	Suvarna, Suguna, Sudarsana, Prabha, Prathibha, Alleppey Supreme*, Kedaram	7	17.4 – 39.12 t/ha
5	Cinnamon	Navashree, Nityashree	2	400 – 500 kg/ha
6	Nutmeg	Viswashree	1	3122 kg nuts/ha

* Varieties approved for release.

Table 2. Disease of spices with biocontrol method

Crop	Disease	Casual organism	Bio control methods
Black pepper	Phytophthora foot rot	*Phytophthora capsici*	Soil application of VAM, *Trichoderma* spp.
	Slow decline	*Radopholus similis, Meloidogyne incognita P.capsici*	Soil application of VAM, *Trichoderma* spp.
Cardamom	Damping off	*Pythium vexans*	*Trichoderma* spp. in solarized nursery beds
	Rhizome rot	*P.vexans, Rhizoctonia solani*	Soil application of *Trichoderma* spp.
	Capsule rot	*Phytophthora meadii P.nicotiane* var *nicotiane*	Soil application of *Trichoderma* spp.
Ginger	Rhizome rot	*Pythium aphanidermatum P. myriotylum*	Soil solarization and application of *Trichoderma* spp.
	Ginger yellows	*Fusarium* spp	Soil solarization and application of *Trichoderma* spp.

Table 3. Technologies developed by IISR to control major pests and diseases of important spices

Major Diseases/constraints	Technology
Phytophthora foot rot in black pepper	Phytosanitation, minimum tillage, two pre- monsoon sprays with Bordeaux mixture (1%), one drenching with Copper oxychloride (1%) combined with Pottassium phosphonate spray and drench, in place of Bordeaux mixture
'Katte' and 'koke kandu' of cardamom and stunted disease of black pepper	Rouging out diseased plants and phased replanting with healthy plants
Nursery management in pepper and cardamom nurseries to suppress disease	Soil solarization with plolythene sheets for 30-40 days as a pre-sowing treatment. Incorporation of VAM and *Trichoderma* in the nursery
Rhizome rot of ginger	Healthy seed selection, seed dressing with *Trichoderma*, and its soil application coupled with organics. Soil solarization
Nematodes and root grubs in cardamom	Spot application of phorate @2.5 g/ clump twice a year during April-May and October – November
'Pollu beetle' in black pepper	Shade regulation and spraying quinalphos (0.05%) during July (21 – 30 days after the setting of berries) followed by three sprays of Neemgold (0.6%) during August, September and October.
Shoot borer in Ginger and Turmeric.	Prune freshly infested shoots at fortnightly intervals during July-August and spray malathion 0.1% at monthly intervals during September-October.