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Exploring spices production at sustainable basis

There is a great scope to improve the productivity of major spices by adopting technologies that will help bridge the gap between potential yields realized in the research stations/progressive farmers' plots and those realized in other marginal farmers' plots. While there is a little scope for enhancing the area under spices in traditional belts of the country, we need to focus on newer niches where the potential for spices cultivation is immense. Fortunately, spices cultivation is now spreading to non-traditional areas and is being expanded in the North-Eastern Hill region through the Tribal Sub Plan, which will subsequently help in including several niche areas of spice cultivation, where opportunities and skill sets for the future exists. In addition, research programmes are to be intensified in the area of high-value compounds in spices for possible drug formulations and to develop nutrigenomics and pharmacogenomics as a composite technology in the area of bioactive compounds. India can withstand competition only by increasing productivity and reducing cost of cultivation, leading to low cost per unit of production. Nurturing and improving sound techniques on precision farming, protected cultivation and urban horticulture can help in surmounting the challenges posed by other growing countries. A well reasoned and cohesive application of cutting edge research, institutional support for development and creative policy initiatives can ensure a vibrant spices sector in our country, says Dr Janakiram, ADG (Hort. Sci.) at the ICAR Headquarters.

INDIA, while asserting its dominance in world spice production and trade, will continue to make impressive strides during the coming decade. The country still holds a major stake in the global spices market with a production of 6,108 thousand tonnes of spices during 2014-15 from 3,317 thousand ha (Table 1). The export in terms of value has reached an all time high of US $ 2.48 billion during 2015-16.

The food and pharmaceutical industry rely on these high-value low-volume commodities to produce an assortment of products that are designed to meet the varied needs of the consumers across the world. The growth rate for spices demand in the world is around 3.19%, which is a shade above the population growth rate. Though every state/Union Territory in the country grows at least a few spice crops, Kerala, Andhra Pradesh, Gujarat, Maharashtra, West Bengal, Karnataka, Tamil Nadu, Odisha, Madhya Pradesh, Rajasthan and North-Eastern states are major spices-producing states.

Among major spice crops, area under black pepper during 2014-15 was 128 thousand ha with a production of 64,640 tonnes. Small cardamom is cultivated in an area of 99.56 thousand ha, with a production of 24,360 tonnes. Kerala has 59% of total cardamom area and contributes 70% of production; Karnataka 34% of area and 23% of production and Tamil Nadu has 7% of area as well as production. India ranks first with respect to ginger and turmeric production, contributing about 32.75 and 94% of world's production, respectively. The ginger production was 7,60,310 tonnes in 2014-15 from an area of 1,41,650 ha with a productivity of 5,367 kg/ha. North-Eastern states

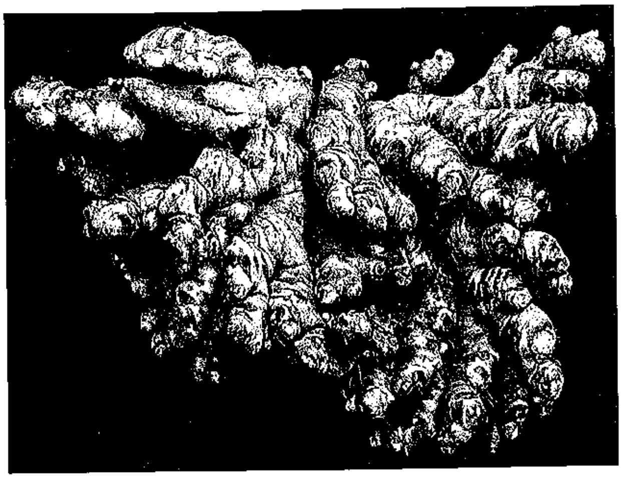
Table 1. Major spices grown in India (2014-15)

Spice	Area ('000 ha)	Production ('000 t)	Productivity (kg/ha)
Black pepper	128.67	64.64	502
Ginger	141.65	760.31	5367
Chillies	760.98	1605.01	2109
Turmeric	184.44	830.39	4502
Cardamom	99.56	24.36	245
Garlic	262.06	1425.46	5439
Coriander	552.66	461.71	835
Cumin	889.76	485.51	546
Fennel	38.66	59.75	1546
Fenugreek	123.35	130.82	1061
Ajwan	24.09	16.42	682
Other seed spices	24.27	20.52	845
Clove	2.32	1.22	526
Nutmeg	21.12	14.40	682
Tamarind	54.48	201.66	3702
Cinnamon/ tejpat	2.74	5.05	1843
Saffron/ vanilla	6.47	1.05	162
Total	3317.28	6108.28	1841

Source: NHB, Gurgaon

Varietal Wealth Enriching Spices Basket

Turmeric IISR Alleppey Supreme



Ginger IISR Mahima

Black pepper IISR Thevam

Black pepper IISR Malabar Excel

Cardamom Appangala 1

account for 37% area under ginger, contributing 48.9% to production, while Karnataka, Kerala, West Bengal, Odisha, Himachal Pradesh and Madhya Pradesh account for the remaining 51% of ginger production. Andhra Pradesh is the leading turmeric producing state (44%) in India, followed by Tamil Nadu (19%). The area under the crop was 18,44,40 ha with a production of 83,03,90 tonnes and productivity of 4,502 kg/ha during 2014-15. Even though India is the largest producer and consumer of ginger and turmeric, our productivity is low compared to China. India also has 2,060 and 18,900 ha area under clove and nutmeg mainly cultivated in the Western Ghats slopes in Kerala and Tamil Nadu, producing 1,070 and 12,780 tonnes of produce, respectively.

In export, 8,42,000 tonnes of spices and spice products valued ₹ 16,238 crore (US$ 2482 million) were exported during 2015-16, registering an increase of 9% in value terms over last year. The share of spices to total agri-products export is about 2.8% in quantity and 7.8% in value. Among the export of different spices, maximum share was from chilli, followed by seed spices, turmeric and black pepper. However in value, mint products and spice oils and oleoresins contributed a major share of the total export earnings.

Improved Varieties

Several high-yielding and improved varieties of ginger, turmeric, cardamom, black pepper and nutmeg have become very popular across the country. High piperine and oleoresin containing varieties of black pepper (IISR Girimunda and IISR Malabar Excel) which are also suitable for cultivation in high altitudes and plains have been released. IISR Thevam and IISR Shakthi are tolerant to *Phytophthora* foot rot disease. High-yielding varieties, Sreekara, Subhakara, Panchami and rot-knot nematode tolerant variety Pournami are suitable for all pepper growing locations of India. Ginger varieties, IISR Varada and IISR Rejatha with high essential oil and oleoresin content are suitable for growing all over India. Apart from high oil content, IISR Mahima is also resistant to nematodes (*M. incognita* and *M. javanica*). High-yielding (Suguna, Suvarna, Sudharsana) and stable curcumin varieties suitable for growing throughout India have been developed (IISR Prabha, IISR Kedaram, IISR Prathibha and IISR Alleppey Supreme).

Cardamom variety (IISR-Appangala-1) is preferred widely by the oil extraction industries, whereas IISR-Appangala-2 and IISR

World's biggest spices germplasm collection

There is worlds biggest spices germplasm collection at IISR, Calicut, consisting of black pepper (3181), wild pepper (1503), cultivars (1669), exotic species (9) cardamom (618), ginger accessions (668), turmeric (1404) and nutmeg (484) accessions.

Vijetha are suitable for mosaic affected areas of Karnataka. Cardamom variety, IISR Avinash, is a rhizome rot tolerant variety. High-yielding and high quality varieties of nutmeg (IISR Viswashree and IISR Keralashree) have also been developed. IISR Keralashree is the first farmer's variety developed under Farmer's participatory breeding programme. Cinnamon varieties (IISR Nithyashree and IISR Navashree) have high shoot regeneration capacity with high bark oil and oleoresin content.

Planting Material

It is often difficult to meet the ever increasing demand for planting material of these popular varieties. Hence we have initiated granting of non-exclusive licenses from 2011 for commercial production of these varieties. Healthy and disease-free planting material is provided to the licensees and they are entrusted with the responsibility of supplying quality planting material without deteriorating the genetic purity. The institute is now linking their clients to these licensees who in turn meet their demand. The institute has issued 24 plant variety licenses to the clients till date. The list of important licensees who may be contacted for supply of certified planting material of spices is given in Table 2.

RESEARCH IN SPICES

Soil-Less Method

The major diseases in ginger are soft rot caused by *Pythium* sp. and bacterial wilt caused by *Ralstonia solanacearum*. These pathogens are both seed and soil borne. Infection by these pathogens can be reduced by at least 50% through the use of disease-free planting material. A transplanting technique in ginger by using single bud sprouts (about 5 g) has been standardized to produce good quality planting material with reduced cost. The yield level of ginger transplants is on par with conventional planting system.

The technique involves raising transplants from single sprout seed rhizomes in the pro-tray and planting in the field after 30-40 days. The advantages of this technology are production of healthy planting material and reduction in seed rhizome quantity and eventually reduced cost on seeds. Other advantages of this method include less planting material requirement (500-750 kg/ha), hence saving in seed cost and only one-fifth of seed material is needed. It aids in 98–100% field establishment and is suitable for high production technology, early/delayed planting and ensures high cost: benefit ratio.

Multiplication of Black Pepper

Non-availability of healthy planting material is a serious problem in black pepper. The present technology is a solution to this. Partially composted coir pith and vermicompost enriched with *Trichoderma* is used as medium for raising seedlings in pro-trays. Single node cuttings of black pepper are planted in trays and maintained under controlled greenhouse conditions and hardened under shade net greenhouse. The seedlings are ready for field planting within 120 days of nursery rearing. This nursery technique has enabled the production of disease-free seedlings with ease for transportation and also enhances successful establishment of vines with vigorous growth. Reduced cost of production (₹ 6.50 paise/plant.) attracts the low income group farmers to adopt this technology.

Vertical Column Method

The continuous demand for quality planting material has created a novel idea of producing orthotrope on vertical column (2 m) having one foot diameter made with plastic coated welded wire mesh (size 4 cm) filled with composted pasteurized cocopeat and vermicompost @3:1 ratio fortified with biocontrol agent, *Trichoderma harzianum*, in poly house fitted with fan and pad system maintaining temperature of 25 to 28°C and relative humidity of 75% to 80% with misting units. Eight to ten cuttings can be planted around each vertical column.

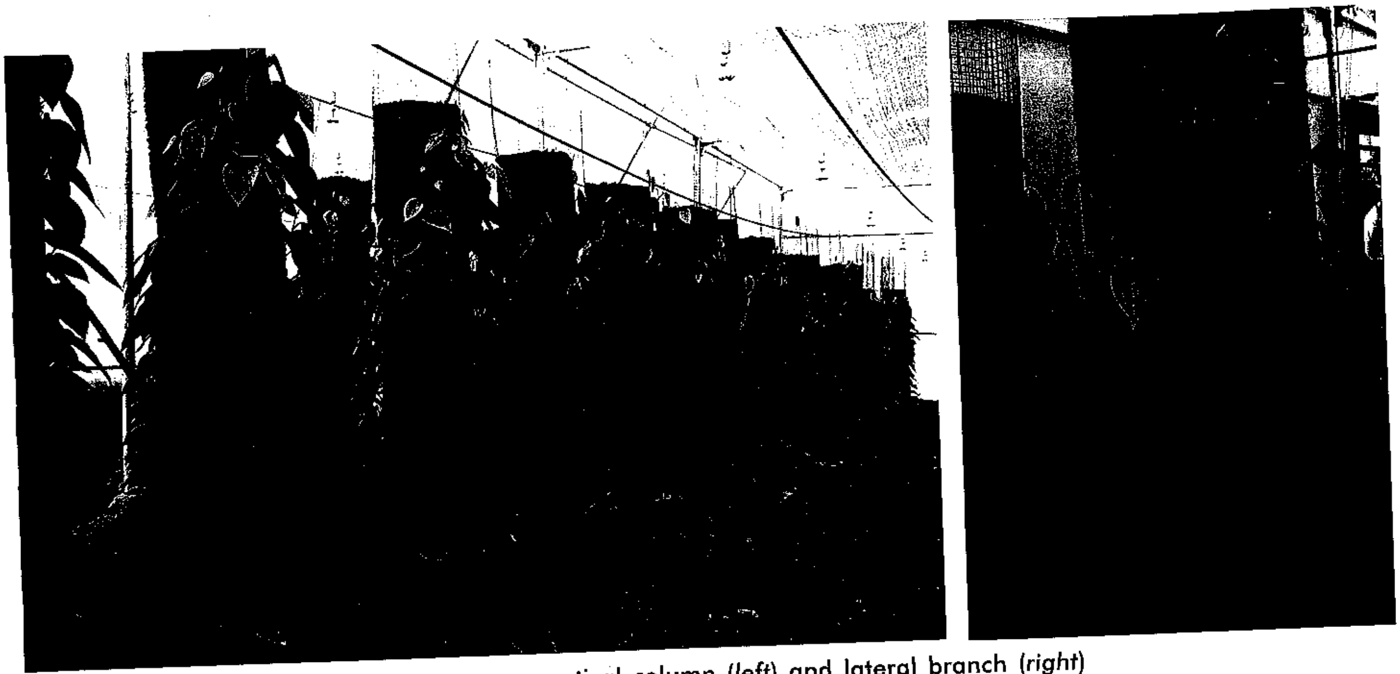
The cuttings are allowed to trail on column and it would take four months to reach the top and produce more than 20 nodes. Each vine invariably produce lateral reproductive branches within three months time at 12th–15th node, whereas vines allowed to grow horizontally on

Maintenance of pro-trays (30-40 days)

Transplant ready ginger plants

Healthy planting material of ginger using pro-trays

Black pepper seedlings in pro-trays



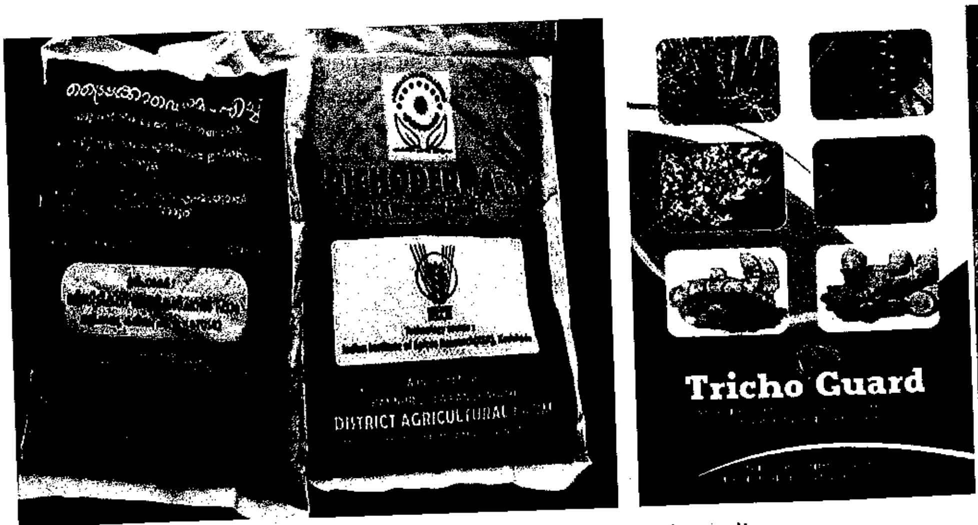
Black pepper on vertical column (*left*) and lateral branch (*right*)

the bed with same medium also produce similar number of nodes but will not have lateral fruit bearing branch. The top 5-7 nodes have lateral branches also. The top 5 nodes can be used as orthotropic shoots as is done in Malaysia and Indonesia to induce fruiting laterals from the base.

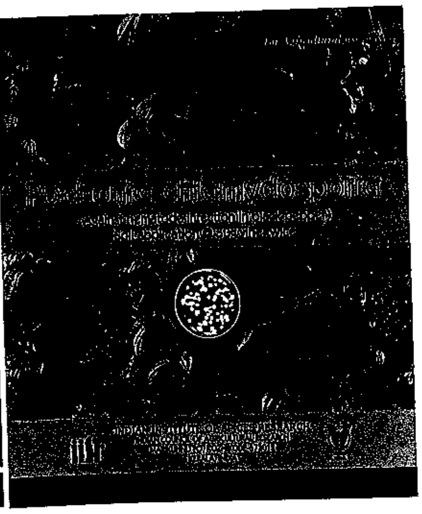
Growing the vine on vertical column can be effectively utilized for the production of three types of planting material, *i.e* single node cuttings, top shoots with lateral branch (use of top shoots for field planting is having advantage of producing fruit bearing branch from the base of the support and start yielding early) and reproductive branch (laterals) which can be used for production of bush pepper kept in the house or gardens. In four to five months time, on an average 150 single nodes (15 cuttings per vine × 10 vines

Use of *Trichoderma harzianum*

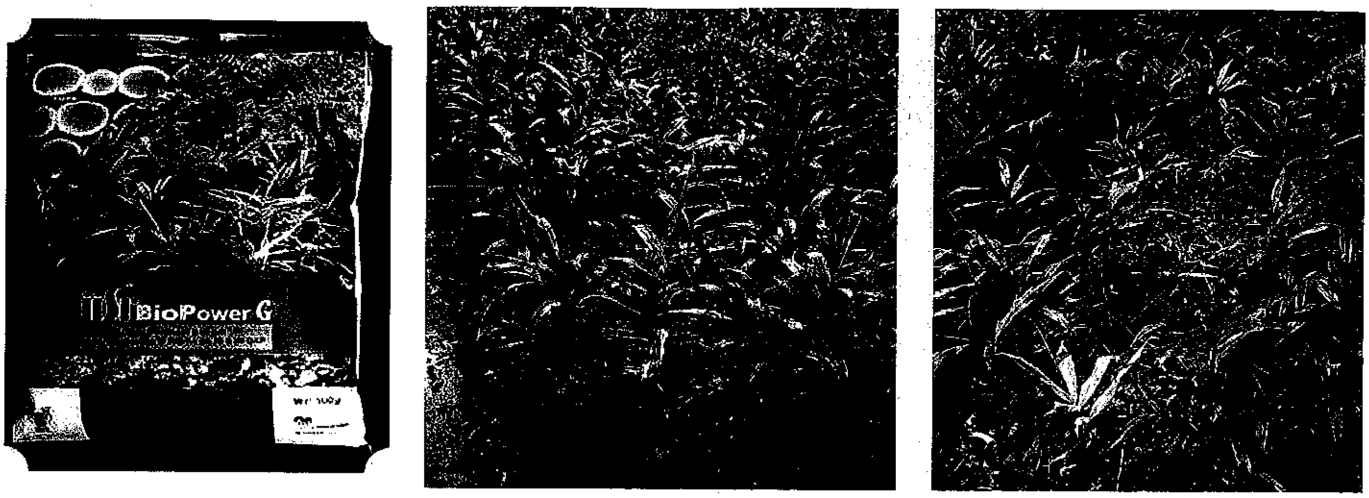
The production of black pepper is hampered by *Phytophthora* foot rot caused by *Phytophthora capsici* not only in India but also in other black pepper growing countries. The talc based bioformulation based on *Trichoderma harzianum* can be used successfully to manage *Phytophthora*. It can be used in Integrated Pest Management as well as under organic farming system in crops like black pepper, ginger, cardamom and turmeric. *T. harzianum* MTCC 5179 is certified as 'biosafe' by International Institute of Biotechnology and Toxicology (IIBAT) as per Central Insecticides Board and Registration guidelines. There is a great demand for the product and IISR has already issued several licenses for its commercial production. District Agricultural Farm (DAF), Thaliparamba, Kannur and Agrilife Biotech, Peroor, Kottayam are our authorized licensees. Another licensee Codagu Agritech is marketing *Trichoderma* as biocapsules. Institute has also developed technology for *Trichoderma* into a liquid formulation, containing minimum population of 10^8 fungal spores per ml that can be stored up to one year without significant reduction in the viable cells.



Talc-based bioformulation of *T. harzianum* of our licensees (*a*) DAF (*b*) Agrilife Biotech



Pochonia chlamydosporia bioformulation



PGPR Talc formulation for ginger (*left*), PGPR treated (*middle*) and untreated ginger in field (*right*)

around the vertical column) per column, one or two laterals and 10 top shoots can be harvested. In a poly house of size 320 sq.m (20 m × 16 m), one can accommodate 300 such columns. In a year three harvests can be made. These cuttings can be rooted further for field planting using pro-trays. The advantage of vertical column method is one can get three type of cuttings, *viz* normal single node cutting, laterals and top shoots.

Pochonia chlamydosporia

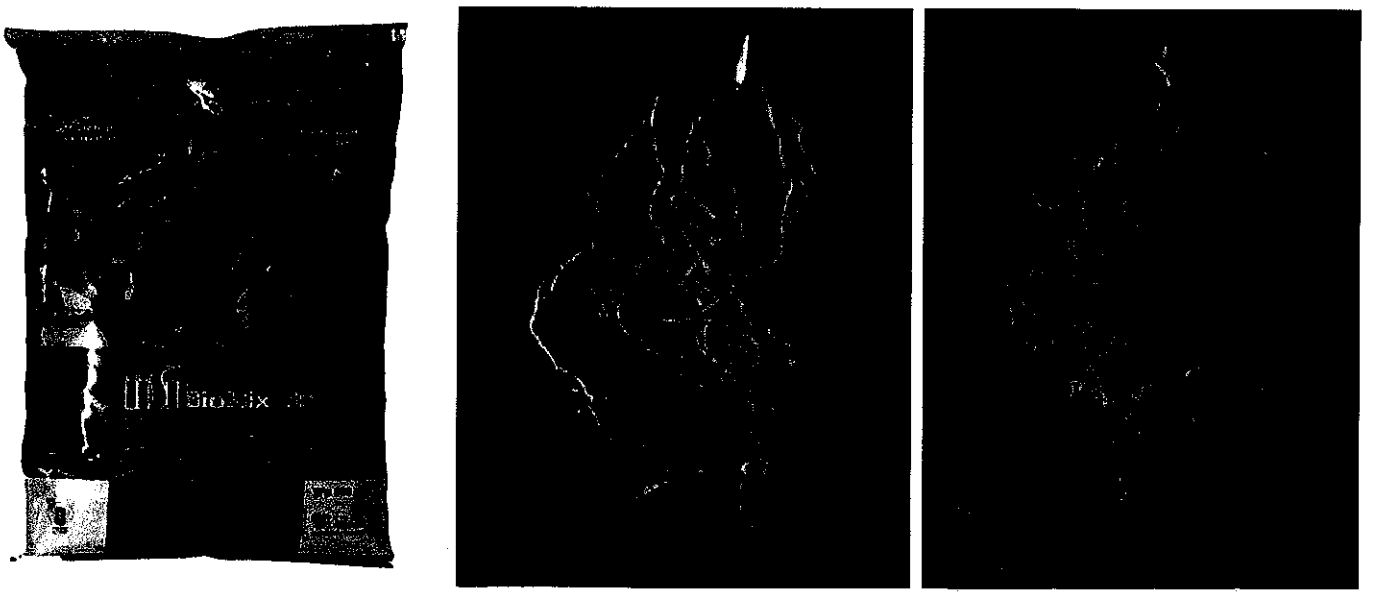
Plant parasitic nematodes, especially root knot nematodes (*Meloidogyne* spp.), are widely prevalent in black pepper gardens of South India and cause significant damage to the plants. Currently they are managed through application of nematicides like phorate and carbofuran. Biological control of root knot nematodes, therefore, is highly relevant in this context. *Pochonia chlamydosporia*, a known nematode biocontrol agent, is a facultative nematode parasite. It proliferates in rhizosphere, colonizes the egg masses of root-knot nematodes, parasitizes their eggs and sedentary females. The fungus attacks all stages of nematode eggs. The immature eggs are more susceptible. The technology is ready for transfer and commercialization to potential entrepreneurs. There is an upcoming demand for *Pochonia* in the event of ban on many popular nematicides.

PGPR Talc Formulation for Ginger

The PGPR technology is a novel process of coating efficient strains of PGPR on seeds. The components consist of live PGPR, inert material and a binding agent. The process is done at a particular temperature which is congenial for organisms to survive and coated seeds can be stored at the room temperature. The formulation can be applied both as rhizome treatment and soil drench. PGPR talc formulation technology was first developed and tested with a plant growth promoting Rhizobacteria (PGPR), *Bacillus amyloliquefaciens* that is specific to ginger. The major advantages are enhanced nutrient mobilization and nutrient-use efficiency, increased growth, yield and assured crop protection against soft rot disease. It may be extended to other crops and bioagents too.

Microbial Consortium

The consortium is a combination of three microorganisms, namely *Micrococcus luteus, Enterobacter*



Formulation of microbial consortium (*left*), effect on root growth in untreated (*middle*) and treated black pepper roots (*right*)

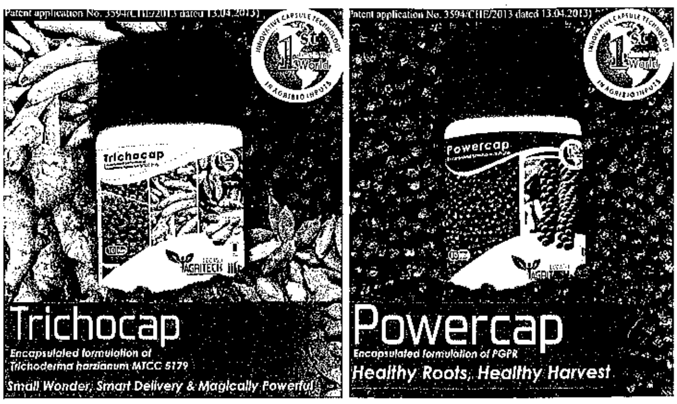
Gelatine capsules containing PGPR *Bacillus amyloliquefaciens* IISR GRB 35

aerogenes and *Micrococcus* sp. It is ecologically safe, increases growth and yield, enhances nutrient mobilization and efficiency in black pepper. It can be applied both in black pepper nurseries and under field condition as soil drench. The institute has recently granted non-exclusive license to M/s Codagu Agritech, Karnataka for commercialization of the technology in encapsulated form.

Novel and Smart Delivery Method

A perfect biofertilizer formulation does not exist and each type (talc, liquid *etc.*) has its own advantages and limits. Nevertheless, a promising advancement has been the development of techniques that allow encapsulating the microbial strain in a nutritive shell or capsule and delivering them to the targeted site. While encapsulating techniques have been fairly successful in the laboratory, attempts to emulate the performance in the field have been largely unsuccessful. Therefore, presently no such commercial products are available in the market. The IISR, Calicut, has made a significant breakthrough in the successful encapsulation and delivery of a plant growth promoting rhizobacteria for growth promotion and disease control in ginger.

The encapsulation process is simple, does not require sophisticated equipments and comes at low investment. Other advantages include reduced cost and easy handling

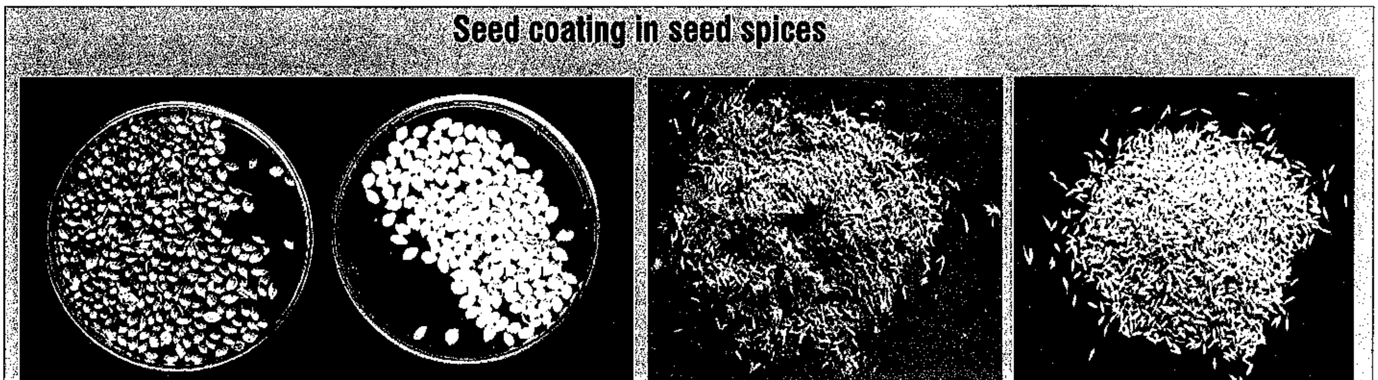


Trichocap and Powercap, the branded products of *Trichoderma harzianum* MTCC 5179 and PGPR marketed by our licensee M/s Codagu Agritech

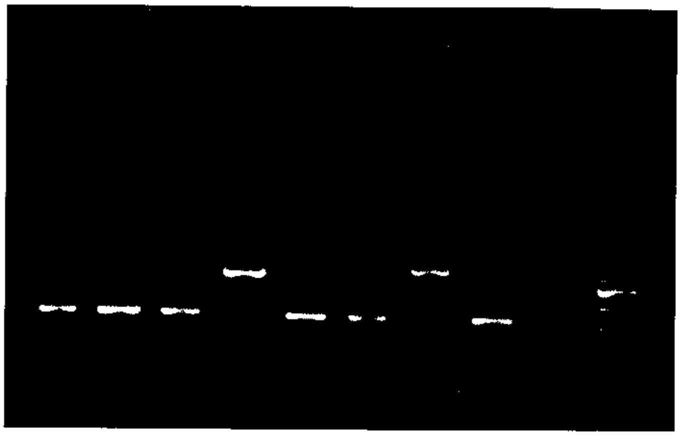
and transport, no harmful by products, less requirement of inorganic and inert material, storage at normal temperature and more importantly, enhanced shelf-life. Besides, this encapsulation technique can be used to deliver all kinds of agriculturally important microorganisms, *viz.* N fixers, nutrient solubilizers/ mobilizers, Plant Growth Promoting Rhizobacteria (PGPR), *Trichoderma*, *Burkholderia etc.* Patent for this delivery process has been filed (Application No. 3594/CHE/2013 dated 13/08/2013) and the technology has been commercialized by providing non-exclusive licenses to private companies. *Trichoderma harzianum* and PGPR are being currently marketed under brand names Trichocap and Powercap by our authorized licensee, Codagu Agritech, Kushal Nagar, Karnataka.

Seed Coating Composition

The PGPR technology is a novel process of coating efficient strains of PGPR on seeds. The components consist of live PGPR, inert material and a binding agent. The process is done at a particular temperature which is congenial for organisms to survive and coated seeds can be stored at the room temperature. Seed spices such as coriander (*Coriandrum sativum* L.), cumin (*Cuminum cyminum* L.), fennel (*Foeniculum vulgare* M.) and fenugreek (*Trigonella foenum-graecum* L.) cultivated predominantly in Rajastan and Gujarat have major constraints like low germination, slow initial growth and high susceptibility to diseases and frost. PGPR are a wide range of root colonizing bacteria with the capacity to enhance plant growth by increasing seed emergence and crop yield. It was



Uncoated and coated seeds of coriander (*left*) and uncoated and coated seeds of cumin after one year (*right*)



PCR based detection of adulteration of chilli in black pepper. Lanes 1-3- *Piper nigrum,* lane 4- *Capsicum annuum,* lanes 5-9 – Market samples of black pepper, lane 10-100 bp ladder.

observed that seeds coated with PGPR exhibited longer shelf-life and germination and remained intact even after 1 year of storage. The technology has wide applicability and can be extended to vegetable seeds imparting the appropriate crop specific bioagent.

Site-specific Nutrient Management

Majority of soils in spice-growing areas are encountering fertility issues due to acidity, nutrient imbalances and deficiencies of secondary and micronutrients that becomes yield limiting. Besides crop specific, soil pH based micronutrient mixtures for foliar application in black pepper, cardamom, ginger, and turmeric crops which guarantees 10-25% increase in yield and quality have also been developed. An innate advantage of these mixtures is that they can also be used in organic agriculture and therefore are benign and environment-friendly. The technology comes at very low cost and hence is very farmer-friendly. The micronutrient technologies have been licensed to entrepreneurs for large-scale production and commercialization.

Soil Acidity Amelioration in Kerala

A recent study shows acidity level at a whopping 91% of samples tested, with 54% of samples testing for strong to extremely acid reaction (pH < 5.5). While it is obvious that P availability should have been seriously hampered in these soils, making it unavailable to crops, we now have a paradoxical situation with 61% of the samples registering high (25–35 kg/ha) to extremely high (100 kg/ha) available P levels. This is possibly due to over-fertilizing (through high analysis complex or straight fertilizers) or adding high amounts of P rich manure. Since crops readily respond to N, growers would have historically applied enough chemical fertilizers or manures to meet the N needs of crops, unaware that they are applying several times the needed amount of P.

Soils with 300 ppm P will take up to 5 years to reach acceptable levels or in the worst-case scenario may require as much as 15–20 years of continuous cropping, with no added P, to reduce high P levels. Therefore, a practical approach would be soil test based site specific fertilizer recommendations based on crop requirement. Targeted yield equations for recommending nutrient requirements for fixed yield targets for spices in soils with varying fertility levels were standardized. Recommendations are being made only based on soil test values. The economic optimum in terms of profitable response for money invested in nutrients was also optimized.

Pre-monsoon Irrigation

Irrigation of black pepper vines around the basin from March to May @ 50 L/vine at an interval of 15 days can markedly enhance spike length, number of spikes, oleoresin content and berry yield. This technology promotes uniform spike initiation and reduces the spike shedding due to late monsoon and guarantees good crop.

DNA Barcoding Technique

Adulterants of any nature in exported commodities adversely affect the legendary fame of Indian spices and thereby hamper the nation's prestige. DNA barcoding has been put into use to detect the plant based adulterants in traded spices such as black pepper powder, cinnamon, nutmeg and turmeric. Though many vegetative adulterants such as papaya seed, wild *Piper* species *etc.* are reported as adulterants in traded black pepper, DNA barcoding method could detect chilli as an adulterant in traded black pepper for the first time. This work has attracted international attention. Probably unscrupulous elements may be finding it lucrative to recycle the exhausted black pepper (black pepper left after the extraction of the pungent principles) as value added black pepper (powder), fortified with other pungent substances like chilli.

Of late, *C. verum* barks are adulterated with a rougher, thicker, cheaper and less aromatic bark of the morphologically similar *C. cassia* (syn. *C. aromaticum*) having a bitter and burning flavor. Our barcoding technique could detect the presence of *C. cassia* in two of the market samples out of five studied thereby confirming the presence of *C. cassia* adulteration in commercial samples of true cinnamon. Similarly in turmeric, we could detect the presences of *Curcuma zedoaria* and cassava starch in one sample each out of the ten branded market samples of turmeric powder studied using DNA barcoding. We can detect the presence of biological adulterants like

- Chilli adulteration in black pepper using *trnH-psbA* locus
- Adulteration of tureric powder with starchy materials like rice, wheat, cassava etc using ITS locus
- Adulteration of cinnamon bark with cassia using *rbcL* locus
- Adulteration of a related species *M. malabarica* in traded nutmeg mace using *trnH-psbA* locus.

Diagnostics for Diseases Infecting Spices

Black pepper is infected by two viruses (*Cucumber mosaic virus* and *Piper yellow mottle virus*), whereas cardamom is infected by two viruses (*Cardamom mosaic virus* and *Banana bract mosaic virus*) which are systemic in nature. Once infected, viruses cannot be eradicated by any means including chemicals. Hence it is advisable to

Virus infected black pepper

use certified virus-free material for planting.

Single tube multiplex reverse transcription (RT) coupled Polymerase Chain Reaction Assay (mRT-PCR) for simultaneous detection of two viruses (cucumber mosaic virus and piper yellow mottle virus infecting black pepper was developed. Loop-mediated isothermal amplification (LAMP) and real-time LAMP based assays were also developed for quick and sensitive detection of virus diseases of black pepper and cardamom. The technology can be used for certification of mother plants/planting material of black pepper for freedom from viruses.

A strain specific and sensitive technique based on Real Time Loop Mediated Isothermal Amplification (Real Time- LAMP) was developed for detecting race 4 strain of *Ralstonia solanacearum* causing bacterial wilt in ginger. The method can be used to index both soil, water as well as seed rhizomes. There is no need for extraction of genomic DNA as technique is standardized with soil supernatant as the template. The time taken for detection is only 3-4 hours and the detection limit is 10^3 CFU/g of soil or rhizomes. The technology can be easily adopted in field for pathogen-free site selection as well as selecting disease-free seed materials for planting.

Rejuvenation of Virus Infected Gardens

Virus infected black pepper vines can be categorized into three groups, viz. Category I (mild infection), Category II (moderate infection) and Category III (severe infection). In severely infected vines (category III), rejuvenation would be very difficult. Apparently in such cases, all the affected vines need to be uprooted and burnt to destroy the inoculums. However, in mild and moderate infection categories, it is possible to rejuvenate such gardens by providing additional foliar nutrition with black pepper special micronutrient formulation (0.5%) after spike emergence during June and during berry development in September. In addition, basal application of neem cake @ 500 g and FYM or compost fortified with biocontrol agents such as *Trichoderma* and PGPR consortium (IISR Biomix) @ 5-10 kg/ vine along with recommended dose of fertilizers during pre- and post-monsoon periods were found to fully restore the health of infected vines in many FLDs at Coorg, Karnataka.

Whole Genome Sequencing

De novo hybrid assemblies using sequence reads from two NGS platforms (Illumina and Roche/454) were made for two isolates of *Phytophthora*. The *de novo* hybrid assembly of two next-generation sequencing (NGS) technologies (Illumina and Roche/454 sequencing) yielded 63.8 Mb genome size at an N50 contig length of 4724 kb, with contig length ranging from 200- 42775 for smallest and largest contigs, respectively. The *de novo* hybrid assembly gave out 32044 contigs and 47280344 bases using Newbler Assembler. A reference assembly was also conducted to compare *P. capsici* genome of joint genome institute and identity was 95.35% with an average read depth of 50X. Structural annotation was carried out using *ab-*

Green Technologies

Nutrient management plans for spices have been standardized for organic farming systems and organic packages have been developed for black pepper, ginger and turmeric integrating composts, oil cakes, biofertilizers/ PGPRs and biocontrol agents. In addition, an entomopathogenic fungus, *Lecanicillium psalliotae,* effective in controlling the thrips was potentially identified and evaluated at different agro-climatic conditions in Kerala and Karnataka. The technology is ideal for adoption in organic horticulture. A technology for the control of cardamom thrips (*Sciothrips cardamomi*) using spinosad 0.0135% (which is derived from *Saccharopolyspora spinosa*) as 3 sprays during March, May and August can substitute the use of synthetic insecticides for thrips control in cardamom.

Two new species of entomopathogenic nematodes, *viz. Oscheius gingeri* sp. n. and *Steinernema ramanai* sp. n. are identified as potent biocontrol agent against shoot borer *Conogethes punctiferalis* and other insect pests infesting ginger and turmeric. A new species of group I tetrahedral shaped multiple nucleopolyhedrovirus (NPV) belonging to the genus *Alphabaculovirus* of family *Baculoviridae*, infecting *Spilarctia obliqua*, a polyphagous pest of ginger, turmeric and other crops was also identified as potential bioagent.

initio gene prediction methods and an approximate of 22,358 coding sequences and 54485 exons were obtained.

Simple sequence repeats (SSR) analysis revealed that there are 1344 SSRs out of 32044 contig sequence analysed. Whole genome alignment and comparison with reference genome revealed 1,298,146 SNP sites; 917 genes were common with reference genome of *P. capsici* (JGI), and 5501 genes are unique in *P. capsici* isolate of IISR. Blast homology based functional annotation revealed the presence of various proteins important for the survival of *Phytophthora* sp. in host plants and virulence associated proteins crucial for its infection. The newly assembled genome of *P. capsici* was structurally and functionally annotated to curate all possible gene by gene information.

PROCESSING AND VALUE-ADDITION

A simple technique of hormone treatment was developed to split open nutmeg fruits without exposure to soil to prevent aflatoxin contamination in nutmeg. The methodology involves harvesting physiologically mature fruits when the colour of the rind change from green to pale yellow/yellow and dipping them in 500 ppm ethrel (2- Chloroethylphosphonic acid) solution for 10 minutes and then storing them in shade. By this method, 90-100% of fruits will be split in 18-20 hours.

A mechanical unit was developed and evaluated for production of white pepper from black pepper. The white pepper obtained had a dry recovery of 68.7% and the capacity of the pulping unit was 125 kg/h. Similarly, a renewable solar energy cooking unit was developed for turmeric curing. It has solar thermal collectors with curved parabolic mirrors which concentrates solar radiation on to a central pipe called as the receiver. The unit has a cooking vessel of capacity 50 kg turmeric/ batch and complete cooking of turmeric could be achieved in 45 min. A hand-held electronic nose was modified with suitable sensor array for determining quality. Samples were analyzed using the modified hand-held electronic nose for essential oil content and could be graded into low (<4.0%), medium (4.0-6.0%) and high (>6%).

Antioxidant activity of spices was tested for its nutraceutical potentials. Methanol extract of Malabar Excel was found to be highest for all the assays followed by *P. colubrinum*. Hexane extract of *P. colubrinum* showed high cytotoxicity under *in vitro* on cervical cancer cell line CaSki by MTT assay.

Entrepreneurship Development and Commercialization

The institute has set up a business planning and development (BPD) unit under the National Agricultural Innovation Project (NAIP) of ICAR, New Delhi. The BPD unit is a business incubation centre designed for the agriculture sector to promote entrepreneurs aided by the vast research and developmental capabilities resident with ICAR. BPD unit will identify in the first place potential technologies of ICAR-IISR and shall equip entrepreneurs to create them into profitable business ventures. The research and development system will act hand in hand to facilitate the extension of the technologies from their place of origin to Agri-business ventures.

The BPD unit is presently giving more impetus to entrepreneurship development and commercialization with respect to technologies developed by IISR. However, in the long run, the unit will act as a co-incubation centre to facilitate commercialization of technologies from sister institutes of ICAR and from innovators outside ICAR. The BPD unit has facilitated the non-exclusive licensing and commercialization of the designer micronutrient formulations developed for black pepper, ginger and turmeric (Table 2).

The centerpiece of the BPD unit is the high-end spice

Products of our spice processing clients

Table 2. Licensees of our plant varieties

Licensee	Variety
Mr Abdul Nabeel P. Pattorakkal, Meppayur P.O.Pin-673524, Kerala	IISR Prathibha
Mr Jigar Dipakbhai Patel 3 Charotar Patel Society, Opp. Swaminarayan Temple, Old Railway Crossing Road, Maninagar, Ahmedabad	IISR Prathibha IISR Rejatha IISR Alleppey supreme
The Director Centre for Overall Development (COD), Matha Tower, Thamarassery, Kozhikode	IISR Varada IISR Alleppey supreme
Mr S. Shashikant Patil Singitam Village, Raikode Mandal, Medak District, Telangana	IISR Mahima
Mr Tom C. Antony Cheripurathu Nursery Chengalam P.O. Kottayam, Kerala	IISR Viswashree
Mr Venugopal S. J. Shri Navaneetha Nursery, Shibara, Narimogra Post, Puttur- Karnataka	IISR Keralashree
Mr Mathew Sebastian Thazhathel Melattur Malappuram	IISR Keralashree
Mr Martin Manual Elavunkal House, Thalayad P.O., Unnikulam, Kozhikode	IISR Thevam
Mr Girish N. Hegde Sahyadri Nursery & Farm, Hulkodu Village, Edagigaleman Post, Sagar Thaluk, Shimog, Karnataka	IISR Thevam IISR Girimunda

processing facility established at ICAR-IISR Farm, Peruvannamuzhi. The unit was commissioned in July 2014 and is compliant with national and international quality requirements. This unit was envisaged to promote entrepreneurship development and improve the competitiveness of the spice industry through scientific training, capacity building and implementation of ISO standards for spice processing. The unit is equipped with state of the art facilities for cleaning and grading black pepper and production of spice powders.

This unit will not only cater to the needs of the farmers in the spice growing belt where it is situated but will also serve as a model unit for the benefit of spice growers and entrepreneurs all over the world. Three clients viz. Subicsha (Sustainable Business Development of Innovative Coconut-based Micro-Enterprises for Holistic Growth and Poverty Alleviation), Maloos pure food mix, a private entrepreneur and Abhiruchi food products, a Kudimbashree initiative has already started the production of spice powders from this facility and three more clients are in the process. ICAR-IISR periodically organizes entrepreneurship development programme (EDP) for the stakeholders to identify suitable entrepreneurs for steering forward the operations of the processing facility.

New Perspectives

The estimated growth rate for spices demand in the world is around 3.2%, which is just above the population growth rate. The forecasted population increase is up to 1619 millions in 2050 with increased GDP and per capita food spending. The per capita demand for spices is expected to increase many fold by 2050. The projected per capita demand for major spices like black pepper, cardamom, ginger and turmeric is estimated to be about 148 g, 53 g, 1.22 kg and 1.63 kg, respectively. With this increase, production levels to meet the local and global demand are estimated to be increased by 2.7-5.7 folds from the present levels. Therefore, we need to continuously strive to increase spices productivity by enhancing input use efficiency, and reducing post harvest losses with an eye on reducing the cost of production.

Dr T Janakiram Assistant Director General (Horticultural Sciences) receiving award for meritorious service to the spice industry

Overall, main researchable areas in spices should encompass:

- Conservation of genetic resources, bar coding and crop improvement using cutting edge technologies and science of '*omics*'
- Increasing productivity of spices through
  - Quality planting material production and supply
  - Productivity enhancement through better input management/precision farming systems
  - Ideotype development for quality and climate resilience
  - Bio-risk management
  - Reduce labour shortage by inventing new methods of harvesting black pepper
  - Protected cultivation of spices for availability in the season
  - Enhancing the skill set of spice crops to tolerate/ circumvent climate change
- New market oriented technologies for secondary agriculture and value addition
- Exploiting the potential of spices as nutraceuticals
- Effective transfer of technologies to target group

For further interaction, please write to:
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