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Dr. Anandaraj, born on 5th March 1954 in Karnataka, obtained his Masters degree from University of Mysore and Ph.D. from Calicut University. He joined Agricultural Research Service (ARS) in the year 1978 and initially served at ICAR-Central Plantation Crops Research Institute (CPCRI) at the Regional Station, Vittal for four years and later at ICAR-CPCRI Regional Station, Calicut. The Regional Station, Calicut has since grown into a separate Institute. Presently, Dr. Anandaraj is the Director of ICAR- Indian Institute of Spices Research, Kozhikode (Calicut). He served for six years as the Project Coordinator (PC) of All India Coordinated Research Project on Spices (AICRPS) and gained knowledge on spices cultivated all over the country besides understanding the Spice Industry. He has also served as the Head, Division of Crop Protection. During his tenure as PC (Spices), he undertook several new initiatives and worked on the influence of environment on quality of spices especially turmeric and ginger. His team has elucidated that the environment plays a critical role on the curcumin content in turmeric. The varieties developed in IISR with 5.5 per cent curcumin was found to record 6.5 per cent curcumin when cultivated in the north eastern part of the country particularly in Meghalaya and Mizoram.

He is a renowned plant pathologist currently serving as National Coordinator of the ICAR Outreach Project on "*Phytophthora, Fusarium* and *Ralstonia* diseases of horticultural and field crops" (www.phytofura.net.in) that is being run in 19 Institutes across India. He is well known for his contributions on epidemiology and management of soil-borne diseases of spice crops.

His team has developed PGPR formulations that markedly enhance yield in spices especially black pepper, ginger and seed spices. Three microbial formulations, 'IISR Biopower G' for ginger, 'IISR Biomix BP' for black pepper and 'IISR Biopower SS' for seed spices have been developed and commercialized for large scale production.

Under his leadership, two applications have been filed for Indian patents on delivery of microbes especially PGPR on seeds and beneficial microbes in hard gelatine capsules. A novel method to produce three types of cuttings in black pepper has been developed. The concept of converting clinging roots of black pepper into absorptive roots by growing them on columns filled with rooting medium was found to enhance the rate of growth of black pepper plants that enhances growth and productivity. The black pepper vines trailed on columns can be harvested within a year. He has about 200 publications including over 70 research papers in peer reviewed journals, books/monographs/chapters. He has contributed three chapters to the UN Encyclopaedia of Life Support System (EOLSS) and he is Fellow of six professional societies. Dr. Anandaraj has guided 6 Ph.D. and 16 M.Sc. students. He has several awards including the Dr. C.S. Venkataram Memorial Distinguished Plantation Scientist award.

Presently he is the Chairman of R&D committee of International Pepper Community (IPC) Jakarta, Indonesia; President of Indian Phytopathological Society, New Delhi and immediate past President, Indian Society for Plantation Crops, Kasaragod, and Indian Society for Spices.

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Status of plantation crops sector in India

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Plantation crops are an integral segment of our agricultural economy and are a significant driving force for growth and development of the agrarian economy of many states in India. The major plantation crops in the country include coconut, arecanut, oil palm, cashew, tea, coffee and rubber. Besides, spice crops and cocoa are also considered as plantation crops. The plantation crop sector contributes a significant amount to the foreign exchange and the magnitude of direct and indirect employment provided by the sector makes it vital for overall economic development.

Decadal trends in area and production of plantation crops

There has been a steady increase in area and production of plantation crops over the last few decades (Table 1). Presently, the cumulative area under six major plantation crops (coconut, arecanut, cashew, tea, coffee and rubber) comes to 5.12 m ha. Besides, crops like oil palm, cocoa, cardamom, pepper, nutmeg *etc.* cover an area of 0.60 m ha. The area under these crops was 2.15 m ha during 1970-71 and increased to 3.18 m ha during 1990-91. During the next two decades the area increased by 1.54 m ha.

Similar to area and production, the productivity of the major plantation crops has also shown a steady increase (Table 2). The increase in productivity is due mainly to availability of improved varieties, better crop production and protection technologies, concerted efforts for technology dissemination and institutional support. The present level of area production and productivity of major plantation crops are provided in Table 3 along with India's share in global production for each of the crop.

Table 1. General trends in area and production of major plantation crops

Crop	1970-71		1980-81		1990-91		2000-01		2010-11	
	Area	Prodn.	Area	Prodn.	Area	Prodn.	Area	Prodn.	Area	Prodn.
Tea	0.35	419.00	0.38	569.60	0.42	720.30	0.50	848.40	0.58	966.70
Coffee	0.14	110.20	0.19	118.70	0.22	169.70	0.31	301.20	0.41	302.00
Arecanut	0.17	0.14	0.19	0.20	0.22	0.24	0.29	0.33	0.40	0.48
Coconut	1.05	60.75	1.08	57.20	1.48	97.30	1.84	125.90	1.90	157.50
Cashew	0.30	0.13	0.46	0.19	0.53	0.29	0.72	0.45	0.95	0.67
Rubber	0.14	0.10	0.19	0.15	0.31	0.33	0.40	0.63	0.48	0.86

Source: Directorate of Economics and Statistics, Ministry of Agriculture, GOI and FAOSTAT
Note: Area in million hectares and production in million tonnes unless otherwise mentioned. The area under rubber pertains to tapped area under the crop; The production of tea and coffee in million kilograms; Production of coconut in '00 million nuts

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Table 2. Yield trends of major plantation crops (1970-71 to present)

	1970-71	1980-81	1990-91	2000-01	2010-11	Present	% change in yield (1980-81 to 2010-11)
Tea	1182	1491	1727	1682	1669	1891	11.9
Coffee	814	624	759	959	838	828	34.3
Arecanut	843	1058	1099	1138	1195	1364	12.9
Coconut	5811	5280	6595	6847	8291	10600	57.0
Cashew	420	399	636	710	720	760	80.5
Rubber	654	788	1075	1573	1806	1633	129.2

Note: Yield in kg ha^{-1} except for coconut where yield is given in nuts per ha
Source: Directorate of Economics and Statistics, Ministry of Agriculture, GOI and FAOSTAT

Major challenges in plantation crops

The plantation crop sector has seen a host of policy initiatives and reforms intended to maintain sustained growth in the sector. The fact that the livelihood security of significant number of small holder producers is dependent on this sector makes it imperative that the plantation crop economy shows vibrant growth. Despite these efforts, plantation crops have been continuously facing the problem of under investment and low capital formation. The yield levels of some of the crops in the sector like coffee and arecanut continue to be well below the desired levels in comparison to the global average productivity level.

The plantation crop sector has shown considerable inertia to adopt modernization. This is visible across the prevalent practices followed in post-harvest operations, level of technology adoption, mechanization and cultivation practices. There is an urgent need for modernization of the plantation crop sector and allied activities. The small size of the holdings in plantation crops presents both challenges and opportunities for sustainable growth. The small holding size brings along with it, a host of problems associated with it. Developing suitable marketing channels and value chains suited for widely disaggregated production environment is one of the biggest challenges faced in almost all the plantation crops. The technologies available, especially in mechanization of operations, are often not suitable for adoption in small holdings. This presents considerable challenges for increasing the efficiency of production through mechanization.

Table 3. Present status of area, production and productivity of major plantation crops

Crop	Area	Production	Productivity	India's shares in global production (%)
Tea	0.58 mha	1095.46 million kg	1891 kg ha^{-1}	24.9
Coffee	0.44 mha	304.5 million kg	828 kg ha^{-1}	3.7
Arecanut	0.45 mha	0.61 mt	1364 kg ha^{-1}	46.6
Coconut	2.14 mha	22700 million nuts	10600 nuts ha^{-1}	16.4
Cashew	0.99 mha	0.75 mt	760 kg ha^{-1}	15.7
Rubber	0.52 mha	0.85 mt	1633 kg ha^{-1}	8.1
Oil Palm	0.23 mha	0.86 mt	3.8 tonnes FFB ha^{-1}	1.8
Cocoa	56.5 '000 ha	14.4 '000 tonnes	255 kg ha^{-1}	Neg
Cardamom	92.4 '000 ha	18.4 '000 tonnes	199 kg ha^{-1}	31.2
Pepper	124.6 '000 ha	52.6 '000 tonnes	422 kg ha^{-1}	13.8
Nutmeg	18.7 '000 ha	12.7 '000 tonnes	670 kg ha^{-1}	11.1

Note: The temporal point of comparison may vary since the latest data available may not pertain to the same year
Source: Directorate of Economics and Statistics, Ministry of Agriculture, GOI and FAOSTAT

The products from the plantation crops have an essentially international character and the move towards open economy means that the international prices of the commodities and the price shocks are easily transferred to the domestic markets. Over the last 5 decades, the prices of the commodities from the primary sector showed a declining trend in real terms. This was especially true in case of the products from the plantation crop sector. The increase in demand for the products did not translate to higher prices due to the rise in productivity of the crops and consequent increase in supply of the commodities. In short, the productivity enhancement did not benefit the primary producer of the commodity and the benefits mainly went to the consuming classes. The depressed prices of the commodities continue to be a major challenge in plantation crop sector. The 3 year moving average of annual prices of selected commodities in the plantation crop sector in the international markets is depicted in Figure 1. It clearly indicates the decline in real prices, except for the period of oil shock during early 1970s and the period of global food inflation witnessed during the first decade of 21st century.

Notes on Prices:

- Cocoa (ICCO), International Cocoa Organization daily price, average of the first three positions on the terminal markets of New York and London, nearest three future trading
- Coffee (ICO), International Coffee Organization indicator price, Robustas, average New York and Le Havre/Marseilles markets, ex-dock
- Tea, average three auctions, arithmetic average of quotations at Kolkata, Colombo and Mombasa/Nairobi.
- Rubber (Asia), TSR 20, Technically Specified Rubber, SGX/SICOM nearby futures contract.

Apart from these, the concerns about the sustainability of the production practices followed in plantation crops sector, the unexploited latent potential for value addition and the need to enhance the relevance and role of research and developmental institutions working in the sector are some of the key areas of concern for the plantation crop sector in the country.

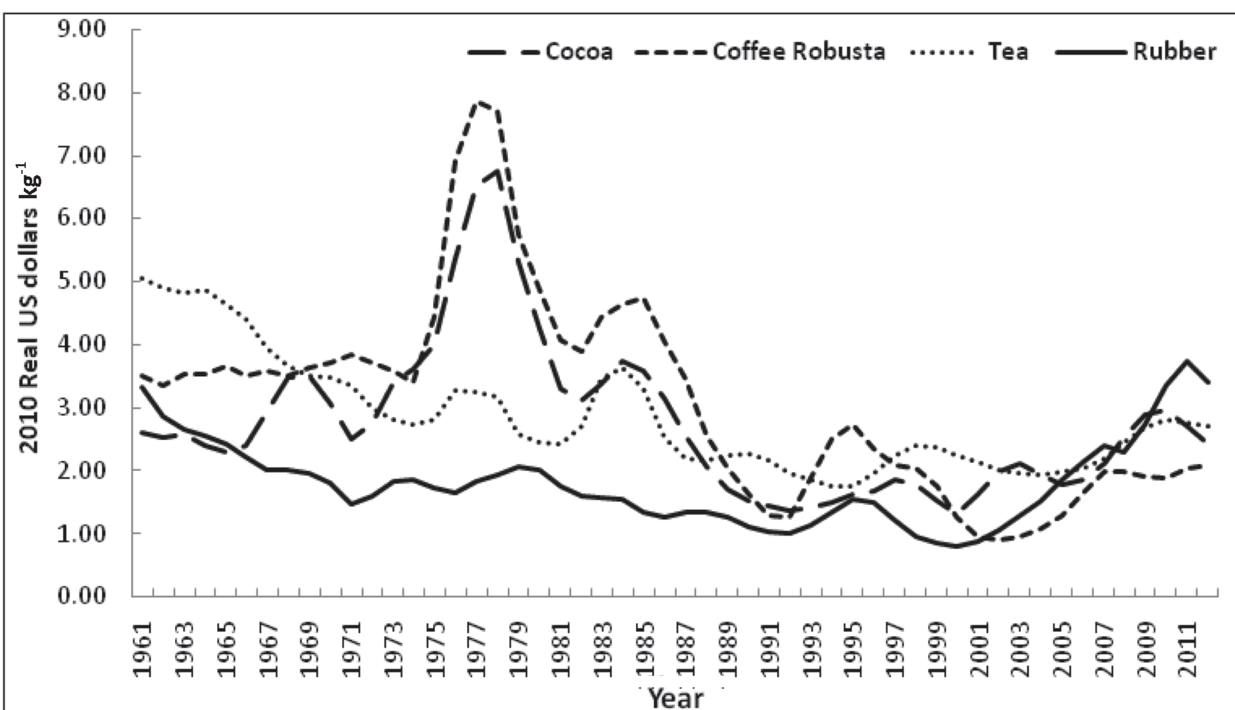

Fig. 1. Three year moving average of annual prices, 1960 to present, real 2010 US dollars

New initiatives in spice crops research

Spices are high value and low volume commodities of commerce in the world market. All over the world, the fast growing food industry depends largely on spices as taste and flavour makers. Health conscious consumers in developed countries prefer natural colours and flavours of plant origin to cheap synthetic ones. Thus, spices are the basic building blocks of flavour in food preparations. The estimated growth rate for spices demand in the world is around 3.19%, which is just above the population growth rate. The population increase forecast is up to 1619 millions in 2050 with increased GDP and per capita food spending. As spices are of high value with nutraceutical compounds, its per capita demand may 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 to 5.7 folds from the present levels. Therefore, we need to continuously strive to harness the power of intellectual minds and challenge conventional thinking by pushing the boundaries of science to increase spices productivity by enhancing input use efficiency, and reducing post-harvest losses with an eye on reducing the cost of production. We also try to discover effective solutions to emerging problems through conventional and modern science techniques thereby producing spices that will improve the quality of life. A few novel initiatives of ICAR-Indian Institute of Spices Research are briefly mentioned below:

(i) Novel and smart delivery method of biocontrol agents through encapsulation

A perfect biofertilizer formulation heretofore 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 deliver 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. ICAR-IISR 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 (Fig. 2). The encapsulation process is simple, does not require sophisticated equipments and comes at low investment. Other advantages include reduced cost and easy handling 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, PGPR, *Trichoderma*, *Burkholderia etc*. Patent for this delivery process has been filed (Application No.3594/CHE/ 2013 dated 13/08/2013)and the technology is being commercialized by providing non-exclusive licenses to prospective entrepreneurs through the Business Planning and Development Unit.

Fig. 2. Gelatine capsules containing PGPR *Bacillus amyloliquefaciens* IISR GRB 35

(ii) Improved soil less method (Pro-tray) for production of healthy planting material of ginger

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. If disease free planting materials are raised it will reduce the problem by half. A transplanting technique in ginger by using single bud sprouts (about 5 g) has been standardized to produce good quality planting material (Fig. 3).

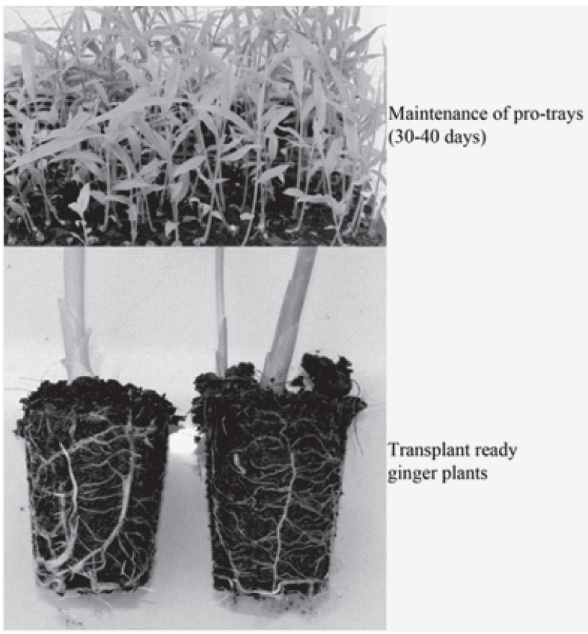

Fig. 3. Production of healthy planting material of ginger using pro-trays

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 planted in the field after 30-40 days. The advantages of this technology are production of healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on seeds.

The advantages of this method include less planting material requirement, 500-750 kg ha^{-1}, hence saving in seed cost and only $1/5^{th}$ of seed material is needed. It aids in 98 to 100 per cent field establishment and is suitable for high production technology, early/delayed planting and ensures high cost: benefit ratio

(iii) Site-specific nutrient management plans and micronutrient formulations for targeted yield in major spices

Nutrient management plans for spices based on soil test values have been standardized for conventional, integrated and organic farming systems. Besides crop specific, soil pH based micronutrient mixtures for foliar application in black pepper, cardamom, ginger and turmeric crops which guarantees 15 to 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.

(iv) Modified serpentine method for black pepper planting material production

In this method, vines are allowed to creep on a bed made of suitable potting mixture (composted coir pith and vermicompost) to the height of 10 to 15 cm at 1.5 to 2.0 m width and convenient length. The bed is treated with biocontrol agent *Trichoderma harzianum*. Here, vines are allowed to strike root and when it reached the end of the bed, entire strip is harvested and each node with a leaf and root are separated individually and planted in pro-tray or ploybags for further establishment. The separation of each node could be done when the entire vine is trailing on the bed. After a week when the bud is activated, it can be taken out and planted in protrays.

(v) Vertical column method for quality black pepper planting material production

The continuous demand for quality planting material created a novel idea of producing orthotropic on vertical 2 m column having one foot diameter made with plastic coated welded wire mesh (size 4 cm) filled with composted pasteurised cocopeat and vermicompost @ 3:1 ratio fortified with *T. harzianum* in poly house fitted with fan and pad system maintaining temperature of 25 to 28 ^{o}C and relative humidity 75 to 80 per cent with misting units. Eight to ten cuttings can be planted around the each vertical column. The cuttings are allowed to trail (Fig. 4a) on the 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 12^{th} to 15^{th} node, whereas, vines allowed to grow horizontally on the bed with same medium also produce similar number of nodes but will not have

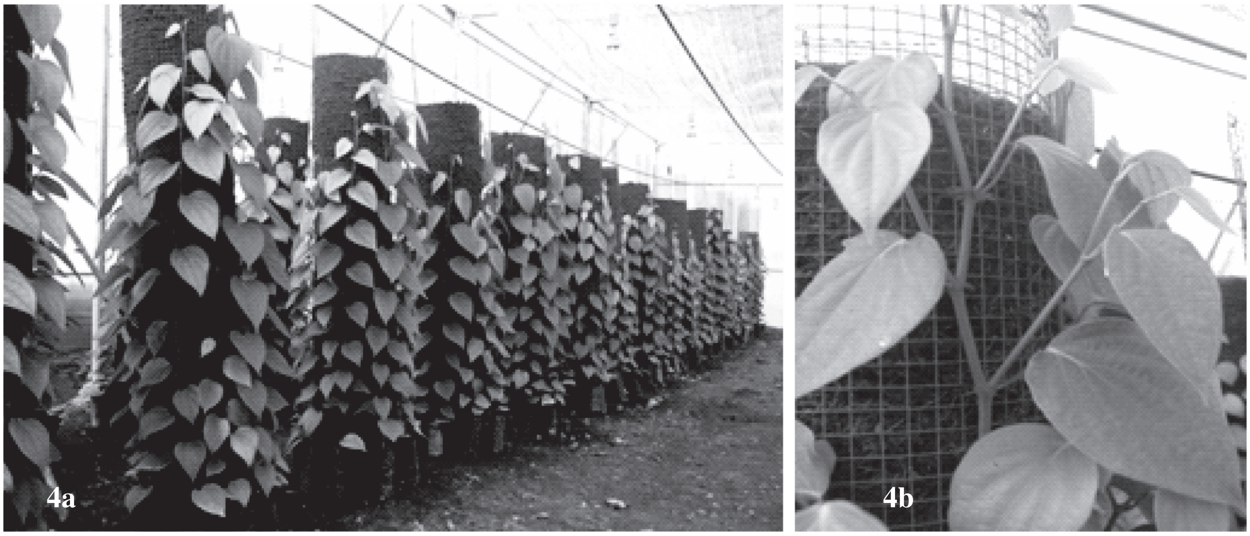

Fig. 4. Black pepper on vertical column (4a) with lateral branch (4b)

lateral fruit bearing branch. The top 5-7 nodes have lateral branches also (Fig. 4b). 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 or plagiotropes) which can be used for production of bush pepper (Fig. 5) kept in the house or gardens. In four to five months time, on an average 150 single nodes (15 cuttings per vine × 10 vines around the vertical column) per column, one or two laterals and 10 top shoots can be harvested. In a poly house size of 320 sq.m (20 × 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.

Growing black pepper plants on columns makes the clinging roots also take up the role of absorption and the rate of growth is enhanced. Since it is in the polyhouse with misting to control temperature and humidity, growth is fast in hot humid climate. The misting units switched on periodically gives adequate moisture and separate irrigation is avoided. As the lateral production undertaken in column after about 10 nodes, one produce three types of planting material. Each column can give 10 orthortropic shoots of 5 nodes each; 20-30 lateral branches that can be made into bush pepper and 100-120 single node cuttings in four months time. As the process is repeated one can harvest minimum of three cycles or maximum of four cycles. The lateral cuttings needed for bush pepper can be developed without sacrificing fruiting laterals from the field and the nursery itself laterals can be produced. This vertical column method is faster and efficient as it produces three types of cuttings.

Fig. 5. Bush pepper in pot

(vi) DNA barcoding technique to detect adulterant in spice products

Adulterants of any nature in exported commodities also 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 and turmeric at ICAR-IISR. Though many vegetative adulterants such as papaya seed and wild *Piper* species 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 (the 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 the 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.

(vii) Whole genome sequencing and annotation of *Phytophthora* infecting black pepper

De novo hybrid assemblies using sequence reads from two next-generation sequencing (NGS) platforms (Illumina and Roche/454) were made for two isolates of *Phytophthora*. The *de novo* hybrid assembly of two 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-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 ICAR-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.

(viii) Business planning and development unit

The institute has been offered with a business planning and development unit (BPD) under the National Agricultural Innovation Project (NAIP) sponsored project and facilities were established by investing ₹1.16 crores. The BPD unit is a business incubation centre designed for the agricultural sector to promote entrepreneurs aided by the vast research and development 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. Being the initial years of inception now the BPD is giving more impetus to entrepreneurship development and commercialisation with respect to technologies developed by ICAR-IISR. However, in the long run, the unit will act as a co-incubation centre to facilitate commercialisation of technologies from sister institutes of ICAR and from innovators outside ICAR.

The highlight of the BPD unit at ICAR-IISR is the spice processing facility established at ICAR-IISR Farm, Peruvannamuzhi. The unit was commissioned in July 2014 and is now ready for operation 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 curry 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. ICAR- IISR periodically organizes entrepreneurship development programme (EDP) for the stake holders to identify suitable entrepreneurs for steering forward the operations of the processing facility.

The way forward

The plantation crop sector is too vital a sector to be neglected in terms of conscious developmental initiatives. The policy perspectives should not only give cognizance to the specific needs of the constituent crops in the sector, but also address the common challenges faced by the plantation crop sector as a whole. The emerging challenges in the sector needs to be specifically marked out in the perspective policy outlines for the sector.

The main researchable areas should include

- Conservation of genetic resources, bar-coding and crop improvement
- Increasing productivity through
  - quality planting material production and supply
  - productivity enhancement technologies and systems through better input management
  - bio risk management
- New market oriented technologies for secondary agriculture and value addition
- Effective transfer of technologies to the target groups

Conclusions

The plantation crop sector is a major determinant of growth of the agricultural sector in the country. While the challenges faced by this sector are numerous, these are, however, not insurmountable. A well reasoned and cohesive application of cutting edge research, institutional support for development and creative policy initiatives can ensure a vibrant plantation crop sector in the country.