Souvenir & Abstracts

SYMPOSIUM
ON
SPICES, MEDICINAL AND AROMATIC CROPS

SYMSAC-VII

'Post-Harvest Processing of Spices and Fruit Crops'

27-29 November 2013

Madikeri, Karnataka

Organized by

Indian Society for Spices
Kozhikode, Kerala

In Collaboration with

Directorate of Arecanut and Spices Development
Calicut, Kerala

Indian Institute of Spices Research
Kozhikode, Kerala

Indian Council of Agricultural Research
New Delhi




NATIONAL SYMPOSIUM ON SPICES AND AROMATIC CROPS (SYMSAC VII)

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27-29 November 2013, Hotel Crystal Court, Madikeri, Karnataka

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Indian Society for Spices, Kozhikode, Kerala
Directorate of Arecanut and Spices Development, Kozhikode, Kerala
Indian Institute of Spices Research, Kozhikode, Kerala

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कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
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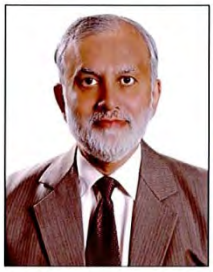

MESSAGE

It is a pleasure to learn that the Indian Society of Spices, Kozhikode in collaboration with the Indian Institute of Spices Research, Directorate of Arecanut and Spices Development, Kozhikode and Indian Council of Agricultural Research, New Delhi is organizing a National Symposium on Spices and Aromatic Crops (SYMSAC-VII) at Madikeri, Karantaka during 27-29 November 2103 and to commemorate the event the Society bringing out a Souvenir and Abstract in a form of publication.

The efforts of the Indian Society for Spices in fostering collaboration with the different stake holders of the spices sector across the country by way of organizing national seminars, symposia, interfaces etc are really laudable. This forum is also an opportunity for effective exchange of ideas among researchers, growers, traders, industry and policy makers. The present symposium seventeenth in the series, targeting post harvest processing of spices and fruit crops is timely as post harvest processing of spices and fruits, is an area of increasing importance to the industry, consumers and farmers alike besides its scope for research.

I wish the Symposium all success.

30-10-2013
New Delhi

(S. AYYAPPAN)

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MESSAGE

I am happy to learn that the Indian Society of Spices, Kozhikode in collaboration with the Indian Institute of Spices Research, Kozhikode, Directorate of Arecanut and Spices Development, Kozhikode and Indian Council of Agricultural Research, New Delhi is organizing a *National Symposium on Spices and Aromatic Crops (SYMSAC-VII)* at Madikeri, Karnataka from 27-29 November, 2013.

India is reputed since prehistoric times as the land of spices. The compelling need for spices led to the landing of the Portuguese navigator, Vasco da Gamma at Kozhikode in 1498. Until the 1970s, India had a virtual dominance in the international spices trade and still continues to be the largest producer, consumer, and exporter of spices in the world. Till 2011, the country produced about 5350 thousand tons from 2940 thousand hectares of area under spices. About 10% of this is exported annually.

In the daily intake of food and culinary preparation, the Indian food habits amalgamate divergent spices and exploit and utilize phytochemicals to add aroma and health in our daily life. This is unique to our civilization and probably rare. While individually the use of peppers, coriander, cumin, cinnamon, turmeric, cloves etc. contribute taste, flavor and aroma. The beauty of Indian cuisine is the proportionality and the blend that in totality contribute what can be summarized as Indian spices. The term is more generic as in reality these permutations and combinations of the above vary from region to region with religion and within a religion based on sub-groups adding to a rich diversity in the way the spices are exploited in our daily foods. Also, doubts are arising whether the presence of pesticide residues in spices is neutralizing the beneficial effects of the active components on cell physiology and function.

Indian spices include a variety grown across the Indian subcontinent. With different climates in different parts of the country, India produces a variety of spices, many of which are native, while others were imported from similar places and have since been cultivated locally for centuries. Spices are used in different forms - whole, chopped, ground, roasted, sautéed, fried and some as topping. They blend food to extract the nutrients and bind them in a palatable form.

The topic selected for the Symposium is very relevant and interesting as post harvest issues of spices and fruit crops are manifold receiving the attention of all stakeholders. The aspects concerning pesticide residue, aflatoxins, post harvest insect pest infestation, preservation of aroma constituents post harvest and cryoprocessing are a few issues of immediate concern. Spices are more in demand if they are cultivated organic, but the quality parameters for post harvest still need to be studied in such a scenario. The Indian Society for Spices, one of the professional Societies in Horticulture sector has been very active in various arena of spices research, development and extension. The society has been regularly organizing symposia and seminars on topics of contemporary relevance. The present *SYMSAC-VII* is yet another stride in this direction.

I wish all success for the Symposium.

(N. K. Krishna Kumar)

CONTENTS

Post harvest losses and management in horticultural crops

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1. Introduction

The horticultural sector has played a vital role in enhancing food security, farm income, alleviating poverty and thereby ensuring sustainable growth in India as well as other developing countries. However, the fact remains that such enhancements are still not to the level envisaged due mainly to large scale post harvest losses. Estimates by the Asian Productivity Organization (APO) suggest that ~30-40% of fruits and vegetables are lost or abandoned once they leave the farm gate. This indeed is an alarming situation and often such losses eat into the profit of the farmers and the society *per se*.

In India, compared to cereals, fruits and vegetables have been found to earn 20-30 times more foreign exchange per unit area due to higher yields and better price in the international market. While we are self reliant in food grains, the demand for fruits and vegetables is increasing at a rapid pace and while they are grown only on 7–8% of gross cropped area, they contribute more than 18.8% of the gross value of agricultural output and 52% export earnings from total agricultural produce. Therefore, considering their immense contribution to our economy, it is high time that we take appropriate measures to curtain such huge and wanton post harvest losses by adopting world standards of quality.

2. Post harvest losses

Though India has attained the second highest position after China in producing fruits and vegetables in world, the post harvest losses touched an alarming amount of Rs. 2.13 lakh crore in 2011-12 and may cross Rs. 2.50 lakh crore (2.5 trillion) in 2013-14 according to the ASSOCHAM study. Absence of food processing units and cold storage units has resulted in 30% of fruits and vegetables becoming unfit for consumption due to spoilage. In India, among the major producing states, West Bengal incurred highest loss of Rs. 13,657 crores followed by Gujarat Rs. 11,398 crores, Bihar Rs. 10,744 crores and Uttar Pradesh Rs. 10,312 crores. The losses in other states were estimated to be Maharashtra Rs. 10,100 Crore, Andhra Pradesh Rs. 5,633 crore, Tamil Nadu Rs. 8,170 crore, Karnataka Rs. 7,415 crore and Madhya Pradesh Rs. 5,332 crores.

A study on post harvest losses of major fruits and vegetables in Karnataka has revealed that factors like production per ha, adverse weather conditions, inadequate storage facilities, inadequate transportation facilities and type of family exerted a significant and positive influence on post harvest losses. The results of the study revealed that in case of fruits, the overall loss at different stages was around 60.08 kg in mango, 392.66 kg in banana, 31.97 kg in citrus, 37.30 kg in guava and 55.37 kg in sapota, where as in case of vegetables the overall loss at different stages was around 177.71 kg in potato, 108.53 kg in tomato, 72.00 kg in brinjal, 67.56 kg in beans and 138.45 kg in onion. Inadequate transportation facilities were viewed as one of the major post harvest problems by 80% of fruit growers and 91.67% of vegetable post harvest management. The major constraints encountered in post harvest handling of farm produce include inefficient handling and transportation, poor technologies for storage, processing, and packaging; involvement of too many diverse actors and poor infrastructure

3. Factor influencing post harvest handling of produce

- Harvesting techniques
- Storage
- Transportation
- Processing
- Cooling facilities (in difficult climatic conditions)
- Infrastructure
- Packaging
- Marketing systems

Although India is a major producer of horticultural crops, many Indians are unable to obtain their daily requirement of fruits and vegetables and the Human Development Index (HDI) is very low. Considerable quantities of fruits and vegetables produced in India are wasted owing to improper postharvest operations listed above and the lack of quality processing. This results in a considerable gap between gross food production and net availability.

4. Major reasons for product loss

All fruits and vegetables contain 65 to 95% water, and even after harvest the living processes continue into the post harvest stage, which depends on the rate at which they use up their stored food reserves and their rate of water loss. Once they exhaust these reserves, the decaying process starts with subsequent death of the produce. Factors that favour and enhance the decaying process make the produce inedible at a faster rate. While a multitude of factors interplay in hastening the decaying process, these complex interactions, however, are overly influenced by external conditions such as temperature and relative humidity.

4.1 Physiological deterioration

Conditions that increase the decaying processes such as such as high temperature, low atmospheric humidity and physical damage increase the rate of natural deterioration. When the fresh produce is subjected to extremities in ambient conditions, modified environments or contaminants abnormal physiological deterioration starts to set in making the produce unpalatable due to obnoxious flavour, failure in ripening or other changes in the post harvest living processes that make it unfit for use.

4.2 Mechanical damage (physical injury)

Careless handling of fresh produce causes internal bruising, which results in abnormal physiological damage or splitting and skin breaks, thus rapidly increasing water loss and the rate of normal physiological breakdown. Skin breaks also provide sites for infection by disease organisms causing decay. The high moisture content and soft texture of the produce make them susceptible to mechanical injury. This can occur during production when the crop is in the field, during harvest of the produce and during marketing. Major factors that cause mechanical damage are:

- poor harvesting practices
- unsuitable field or marketing containers and crates, which may have splintered wood, sharp edges, poor nailing or stapling
- overpacking or underpacking in containers
- careless handling, such as dropping or throwing or walking on produce and packed containers during the process of grading, transport or marketing.

These factors may culminate in splitting of the produce from the impact, internal bruising that may not be externally visible, superficial grazing or scratches affecting the skins and outer layer of cells, crushing of the produce etc. In case of mandarins, which are mostly hand plucked by using ladders rested on bamboo support, it is essential to prevent the tearing of branches bearing fruits. The quality of the produce is greatly affected by the damages/injuries during the harvesting. Mandarin fruit tend to "plug" when snapped from the tree, i.e., a piece of the peel from the fruit remains attached to the stalk. It is preferable to use clippers to clip the fruit from the tree to avoid damage. The other cause of deterioration in the fruit quality is harvesting of immature or over mature fruits. Similarly, fruits are spoiled when they are harvested by pulling the fruit, causing rupturing of the peel of loose skin of the fruits. Therefore, great care should be taken during harvesting/plucking the fruits.

4.3 Temperature effects

Extreme temperatures also damage the produce and commodities vary considerably in their temperature tolerance. Their levels of tolerance to low temperatures are of great importance where cool storage is concerned. Freezing injury is caused when the produce is subjected to temperatures between 0 and -2^{0}C. Frozen produce has a water-soaked or glassy appearance. And the produce which has recovered from freezing is highly susceptible to decay. While a few commodities are tolerant of slight freezing, storing at such temperatures shorten the post harvest/ storage life.

Chilling injury also occurs when some types of fresh produce are stored at low but non-freezing temperatures. Such crops are mostly of tropical or subtropical origin, but a few temperate crops may also be affected. Symptoms due to chilling injury become apparent when the produce is removed from cold storage and sent to the market, where they would be stored at ambient temperature.

Injuries due to high temperatures are also common occurrences when fresh produce is exposed to high temperatures caused by solar radiation. This will hasten the deterioration process especially when the harvested produce is left in the sun at temperatures as high as 45-50^{0}C. Such high temperatures often result in high rate of respiration and will make the produce inedible when packed and transported without cooling or adequate ventilation. Besides, long exposure to the tropical sun will cause severe moisture loss from the produce making them unsuitable for marketing.

4.4 Diseases and pests

Fresh produce can become infected before or after harvest by diseases caused by fungi and bacteria that are able to penetrate the unbroken skin of produce, while others require an injury in order to cause infection. Damage by diseases and pest is considered a major factor responsible for post harvest loss of the produce. Post-harvest disease in fresh produce causes decaying, which makes the produce unusable. The onset of infection by the pathogens often occurs in the field before harvest. Such infections also cause loss in quality of the produce due to skin blemishes or discoloration that lowers the commercial value of the produce.

Field infections before harvest may not become visible until after harvest. Infection after harvest can occur at any time between the field and the final consumer. It is mostly the result of invasion of harvesting or handling injuries by moulds or bacteria. Post-harvest diseases can also be spread by field boxes contaminated by soil or decaying produce or both, contaminated water used to wash produce before packing. Decaying rejected produce left lying around packing houses, contaminating healthy produce in packages etc.

Although relatively few post-harvest losses of fresh produce are caused by attacks of insects or other animals, localized attacks by these pests may be serious. Insect damage is usually caused by insect larvae burrowing through produce and such infestation usually occurs before harvest. Post-harvest spread is a problem where produce is held in store or is exposed to lengthy periods of transport. Rodents and other animal pests could be a problem when the produce is stored on the farm.

5. Post harvest mismanagement and aflatoxins

Spoilage in agricultural products has become a common occurrence at various stages of production and storage and is significant in terms of trade, food safety and public health. The most common spoilage is caused by microbial contaminants especially mycotoxins, which are secondary fungal metabolites with chemical structures suitable to cause a variety of toxic effects in humans and animals. Some of these compounds may be carcinogenic, cytotoxic, oestrogenic, immunosuppressive, mutagenic, nephrotoxic and teratogenic. If ingested, they may cause severe disorders, including alimentary toxic aleukia (ATA), diarrhoea, oesophageal cancer, feed refusal, irregular oestrous cycle, nervous system disturbances, pulmonary oedema, and vomiting.

It has been reported that 5–10% of agricultural products in the world are spoiled by microbial contamination to the extent that they cannot be consumed by humans or animals. Such contamination due to mould growth and associated aflatoxin (AF) production can occur in commodities such as corn, peanut, tree nuts and spices. According to FAO estimates, 25% of the world food crops are affected by mycotoxins each year and also crop loss due to AFs contamination costs US producers more than $100 million per year on average including $26 millions to peanuts ($69.34/ha). Food products contaminated with AFs include cereal (maize, sorghum, pearl millet, rice, wheat), oilseeds (groundnut, soybean, sunflower, cotton), spices (chillies, black pepper, coriander, turmeric, ginger), tree nuts (almonds, pistachio, walnuts, coconut) and milk.

Spices also contain high moisture content (55 to 85%) at the time of harvest and even the dried produces are highly hygroscopic in nature and tend to absorb moisture from air during storage. The hot and humid climate coupled with unsophisticated production and storage conditions and extended drying times can cause considerable hygiene and quality problems and spices exposed to some of these factors are likely to have a higher incidence of fungal infection (*Aspergillus* spp.) which might increase the likelihood of the presence of aflatoxins.

The best way of mycotoxin control is to produce a good crop free of microbial contaminants. During storage and when conditions are favorable, spoilage moulds, especially xerotolerant species of *Aspergillus, Fusarium* and *Penicillium* will continue to grow contributing to mycotoxin accumulation. Among the post-harvest control strategies that have been developed to avoid or reduce this kind of risk, maintaining elevated CO_2 levels (~75%) in partially dried grain lots or the use of essential oils and anti-oxidants have been reported. However, these technologies are not widely employed. Inhibition of microbial growth in the raw material by drying is the most efficient way to reduce microbiological and aflatoxin contamination. Drying of spices to 10% moisture content or lower within 48 hours can reduce the risk of fungus growth and consequent aflatoxin production. Good storage of the produce and coupled with good monitoring systems to detect incidences of fungal infection is by far the most effective post-harvest mycotoxin management method suitable to detect any onset of spoilage.

6. Strategies to reduce post harvest losses

i) Pre-harvest strategies

An important strategy to minimize post harvest losses should involve exercising safeguards during the production phase itself. This essentially should involve selection of suitable varieties, selection of proper planting material, crop management, and disease and pest management. This would ensure a high quality produce. Besides, proper and scientific harvesting technique/procedure would also ensure that the product is not susceptible to post harvest maladies.

In case of mandarins, fruits should be clipped (using clippers) in such a way that the button remains intact with the fruits. Sometimes, longer stalk portion of the clipped fruits left during harvesting, pierces into other fruits and causes injuries in them that pave the way for attack of wound pathogen. Therefore, while clipping the stalk should be cut close to the fruit, so as to preclude it from puncturing the rind of other fruit

during harvest and handling. Harvesting under wet conditions should be avoided, since wet fruits are more susceptible to microbial growth and soil particles may cling to wet crops, exposing them to soil-borne rot organisms. Do not allow the fruit to fall on the soil, as the impact leads to mechanical injury that makes fruit more prone to decay. Care should be taken at the time of plucking the fruit that the button remains attached to the fruit.

ii) Packing Stations

In developed countries where the fruits and vegetables are sorted, cut and placed in bulk containers and transported to packing stations where they are once again trimmed, sorted, graded, packed in cartons or crates and cooled. They are then temporarily placed in cool storage for subsequent loading or are loaded directly onto refrigerated vehicles, and transported to the market. Other important operations at the packing stations include SO_2 fumigation, fungicidal dipping, surface coating with wax, ripening and conditioning, vapor heat treatment etc. However, there is absolutely no such accepted concept of grading and packaging in India. No pretreatment is done and the produce is generally packed as such in the field after harvest and transported to wholesale markets, where large portions of inedible/spoilt produce is discarded and wasted. This could be done before transportation just after harvest to reduce both transportation costs and environmental pollution. Establishing packing stations at important points is, therefore, imperative to prevent such wastage of such precious horticultural produce. Significant advances have ensured that we now have packing lines equipped with sensors to reject unwanted fruits right at the sorting stage. Besides, packing lines with automatic grading and packing of the required size fruits are available in advanced countries.

iii) Primary Processing

The harvested produce should be minimally processed at packing stations immediately after harvesting, through the removal of inedible parts, following which they can be marketed in unit packs. Between 10 and 60% of the fresh produce marketed and purchased by consumers in India are rejected as inedible. Primary processing is a necessary step that not only renders these commodities edible, but also adds value to them.

iv) Packaging

Packaging aka 'The silent salesman' plays an important role in the transportation and marketing of products and also aids in protection and maintenance of their quality. This step is crucial and is the only interface of consumers with the product. More often than not wood has been the main packaging material for fruits and vegetables. However, there is an urgent need to identify substitutes to timber in an effort to protect forest resources. Considerable work has been done by different agencies in introducing alternative types of packaging. Corrugated fibre board (CFB) containers consume one third of the wood required for producing timber boxes of the same size. An improvement has been the ventilated CFB box developed at the IARI, which contains ventilated partitions. Thus, new packaging concepts are being developed where packaging design, properties of packed product and packaging material are integrated.

v) Storage

The lowest temperature that does not cause chilling injury is the ideal storage temperature for fresh fruits and vegetables. Mechanical refrigeration is generally used which is, however, energy intensive and expensive, involves considerable initial capital investment, and requires uninterrupted electricity. Appropriate cool storage technologies are therefore required in India. Improvements have been made in pre cooling, storage and packaging. In pre cooling, forced air cooling is available for fresh fruits, and hydro cooling for fresh vegetables. New developments in storage include controlled atmosphere and modified

atmosphere storage. Dynamic control systems and controlled atmosphere storage are most technologically advanced processes that are used to precisely control the atmosphere in the container, make adjustments during shipment, record changes in the atmospheric composition during journey and provide data for quality control purposes.

More recently, controlled atmosphere/ modified atmosphere packaging has come into prominence. These involve adjustment of the atmospheric composition surrounding commodities by removal (mainly O2) or addition (mainly CO2) of gases from the environment surrounding the fruits and vegetables, which plays important role resulting in equilibrium modified atmosphere. Equilibrium modified atmosphere packaging (EMAP) has unique advantage as it slows down the normal respiration of the product and prolongs the shelf life. Packing vegetables by gas flushing or by compensated vacuum is another technology gaining prominence. Here, the package or carton is flushed with desired gas mixture, whereas in compensated vacuum technique, the air is removed from the pack totally and desired gas mixture is then inserted.

vi) On farm storage

On farm storage is required in remote and inaccessible areas of India, to reduce losses in highly perishable fresh horticultural produce. Low-cost, low-energy, environmentally friendly cool chambers made from locally available materials, and which utilize the principles of evaporative cooling, have been developed in response to this problem. These cool chambers are able to maintain temperatures at 10–15^{0}C below ambient, as well as at a relative humidity of 90%, depending on the season. Fruits and vegetables are stored in plastic crates within the chamber. The shelf life of the fruit and vegetables maintained in the cool chamber was reported to be increased from 3 days at room temperature, to 90 days.

vii) Containerization

Containerization provides an excellent system for the shipment of goods from one place to another. Refrigerated containers are used in the transportation of fruits, vegetables and flowers in many developing countries. The design and fabrication of ventilated containers which incorporate evaporative cooling systems should be considered for the Indian context. One of the greatest advantages of the container is that it can be placed on truck or rail, without interfering with the movement of the vehicle.

vii) Cold/Cool Chain

The adoption of cold chain systems for maintenance of low temperatures at different stages of handling helps in reducing losses and in retaining the quality of fruits and vegetable. High cost and the lack of abundant uninterrupted power supplies, make it impossible to develop cold chain systems in India. Consideration should, however, be given to the development of alternative cooling systems based on evaporative cooling techniques..

7. Government efforts to reduce post harvest losses

With the creation of Agricultural and Processed Food Products Export Development Authority (APEDA) and National Horticulture Mission (NHM) a number of initiatives have been taken for promotion of export of fresh fruits and vegetables. These agencies have embarked on creating a network of infrastructure facilities for transportation, packaging, grading, storage and export. Some of their initiatives include providing pack house/ on farm collection & storage unit at 50% of the capital cost, pre-cooling unit, mobile pre cooling unit, cold storage units, CA and MA storage units, primary/ mobile/ minimal processing units which are provided based on credit linked back-ended subsidy @ 40% of the cost of project in general areas and 55% in case Hilly & Scheduled areas for individual entrepreneurs. Subsidy is also provided for ripening chamber,

evaporation/ low energy cool chamber, preservation units and PUSA low energy cool chambers, reefer vans/ containers. The assistance support under these schemes has definitely boosted the momentum for creation of post harvest infrastructure for various fruits and vegetables. This has created better value addition opportunities and export potential. The promotional schemes of APEDA and Ministry of Agriculture under the aegis of NHM have led to creation of basic infrastructure in post - harvest handling for export of fruits and vegetables.

8. Conclusions

Post harvest management involves scientific handling of a harvested produce to prolong the shelf life, enhance freshness as well asappearance. Nearly, 20-25% of the produce is wasted due to faulty Post-harvest management during harvesting, packaging, storage, grading and transportation etc. Proper scientific postharvest management can minimize these losses. Besides, post-harvest management, good pre-harvest operations such as use of proper harvesting tools and assessment of maturity also improve the shelf life of the and reduce losses to a great extent.

9. Source

Choudhury ML (2006) Recent developments in reducing postharvest losses in the Asia-Pacific Region. In: Post harvest management of fruit and vegetables in the Asia-Pacific Region. APO, 15-22.

Estimation loss of horticulture produces due to non-availability of post harvest & food processing facilities in Bihar & UP, ASET, New Delhi, Socio-Economic Research, Planning Commission, Government of India

Prevention of post-harvest food losses fruits, vegetables and root crops a training manual, FAO, Rome, http://www.fao.org/docrep/t0073e/T0073E00.htm#Contents

Prime financial assistance schemes of government of India for production, post harvest management, processing, marketing and exports of agricultural and horticultural produce. Confederation of Indian Industry.

Management strategies to reduce harvest and post harvest losses in black pepper, cardamom and ginger

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1. Introduction

In India, horticultural crops (including fruits, vegetables, flowers, nuts, aromatic and medicinal crops, plantations and spices) are cultivated in an area of 21.825 m. ha with a production of 240.531 mt. Spices constitute 13.5% of the area and 2.2% of the production of horticultural crops.Spices have a global demand and they can earn valuable foreign exchange. India is known as the "Home of Spices" and produces a large number of spices. About 60 spices such as pepper, cardamom, chillies, ginger, turmeric, coriander, cumin etc are grown in the country. India exports only a small quantity of spices (10% of the total produce) to 137 countries in the world. The rest is consumed in the Indian market, as there is an immense domestic demand. Currently, India is one of the major producers of ginger and turmeric in the world besides other spices. The average production of spices in India is over 63.24 lakh tons and area under cultivation of spices is approximately 35.41 lakh ha. During the 2012–13, a total of 6,99,170 t of spices and spice products valued Rs.11171.16 crore (US$2040.18 million) has been exported from the country as against 5,75,270 tons valued Rs.9783.42 crore (US$ 2037.76 million) in 2011–12, registering an increase of 22% in volume and 14% in value.

Each state cultivates one or other spices. Among spices, black pepper (King of Spices), small cardamom (Queen of Spices) and ginger are occupying preeminent position in spice trade. Black pepper and small cardamom are mainly confined to southern states, whereas ginger is cultivated throughout the country. During 2010–11, black pepper was cultivated in an area of 2,01,381 ha with a production of 48,000 t. Kerala has relatively large area under this crop but productivity is low compared to Tamil Nadu and Karnataka (Table 1). Small cardamom is grown in an area of 71,012 ha with a production of 10,380 tonnes. Kerala has maximum area and production followed by Karnataka and Tamil Nadu. Ginger production is 9,42,860 tonnes from 1,70,957 ha. Karnataka is the leading producer of this crop.

We export around 33% of our production of black pepper, 22% in cardamom and 12% in ginger. During 2012–13, black pepper export is 16,000 tonnes to various countries earning Rs.67,256 lakhs. Black pepper is exported in 12 forms; however, black pepper garbled is a major item of export followed by crushed or ground pepper. Oleoresin and green pepper in brine are also exported. Cardamom export is 2,250 tonnes valued Rs.18,505 Lakhs and ginger export is 19, 850 tonnes with a value of Rs.16,863 lakhs. Cardamom is exported in the form of dried capsule, powder, oil and oleoresin. Ginger is exported in the form of fresh, dried, powder, oil and oleoresin, after processing and value addition. Careful pre and post harvest management would reduce the crop loss and each crop requires specific strategies and management in this direction.

[1]*Former Director, ICAR Research Complex, Goa*

A new consciousness is growing all over the world against the food items with disease-causing organisms, poisonous substances and impurities. Parallel to this, the degree of excellence which consumers expect from foods is also growing. We export mostly to developed countries like USA, UK, Germany, other European Countries, Japan, Canada etc. These countries have very stringent food laws and regulations to ensure that foods which include spices, are safe, whole - some and produced under hygienic conditions. Hence, spices exported these countries should be free from bacterial contamination, mould, mycotoxins, harmful chemicals including pesticide residues and other pollutants, insect infestation and filth contributed by animals, insects or insanitary conditions in the farm, warehouse, package or carrier.

While it is imperative to produce clean spices with better quality, it is equally important to minimise both pre and post harvest losses of pepper, cardamom and ginger which are the major spices. Processing and value addition are also very important not only to get better returns to farmers but also facilitate reduction of fright charges and get the fast changing consumer preferende of ready to use product.

Table 1. Statewise area, production and yield of black pepper, cardamom, ginger

Crop/ State	Area (ha)	Production (tonnes)	Yield (kg/ha)
Black pepper			
Karnataka	21061	18240	866
Kerala	172182	20640	120
Tamil Nadu	3009	9120	3031
Total including others	***201381***	***48000***	238
Cardamom (small)			
Kerala	41242	7935	192
Karnataka	25209	1710	68
Tamil Nadu	4561	735	161
Total including others	***71012***	***10380***	146
Ginger			
Karnataka	46511	168310	3619
Orissa	17120	126530	7391
Assam	16386	112548	6869
Meghalaya	9438	52922	5607
Arunachal Pradesh	6601	52304	7924
Gujarat	4378	69581	15893
Uttaranchal	4153	41944	10100
Sikkim	6700	35970	5369
Kerala	6088	33197	5453
West Bengal	11406	24606	2157
Andhra Pradesh	2472	23054	9326
Total including others	**170957**	**942860**	5515

Source: Spices Board

An attempt is made in the pepper to highlight various steps and measures involved in harvesting, processing and grading etc. with a view to reduce post harvest losses.

2. Black pepper

i) Harvest

Black pepper takes 7-8 months after flowering to reach full maturity. The crop is harvested during December–January in plains and January-April in the high ranges of Western Ghats. It is important to harvest green pepper at proper stage of maturity in order to achieve a dried product of good colour and appearance. The spikes are nipped of by hand and collected in bags when one or two berries in the spike turn red or yellow. At the time of harvesting no chemical should be applied to ward off red ants. Normally, single pole bamboo ladder is used as a support for harvesting.

If the berries are allowed to over ripe, there is heavy loss due to berry drop and damage by birds. Recent advances in product diversification have necessitated harvesting of the berries at different stages of maturity to meet consumers preferences. The level of maturity required at harvest for processing into different pepper products is given in Table 2 (Govindarajan 1979). As farm labour force has become scarce and costly, mechanisation for harvest is essential and research is being pursued in this direction.

Table 2. Optimum maturity at harvest for pepper products

Product	Stage of maturity at harvest
Canned pepper	4-5 months
Dehydrated green pepper	10-15 days before maturity
Oleoresin and essential oil	15-20 days before maturity
Pepper powder	Fully mature with maximum starch
Black pepper	Fully mature and when 1-2 berries start turning from yellow to red in each spike
White pepper	Fully ripe

ii) Post harvest processing

a) Threshing

Threshing can be done both manually and by mechanisation. Traditionally, small farmers' separate the berries from the spike by trampling with human legs. This method is crude, tedious and unhygienic. Chances of extraneous matter, soil particles and filth contaminating the produce are also high.

Mechanical threshers with capacities varying from 50 kg/h to 1200 kg/h are available which can thresh quickly and provide cleaner products (Amala Dhas & Korikanthaimath 2003). Considering the shortage of human labour, mechanical threshing can be popularized at cluster level on custom hiring basis.

A mechanical rasp bar drum type pepper thresher with capacity of 400 kg/h has been developed at Tamil Nadu Agricultural University (TNAU), Coimbatore which is operated by a 2 hp motor (Thirupathi & Visvanathan 2008). This thresher consists of a metallic drum provided with rasp bars, concave, oscillating sieve, power source and power drive. The power to the drum is transmitted through V pulley arrangement. The performance of the thresher was evaluated for the capacity, breakage and threshing efficiency at various speeds of operation. The capacity of the thresher increased from 320 to 400 kg/h as the speed of the drum increased from 300 to 450 rpm. An increase in speed also increased the efficiency of threshing.

A local farmer at Wayanad has developed a pepper thresher of 700 kg/h. It consists of a metal drum with rubber lining rotated by a one hp motor and the threshing efficiency was 99 %. The damage caused to the berries was negligible (John Zachariah 2000; Jayashree & John Zachariah 2012a).

b) Blanching

The quality of the black pepper can be improved by a simple treatment of dipping the mature berries taken in perforated vessel in boiling water for a minute before drying. This processing technique has several advantages *viz*., uniform coloured product, reduced microbial load, drying in 3-4 days as against 5-6 days in the traditional practice. Besides, it also removes the extraneous impurities like dust from the berries.

Blanching is known to activate the phenolase enzyme which is responsible for producing the black colour. It also ruptures the cells and thereby accelerates the escape of moisture from the inner core and simultaneously enhances the black colour with the help of resinoids inside the berry. Hence, blanched pepper will have more shining black colour and it dries at a faster rate.

The black colour that pepper acquires on drying is due to the oxidation of colourless phenolic compounds present in the skin. Polyphenolase (0-diphenol oxidase) present in the fruit wall converts colourless phenolic subatrates (3, 4 dihydroxy phenyl ethanol glycoside) present in the cell to black polymeric compounds (Variyar *et al*. 1988).

c) Drying

Pepper has moisture content of 60 to 70% at harvest which should be brought to safer levels of 10-12% by adequate drying. The green colour of mature pepper is due to the presence of chlorophyll pigment. During drying, enzymatic browning sets in and the phenolic compounds are oxidized by atmospheric O_2 under the catalytic influence of phenolase and the berries eventually turn black (Mathew 1994).

Sun drying is the conventional method followed for drying of black pepper. The despiked berries are spread on concrete floor and dried under sun for 3-5 days to bring the moisture content below 10%. Dried black pepper with high moisture content (>12%) is susceptible to fungal attack. Mycotoxins produced by the fungal attack render the pepper unfit for human consumption. In order to achieve a quality dry product, pepper berries are spread on clean dry concrete floor / bamboo mats/ PVC sheets and dried in the sun for a period of 4-6 days. The average dry recovery varies between 33-37% depending on the varieties and cultivars (John Zachariah 2000).

Solar tunnel dryer for pepper

The solar tunnel dryer consists of a single drying chamber of size 2 × 3 m to a height of 2 m for drying 100 kg pepper (Thirupathi & Visvanathan 2008). The chamber is cylindrical shaped tunnel constructed using pipe frame structure called hoops that are placed at equal distance from one another and cross connected. The floor is covered with black sheet of 200 micron thickness, which facilitates better absorption of solar radiation. The black body absorbs more heat from surrounding and thus increases the temperature inside the tunnel. The metallic frame structure of the tunnel dryer is covered by UV stabilized semi transparent polyethylene sheet of 200 microns. The solar radiation is transmitted through plastic sheet, which has transmitivity of 90%. The UV sheet is transparent to the short wave radiations and opaque to long wave radiations. During bright day light, the short wave radiations are entrapped through the UV sheet, heat the absorber and get converted into long wave radiation. This conversion of short wave radiation to long wave radiation causes an increase in temperature inside the dryer. Heat is transferred from the absorber to the air inside the tunnel and the heated air inside the dryer while passing over the products placed in trays absorbs the moisture.

Mechanical driers

Mechanical driers are sometimes used to dry black pepper. Natural convection reverse air flow mechanical driers developed by Regional Research Laboratory, Trivandrum are used by the farmers and cottage scale industrial units for drying of black pepper. These dryers are widely used for drying of coconut, spices,

ayurvedic products, etc. Models of varying capacities operated either electrically or by burning agricultural wastes can be used for drying of black pepper also. An electrically operated black pepper drier of 100 kg capacity has been developed by TNAU, Coimbatore. The unit consists of a blower, heating chamber and a drying chamber. The air in the heating chamber is heated by 3 electrical heaters each of 500 W (Sreenarayanan *et al*. 2003).

d) Cleaning and grading

The dried pepper is cleaned to get rid of the extraneous matter such as dirt, stalks, leaves etc. Magnetic separator is used to remove metallic contamination such as iron fillings and stray nails. Vibratory conveyors with inclined decks in combination of sir classification are used for efficient de-stoning of spices. Broken pepper and light pepper grades are separated pneumatically; pin heads which come along with garbled pepper are separated by sieving. As the export potential for pepper is more, the market value can be increased by the removal of unwanted foreign materials. Cleaning on a small scale is done by winnowing and hand picking which removes most of the impurities. Such units consist of a fan/ blower and a feeding assembly. The fan is placed at the rear end of the hopper. Cleaning is achieved by feeding the material through the hopper into a stream of air blowing in perpendicular direction. The heavier fractions (dust, immature berries, pin heads and spent spikes) are blown away. Grading of black pepper is done by using sieves and sifting black pepper into different grades based on size. Fig. 11 shows the manual grading of pepper using sieves of required size.

TNAU has developed a hand operated cleaner cum grader suitable for cleaning and grading operations (Thirupathi & Visvanathan 2008). The unit consists of a rotor made of sieves, shaft. Screw auger, handle, hopper, frame, outlets and handle. Along the length of the rotor is divided into three segments of each 450 mm to mount sieves of various opening. A screw is provided inside the rotor for easy converting of the feed materials to the sieve perforations. A feed hopper to hold about 15 kg of pepper has been provided at the feed inlet end with appropriate side slopes for easy feeding of the feed into the sieves. Four inclined outlets are provided for collection of impurities, cleaned and graded products. The unit is provided with three sieves with round holes of size, 3.5 mm, 3.8 mm and 4.8 mm diameters. These sieves are as per the Agmark specifications. At an operating speed of 25 rpm, the unit has a maximum effectiveness of 66.4% and capacity of 430 kg/h. Quantity components of various grades are given in Table 3.

Table 3. Quality parameters of different black pepper grades

Grade	Moisture %	Volatile oil % v/w	Piperine %	NVEE %	Starch %	Crude fibre %
Pin heads	13.0	0.6	0.8	7.10	11.5	27.4
Light pepper	13.0	2.9	4.1	13.5	14.6	27.8
Malabar Garbled	13.0	3.7	5.0	12.3	39.7	11.8
Tellicherry Garbled EB	13.0	2.2	4.4	9.1	39.7	10.8
Tellicherry Garbled Spl. EB	10.0	3.2	4.9	10.3	40.9	9.2
Malabar ungarbled	12.0	2.8	5.0	11.4	41.8	12.5
Tellicherry ungarbled	12.0	4.0	6.3	13.5	39.3	11.0
High range ungarbled	12.0	2.6	4.0	11.1	41.8	10.5
Half pepper	-	4.2	6.8	13.1	-	-

Source: Pepper- a profile; CFTRI, Mysore, 1985

e) Packaging

Pepper is hygroscopic in nature it absorbs moisture during rainy season resulting in mould attack and insect infestation as it has good amount of starch. Mould and insect damage can lead to loss of aroma, caking and hydrolytic rancidity. Efficient packaging and proper storage is essential to ward off this problem. Whole

pepper is generally packed and transported in gunny bags and polyethylene lined double burlap bags. Dried pepper having a moisture level of 10-11% can be stored without any mould growth in jute gunny bags with polyethylene lining or in laminated paper bags (Balasubramanyan *et al.* 1978).

Organically grown black pepper should be packaged separately and labeled. Mixing different types of pepper is not good from a commercial point of view. Eco friendly packaging materials such as clean gunny bags or paper bags may be adopted and the use of polythene bags may be minimized. Recyclable/ reusable packaging materials can be used wherever possible.

f) Storage

Spices are to be stored with utmost care as they deteriorate rapidly. The graded produce is bulk packed separately in multi layer paper bags or woven polypropylene bags provided with food grade liners for export or in jute bags. The bags are arranged one over the other on wooden pallets after laying polypropylene sheets. The precautions to be followed during storage are:

(1) Moisture level in pepper is to be in the range of 10-11% before it is stored.
(2) Store houses to be constructed scientifically and it should be damp, rat and bird proof. The room should have controlled ventilation and devised for control of humidity and temperature.
(3) The room should be properly fumigated before storage
(4) The walls should be white washed regularly
(5) Proper drainage should be provided
(6) Polyethylene-lined gunny bags or laminated HDPE are ideal for storing pepper

Rooms used for storing pepper should not be used for other items like cereals or other spices like chillies, turmeric etc. Strong pungent odour of other spices may spoil the aroma of pepper. A good dehumidifier fitted in the storage rooms can eliminate mould and insect attacks by keeping the atmosphere always dry.

g) Quality

The quality of black pepper is largely determined by berry size, colour, light berry content, damaged berries, moisture content, microbial load, presence of foreign matter, insect infestation etc. These factors are essentially determined by harvesting, processing and handling practices at growers level and grading and storage practices adopted at the traders or exporters level. Another quality aspect gaining importance is the microbial contamination level, which should not exceed acceptable limits.

In the international market, quality specifications for trade are laid by the importing as well as the producing countries. The parameters assessed are extraneous matter, light berries, pinheads, bulk density, insects, excreta and microbiological aspects like presence of *Salmonella, E. coli*, aflatoxin etc. American Spice Trade Association (ASTA) or European Spice Association (ESA) or International Pepper Community (IPC) or International Organization for Standardization (ISO) specifications are the commonly adopted standards in the international trade. The Agmark, ASTA and ESA specifications for cleanliness and quality are given in Table 4.

Table 4. A comparison of physical quality standards adopted by various countries and institutions for black pepper: 2010

Particular	Agmark (India)	ASTA	ESA	Japan	Malaysia	IPC
1. Organic extraneous matter (% m/m) max	0.8					
2. Inorganic extraneous matter (% m/m) max	0.2	1			1	1
3. Light berries (% m/m) max	5				2	2
4. Pinhead and broken berries max	4					
5. Bulk density (g/L) min	490					550
6. Moisture % (max)	11	12	12	11	10	12
7. Total ash (% m/m) max	6		7			
8. Non volatile ether extract % (min)	6					
9. Volatile oil % (mL/100 gram)	2.5		2			
10. Piperine content (% m/m) min	4					
11. Whole insects dead (by count)		2			≤ 2 in sample	
12. Excreta mammalian (mg/lb)		1			0	
13. Other excreta (mg/lb)		5		0		
14. Mold (by weight)		6			1	
15. Insects defiled /infested % by weight max		5		0	1	
16. Acid insoluble ash (% w/w) max			1.5			
Note: % m/m = per cent mass / mass, % w/w = per cent weight /weight, mg/lb = milligram per pound, g/L=gram per litre						

Source: Aarathi *et al*. (2012)

3. Cardamom

Cardamom being high value and export oriented crop, systematic and timely attention by adopting high production technologies and clean and hygienic processing techniques with appropriate grading etc. is quite essential in realizing better returns to growers (planters).

Scientific cardamom plantation management practices can minimise both pre and post harvest losses (Korikanthimath 1993; Korikanthimath 2001; Korikanthimath *et al.* 2005; John Zachariah & Korikanthimath 2000; Sudharshan & Korikanthimath 2005).

Selection and cultivation of high yielding clones with precision farming can play an important role in improving quality attributes of cardamom (Korikanthimath *et al.* 1997; Korikanthimath *et al.* 1999).

i) Influence of stage of harvest on the recovery percentage of cardamom

Attempts were made to assess the influence of stage of harvesting on the recovery percentage and quality of cardamom based on market survey, planters samples dried in commercial community driers and different stages of maturity. Random market sample survey revealed the presence of immature capsule to the extent of 41.50% of dry cardamom. Recovery percentage of cardamom of various planters cured in a commercial drier varied from 11 to 30 with majority of the samples recording less than 18. Further, studies carried out to know the influence of stage of harvesting on the recovery percentage of cardamom indicated that there was not much variation among Mysore, Malabar and Vazhukka types. The mean percentage of recovery at ripened (fruit) stage was 29 and physiologically matured stage 24 as against 14 at immature stage in Malabar type. Study suggested that there is ample scope to increase the recovery of cardamom by resorting to correct stage of picking at physiologically matured to ripened (fruit) stage (Korikanthimath & Naidu 1996).

ii) Harvesting

Cardamom plants start bearing 2-3 years after planting seedlings or suckers. Panicles appear from the bases of plants from January onwards and flowering commences from April and continues until August, although some flowers may be seen almost through out the year. Generally flowering is highest during May – June. Fruits mature in about 120 days after flowering (Anandaraj & Sudharshan 2011). Cardamom fruits are small trilocular capsules, containing 15-20 seeds. On maturity seeds turn dark black in colour. A healthy plant on an average produces annually about 2000 fruits weighing about 900g, which on drying and curing gives about 200 g marketable produce (Korikanthimath 2002).

As the flowering continues over a long period, cardamom capsules ripen successively at intervals over an extended period necessitating several pickings. Harvesting should be taken up only at a time when the seeds inside the capsules have become black in colour or reached the maturity stage. Generally in the peak season, harvesting is carried out at an interval of 15 days and completed in 8-10 rounds (Korikanthimath 1983). In Kerala and Tamil Nadu harvesting starts from August – September and continues till February-March, where as in Karnataka areas picking starts in August and continues till December-January. Fruits that are just ripened or physiologically ripened are picked by experienced workers.

Two types of pickings are adopted - light picking and hard picking. In the first one only mature capsule are harvested. In hard picking semi-mature crop is also removed. Though this may reduce the curing percentage, it could increase the picking average, secure green coloured capsules and also reduce the chance of capsule splitting in the field. The choice depends on the availability and cost of labour.

iii) Human resource use efficiency in relation to different rounds of harvesting and yield in cardamom

A field investigation was taken up in cardamom plantations to study the labour requirement in relation to their efficiency of work in various rounds of picking wet capsules and to derive the recovery percentage of dry capsules to wet capsules in order to know the percent incremental growth in picking during various rounds to the very preceding round of picking.

The increasing (up to third round), constant (fourth and eight round) and decreasing (ninth round onwards) returns to the yield was noticed confirming to the principles of diminising returns. However, the recovery percentage of dry capsules to wet capsules has been consistent between 19.65 (minimum) to 23.0 (maximum) with an average of 21.72 for the 11 rounds of picking (1995-96 to 1999-2000 average). The proportionate increase in the recovery as noticed from the second round of picking onwards to the preceding round of picking has been inconsistent which is mainly due to the varying quantities of the yield (wet capsules) obtained from each round of picking.

The labour efficiency measures show that for every man equivalent per annum (250 hrs per annum), on an average for 1995–96 to 1997–98, 1% of the area is cropped and about 3.2 hours more work is drawn for the unit area of 1 ha. This shows that there is an efficient utilization of labour force in each rounds of picking stressing the importance of women laboures in picking of physiologically mature and matured capsules (Korikanthimath *et al.* 2000).

iv) Retention of green colour

Colour of processed produce is an important factor in consumer market. Most markets, especially in the Middle East prefer green coloured cardamom. The green colour of cardamom is due to the presence of chlorophyll.

Among the different chemical treatment tried to retain green colour of harvested capsules, soaking fresh capsules immediately after harvest in 2 % sodium carbonate solution for 10 min fixes green colour during subsequent drying and storage (Natarajan *et al.* 1968).

v) Pre-drying operations

Capsules after harvest are washed thoroughly in water to remove adhering soil before taking for drying in kilns. It was found that pre-soaking (quick dip) of capsules in hot water at 40°C and dipping capsules for 10 min in 2% sodium carbonate helped in better retention of green colour of cured capsules. Volatiles extracted from capsules pre soaked in hot water and sodium carbonate solution were subjected to gas liquid chromatography analysis. Results indicated that there were no significant changes in oil profile due to hot water or sodium carbonate treatments (Anonymous 1991). Degradation of chlorophyll or bleaching of green colour occurred when the capsules were exposed to sun. Post harvest delay prior to curing is known to cause chlorophyll breakdown, a better storage system could help to minimise such loss of chlorophyll.

Various trials conducted to study the impact of pre curing on storage indicated that:

(1) Capsules cured immediately after picking retained more green colour
(2) Loss of greenness was more significant if capsules were stored for more than 12 h from picking
(3) Bagging capsules helped to minimize the rate of loss of green colour. Jute bag was found to be better for storing fresh capsules compared to poly propylene woven bags. Low temperature of fresh capsules was found to reduce post harvest pre curing loss of greenness. Capsules stored in low energy or zero energy cool chamber were found to be distinctly greener than the capsules stored under open condition.
(4) Influence of stage of harvest on the recovery percentage of cardamom.

vi) Curing

Cardamom capsules at harvest, depending on the degree of maturity, have a moisture content of 70-80 per cent. For proper storage of capsules, the initial moisture content has to be brought down to 8-10 per cent by curing. Curing plays an important role in preserving the green colour of capsules since as much as 60-80 per cent of the initial colour is lost while processing.

The most widely adopted system for curing cardamom capsules is a slow or passive process stretching from 18-30h with an initial temperature of around 50°C. Both the degree of maturity and curing temperature influence the percentage of splits in cured capsules, however temperature has greater influence (Anonymous 1991). During the curing process, if the temperature exceeds the threshold levels or the inflow of air is insufficient, capsules develop brown streaks as a result of heat injury. In case of fairly high temperature, oil from seeds oozes out. Maintaining the temperature at 40°C during the curing process helps in greater retention of colour. Increase in curing temperature increases the percentage of split and discoloured capsules. Curing at temperature of 60 and 55°C significantly increased percentage of yellow capsules.

Two types of drying are generally adopted *viz*., natural sun drying and artificial drying by using fire wood, fuel or electric current. Drying operation demands heavy input of energy.

(a) Sun drying

Sun drying is generally undesirable for cardamom. Main reason is the bleaching effect due to the action of UV light present in sun light. As the capsules are turned frequently during sun drying, splitting of capsules is more. Cloudy atmospheres and frequent rains hinder proper sun drying. The method is prevalent among the small holdings in and around Sirsi in Karnataka.

(b) Artificial drying

(i) Electrical dryer

A dryer having dimensions of 90 × 84 cm is more common. Inside the dryer, 24 numbers of aluminium trays of size 81 cm long and 40 cm wide can be placed one over the other with a gap of 2 cm between the trays. Green capsules after harvest are to be uniformly spread in trays and arranged in the dryer. Uniform heat distribution is ensured by means of fans. This way, 50 kg of capsules can be dried in 10-12 h. It is possible to obtain medium green coloured cardamom by maintaining the temperature between 45 and 50°C.

(ii) Pipe curing (Kiln curing)

This is one of the best methods to obtain high quality green cardamom. The structure usually consists of walls made of bricks or stones and tiled roof with ceiling. A furnace is situated on one side of the chamber, heat is generated by burning firewood or farm waste. A pipe made of iron or zinc sheet starting from furnace passes through the chamber and opens outside the roof. The heated air current generated in the furnace passes through the pipe and increases the temperature of the room. The fans located on the either sides of the wall uniformly spread the temperature. Inside the room wooden/ aluminium trays are to be piled one over the other with spacing of 20-22.5 cm between the trays. The fire in the furnace is regulated to maintain a temperature of 40-50°C. Using this facility, high quality green cardamom can be prepared in 18-22 h. A drying chamber of dimension 4.5 m length and width is sufficient for a plantation producing 1800-2000 kg of raw cardamom. Some of the kilns make use of brick constructed heat conveyer lines (Kachru & Gupta 1993).

(iii) Bin dryer

This is a dryer designed by the University of Agricultural Sciences, Bengaluru (Karnataka). Drying unit consists mainly of a blower with a motor, electrical heating unit and drying chamber. The blower is of backward curve vane type coupled to carry 373 kW motor, 2820 revolutions per minute. Volume of air driven through the dryer can be adjusted from 1.5-8 cm^3/ s. The dryer is made of mild steel, asbestos sheet and wood. Aluminium or steel trays of size 0.4 × 0.6 m can be arranged one over the other. Required amount of air passes below the trays by means of centrally located flue pipe. Cardamom capsules are to be uniformly spread on these trays. Hot air passing through the pipes increases the temperature ranging from 30 to 80°C. Good quality cardamom can be produced by drying capsules at 55°C by maintaining the volume of air at 3.7 m^3/ s. The relative humidity ranges from 65- 92% during drying (Gurumurthy *et al*. 1985).

(iv) Melccard dryer

This is a fire wood operated dryer being used at Bodinayakanur region of Tamil Nadu. It consists of a fully insulated (fire bricks with mud coating) oven kept 3 m below the dryer. The hot flue gas from the oven is passed to an iron tank through the insulated pipes. Four iron tubes fitted at the four corners of the smoke tank carry the flue gases inside the dryer and is finally exhausted through the chimneys. Heat to the dryer is transferred from the surface of smoke tank and flue pipes. A central opening at the ceiling (with an exhaust fan) of the dryer ensures removal of moist air. A double wall structure with a gap filled with insulation materials prevents heat loss. Roofing is also insulated with thick glass wool. The dryer can be charged easily from outside by opening four doors at the front. All the trays move smoothly on rails fixed inside the dryer. Trap doors attached can be opened periodically to clean off the soot formed in the interior of the flue pipe (Palaniappan 1986). Dried capsules are rubbed by hand or with coir mat or wire mesh and winnowed to remove other plant residues and foreign matters. They are then sorted out according to size and colour.

(v) Cross –flow electric dryer

This is a tray type cross flow dryer having capacities ranging from 25 to 400 kg. The air is heated by 15 KW electric heaters and circulated over the material but 0.5 hp electric fan. The drying time is reduced at full loading condition at about 18-20 h (Kachru & Gupta 1993).

(vi) Solar cardamom dryer

Direct type solar cardamom dryer developed by CPCRI, Kasaragod, Kerala for copra drying can also be used for cardamom. The dryer has an area of 1 m^2 drying surface made of black painted wire mesh tray over black painted corrugated GI sheet inclined at 12.5^o. The aluminium foil reflectors of 1.5 m^2 are provided from three sides of the dryer. Material load density can be three times than that used in open drying system. Complete drying of cardamom could be achieved with in 3 days using this dryer in comparison to 5 days in open sun. Bleaching of cardamom capsules due to the action of UV rays in sun light is a disadvantage of this dryer.

(vii) Mechanical cardamom dryer

Developed by Regional Research Laboratory, Trivandrum, Kerala, this dryer consists of a centrifugal blower, electrical furnace, conducting arrangement for uniform hot air flow and a drying chamber. It can be used for cardamom drying at a load of 120 kg fresh cardamom/ batch. It takes about 22 h for complete drying at a temperature of 50^{o}C. The product is claimed to possess superior green colour, flavour and appearance (Kachru & Gupta 1993).

(viii) Through flow dryer

This is fabricated by CFTRI, Mysore. The dryer consists of a centrifugal blower, electrical furnace ducting with arrangements to distribute the flow of hot air uniformly and a drying chamber where 120 kg fresh cardamom capsules can be loaded to a bed thickness of 20 cm. The air velocity at 60 cm/s and the drying temperature was thermostatically controlled. The hot air carrying the humidity was not allowed to recycle. It was found to take about 22 h to complete drying of 120 kg fresh capsules at a temperature of 50^{o}C.

(c) Bleached cardamom

Bleached cardamom is creamy white or golden yellow in colour. Bleaching can be done either with dried cardamom capsules or freshly harvested capsules as starting material.

(i) Bleaching of freshly harvested capsules

Fresh capsules soaked for 1 h in 20 per cent potassium meta bi sulphite solution containing 1 per cent hydrogen peroxide solution degrade the chlorophyll. The colour of the capsules after drying is golden yellow.

Sulphur bleaching

It involves sulphur fumigation with alternate periods of soaking and drying. Capsules are soaked in 2 per cent bleaching powder (20 g sulphur in one litre of water) for 1 h and spread on wooden trays, which are arranged inside air tight chambers. Sulphur dioxide is produced by burning sulphur (15 g sulphur for one kg of capsules) and made to pass over the trays. The process of soaking and drying is repeated 3-4 times depending upon the intensity of white colour required.

Potassium meta bisulphite bleaching

In this method capsules are treated with 2% potassium meta bisulphite containing 1% hydrochloric acid for 30 min. Further they are transferred to 4% hydrogen peroxide solution for 6h.

Hydrogen peroxide bleaching

Hydrogen peroxide at low concentration (4-6%, pH- 4) can bleach capsules in 6-8h of soaking. These capsules are then dried to moisture content of 10%. Bleached capsules contain sulphur which protects cardamom from pests. However, it was found that bleaching lead to loss of volatile oil.

Conventional bleaching

In Karnataka state of India, bleaching of cardamom is carried out by steeping the dried capsules in soap nut water. The fruits of soap nut (*Sapindus saponaria*) are mixed with water in large vessel and stirred vigorously to produce plenty of lather. Dried cardamom capsules are steeped in this water with occasional stirring. After an hour or so the fruits are collected in wicker baskets and water is allowed to be completely drained off and then spread out on mats for drying. Clean water is occasionally sprinkled over the cardamom capsules. The process of sprinkling water and drying is continued for a couple of days till a good quality bleached product is obtained.

In general, bleaching of dried capsules lead to loss of volatile oil probably as the bleaching process makes the husk brittle. However, bleached cardamom has white appearance and is resistant to weevil infestation due to sulphur dioxide content (Govindarajan *et al*. 1982).

d) Quality standards and grade specifications

Dried cardamom requires cleaning to remove all stalks and dried remains of floral parts. This should be done by rubbing dried cardamom over a coarse surface of wire-mesh or bamboo trays. This is very well carried out while the cardamom is still hot in the curing kill.

Government of India and the Indian Standard Institution (ISI) have prescribed fairly well defined grades, popularly known as 'AGMARK' grades and Indian specifications or standards on the basis of important quality factors like colour, weight per unit volume, size and percentage of 'empties' malformed, shrivelled and immature capsules.

AGMARK grade designations of 'true' small cardamom and specifications for cardamom seeds (ISI, New Delhi) are presented in Table 5 and 6 respectively.

Table 5. Agmark grade designations of 'true' small cardamom

Quantity	Grade	Trade name
Alleppey Green cardamom	AGEB	Cardamom Extra Bold
	AGB	Cardamom Bold
	AGS	Cardamom superior
	AGS 1	Shipment Green 1
	AGS 2	Shipment Green 2
	AGL	Light
Coorg Green Cardamom	CGEB	Extra Bold
	CGB	Bold
	CG 1	Superior
	CG 2	Coorg Green Motta Green
	CG 3	Shipment

	CG 4	Light
Bleached and/ or half bleached cardamom	BL 1	-
	BL 2	-
	BL 3	-
Bleached white cardamom	BW 1	Mysore/ Mangalore Bleachable Cardamom - clipped
	BW 2	Unclipped
	BW 3	Bulk
	BW 4	Bulk cardamom - unclipped
Mixed cardamom	MEB	Mixed Extra Bold
	MB	Mixed Bold
	MS	Mixed superior
	MS 1	Mixed shipment 1
	MS 2	Mixed shipment 2
	ML	Mixed light
Cardamom seeds	CS 1	Prime
	CS 2	Shipment
	CS 3	Bokens

Table 6. Specifications for cardamom seeds, India (Indian Standards Institution, New Delhi)

Grade	Trade name	Extraneous matter	Light seeds	Weight (G/I-min)	General characteristics
CS-1	Prime	0.5	3.0	675	Decorticated dry seeds
CS-2	Shipment	1.0	5.0	660	of any variety of
CS-3	Brokens	2.0	-	-	*Elettaria cardamum*

e) Differential pattern of return-inflow in relation to various grades of cardamom

A field trial was conducted in Coorg, Karnataka to study the differential pattern of return inflow from the various grades of cardamom over a 3 year period (1995–96 to 1997–98). The study showed that, on an average for three years, grade I-7 mm size cardamom fetched higher price of Rs.483.36/kg accounting for Rs.2,51,571.98 as a total return inflow of the 79.90% of the total quantity of cardamom sold followed by other grades. It was observed that, about 1.75 times more of return inflow could be expected from the graded lot than from the un-graded lot of cardamom with a differential optimum gain of Rs.1,75,053.58/ha for the same level of average yield. The yield and price realized for the cardamom for three years were found to have significant positive association with each other in the respective years (Korikanthimath *et al.* 2001).

4. Ginger

i) Harvesting

The time of harvest depends on the product for which the rhizomes are used, price trend in the market and climatic conditions. When rhizomes is used for vegetable or for preparation of ginger preserve, candy, soft drinks, pickles and alcoholic beverages, harvesting should be done 4-5 months after planting, whereas, when it is used for dried ginger and preparation of value added products like ginger oil, oleoresin, dehydrated and bleached ginger, harvesting should be done between 8-10 months. Fibre, volatile oil contents and pungency levels are the most important criteria in assessing the suitability of ginger rhizomes for processing (Purseglove *et al*. 1981) and relative abundance of these components depend on stage of maturity at harvest

(Natarajan *et al*. 1972). Oleoresin and oil content rose sharply up to $5^1/_2$ to 6 months beyond which there was a decline and fibre development was extremely rapid between 6 and 7 months of growth (Winterton & Richardson 1965). Although there is fibre in the rhizome from the time it begins to develop, the amount is insignificant in the initial stages. Aiyadurai (1966) has reported that crude fibre content increased beyond 260 days after planting. The diameter and strength of fibre has increased with physiological age of rhizome. Fibrous ginger is unacceptable for processed confectionary because of its reduced palatability. In Australia, harvesting of confectionary grade ginger begins when 40 to 50%t by weight of the rhizome is free of commercial fibre, and continues down to 35% level (Whiley 1980). Increase in crude fibre and decrease in fat and protein content of rhizome were noticed after $6\ ^1/_2$ months (Jogi *et al*. 1972). Oleoresin and oil content for different cultivars reached its maximum 265 days after planting (Nybe *et al*. 1982). Ratnambal *et al*. (1989) have observed that dry recovery, starch and crude fibre were positively correlated with maturity whereas essential oil, oleoresin and protein were negatively correlated with maturity.

In India, early harvest at 200-215 DAP gave higher yield than late harvest at 230-245 DAP (Aiyadurai 1966). In Australia, early harvest yielded 50 tha^{-1} and late harvest 90-100 tha^{-1} (Lee *et al*. 1981). However, Nair & Varma (1970) and Pawar & Patil (1987) observed no differences in yield when ginger was harvested 215 to 275 days after planting. Harvesting of ginger is carried out by using a spade, hoe or digging fork and by mechanical diggers at Queensland. Care is required during harvesting to minimise damage to rhizomes. The soil, roots and tops are separated from rhizomes and washed. In India, harvesting time is from January to April and it may vary with the locations. Irrigation is stopped one month before harvest, allowing the tops to dry. Leaves and stem are cut to the ground level and the rhizomes are dug out by hoeing or ploughing. In the plains where the average temperature is between 30-35^{o}C the crop is ready for harvest in about eight months after planting when turn yellow, and start drying up gradually. In Nepal and Sikkim and Darjeeling in India, removal of seed (mother) rhizome after 2-3 months of planting is a local practice. By this practice, farmers get back their investment on seed rhizome. Late harvest is practiced in areas where there is no damage for rhizome due to heat or pests and diseases (Kandiannan *et al*. 1996).

The fresh ginger after harvest is some times subjected to washing, which is performed to remove soil dirt, spray residues and other foreign materials. Manual cleaning by rubbing under the thumb is commonly followed for small scale cleaning in the farm. In large plantations, high pressure jet is used for washing. For this type of cleaning, the ginger rhizomes are soaked in still water overnight and the next day water spray jet at high pressure is directed on to the rhizomes which forcefully remove the firmly attached dirt on the rhizomes. Drum type washer is also quoted as a commercial device (Kachru & Srivastava 1988) for cleaning ginger rhizomes. However the use of such washer has not been reported. Washing of ginger is essentially followed when oil is extracted from green ginger with out drying. Sreekumar *et al*. (2002) reported the use of washed and cleaned fresh ginger for extraction of essential oil in the processing facility set up at Manipur.

ii) Processing

a) Peeling

Peeling serves to remove the scaly epidermis and facilitate drying. The outer skin of ginger is scrapped off with a bamboo splinter or wooden knife having pointed ends. Iron knife is not recommended as it may leave black stains on the peeled surface, affecting the appearance, or may lead to colour fading. During peeling, it should be ensured that the cortical parenchyma, which is rich in essential oil bearing cells, are not removed or cut as it would cause loss of volatile oil and thereby, decrease the aroma of the peeled rhizome. Since scraping of ginger is a laborious process, attempts have been made for chemical and mechanical peeling of ginger.

Chemical peeling

Chemical peeling using NaOH, (widely known as lye peeling) is one of the most common and the oldest methods for peeling fruits and vegetables. Theoretically, lye peeling is a complex process involving diffusion and chemical reactions. Once the caustic solution of NaOH comes in contact with the surface of the fruit, it dissolves the epicuticular waxes, penetrates the epidermis, and diffuses through the skin into the fruit (Floros *et al*. 1987).

Randhawa & Nandapuri (1970) reported that peeling of ginger was easier by dipping in boiling lye, followed by washing and then steeping in acid solution. The process consisted of putting the ginger meant to be peeled in a wire – gauze cage and dipping into hot boiling lye for the required period. The lye solution causes the separation of the skin of the rhizome from the flesh beneath the epidermal layer. Dipping for 5, 1 and ½ minutes in boiling lye solutions of 20, 25 and 50% concentration, respectively, removed the peel. The ginger was then washed in running water and finally kept in 4% citric acid solution for 2 hours. However, this process could not result in quality dried product and is not commercially practiced.

Trials have been carried out by dipping the ginger rhizomes in boiling water for a short time prior to peeling (Natarajan *et al*. 1972; Lawrence 1984). Ginger treated with boiling water gives a dark final product, and hence this treatment was not recommended. Floros & Chinnan (1989) suggested that three factors that mainly affect the lye peeling process are processing time, lye concentration, and temperature. Time was found to be the most important factor followed by lye concentration.

The effect of lye pre-treatment on the peeling efficiency and ginger meat loss before mechanical peeling was studied by Charan *et al.* (1993). Lye treatment of ginger in 7.5% solution for 5 minutes before machine peeling indicated that the peeling efficiency of the machine could be increased and the meat loss reduced. Peeling efficiency of the machine operating in 3 and 4 passes increased from 73 to 83% and from 75 to 86 % respectively by lye pre-treatment where as the corresponding meat loss was reduced from 3.3 to 1.9 per cent and 3.8 to 2.4 per cent. However the application of this unit in large scale needs to be further studied and optimized (Jayashree & John Zachariah 2012b).

Mechanical peeling

Ginger rhizomes have irregular shape for a machine to deal with, especially when only a very thin layer of skin has to be removed. Natarajan *et al.* (1972) reported that some commercial undertakings have tried using machines fitted with abrasive rollers, but with little success. As the time of abrasive peeling increased, more and more outer skin and tissues layers were lost, resulting in a progressive decrease of oil content (Sills 1959).

A mechanical brush type ginger peeling machine was developed by Agrawal *et al.* (1983). It essentially consisted of two continuous brush belts being driven in opposite direction with a down ward relative velocity by a variable speed motor. The movement of the brush belts in opposite direction provided the abrasive action on the ginger passing in between while the downward relative velocity provided the down ward flow of ginger. The spacing between the belts and the belt velocity could be varied. The machine was reported to function satisfactorily during the limited tests performed on stored ginger.

Evaluating the machine parameters were however essential because peeling of skin was associated with the loss of ginger meat from underneath the skin. The epidermal cells in ginger contain most of the essential oil which imparts the ginger it's characteristic aroma and is perhaps the most important factor in determining its market price (Jaiswal 1980). Therefore the loss of ginger meat from underneath the skin would result in not only reduction in the loss of ginger weight but also in heavy loss of economic value of ginger.

Agrawal *et al.* (1987) optimized the operational parameters of the abrasive brush type ginger peeling machine for maximum peeling efficiency with minimum meat loss. The parameters optimized were brush belt spacing (1 cm) and belt speed (65 rpm) of the driving brush belt resulting in the belt relative velocity of 199 cm/s. Number of passes required was 4 to 5 and the capacity of the machine at the recommended

parameter values with 5 passes were 20 kg/h. When operated at its full capacity, the machine had a peeling efficiency of 71% with ginger meat loss of 1.6%.

The performance of the abrasive brush type ginger peeling machine could be improved by redesigning the peeling unit (Ali *et al.* 1990). Experiments were conducted to study the effect of various combinations of brush spacing, height and to recommend the optimum machine operational parameters. It was recommended that brush spacing of 1.9 cm and brush height of 2 cm and four or five number of passes with brush tip spacing of 1 cm at the relative velocity of 199 cm/s in downward direction were the best parameters to peel 2 cm thick ginger. The average peeling efficiency and the material loss were found to be 87.92 and 8.22%, respectively.

The final prototype of the abrasive brush type ginger peeling machine was reported by Ali *et al.* (1991). The machine essentially consisted of two continuous vertical abrasive belts with brush of 32 SWG thick steel wires, 2 cm long and spacing of 1.90 cm. The peeling zone of the ginger peeling machine was increased from 15 × 90 cm to 30 × 135 cm. Thus the number of passes was reduced from five to three. The gear reduction device was replaced by the jack pulley for power transmission. The peeling efficiency and material loss were 83.46 and 4.33%, respectively. The capacity of the machine at the recommended parameters was 200 kg/ h.

Charan *et al.* (1993) developed a small manually operated ginger peeling machine for application at farmer's level. The machine utilized locally available materials for its construction. The moving abrasive surface was made of coconut fibre brushes (30 mm length) mounted on two endless canvas belts of 40 mm width and 5 mm thick. The stationary abrasive surface was also developed with the same abrasive brushes arranged side by side on a wooden plank of 780 × 240 × 15 mm in size. The capacity of the machine to peel untreated ginger was 24 kg/h. The peeling efficiency and meat loss were 71% and 1.3%, respectively.

b. Drying

Peeled rhizomes are washed and dried uniformly under sun for 7 to 10 days. Ginger should be dried on clean surface to ensure that no extraneous matter contaminate the product. Care should be taken to avoid mould growth on the rhizomes while drying. During the first few days of drying each rhizome is turned at least once per day to ensure that it is dried uniformly. In order to get rid of the last bit of the skin or dirt, the rhizomes are rubbed together during drying. Rhizomes must be dried to a moisture level of 10% and stored properly to avoid infestation by storage pest. Improperly dried ginger is susceptible to microbial growth.

Traditionally ginger is sun dried in a single layer in open yard. The dried ginger presents a brown, irregular wrinkled surface and when broken shows a dark brownish colour. The drying of ginger usually leads to the loss of volatile oil by evaporation. Mathew *et al.* (1973) have shown that this loss may be as high as 20%. Extent of cleaning the rhizome prior to drying has a considerable influence on the volatile oil content of the end product. Removal of cork skin not only reduces the fibre content but also enhances the volatile oil loss through rupture of the oil cells which are near the skin. Jamaican ginger, which are cleanly peeled, have somewhat lower volatile oil and fibre contents than other commercial dried gingers which are partially peeled or unpeeled (Purseglove *et al*. 1981).

Mani *et al.* (2000) studied different drying methods of ginger. The drying methods reported were sun drying, vacuum oven drying at 60°C under 500 mm of Hg vacuum pressure and hot air oven drying at 60°C. Sun drying took 104 h for complete drying. In vacuum oven drying it took 48 h, however there was growth of black fungi all over the surface. In hot air oven, drying continued even after 88 h. But however, the ginger dried after cutting in to slice of 1.27 cm thick without peeling and dried under sun helped to get higher volatile oil yield.

Kachru & Srivastava (1988) reported a tray type solar cabinet dryer, designed and developed by Sukhadia University, Udaipur for drying ginger. The total time required for drying ginger from initial moisture content of 45-5 to 10% (d.b.) or less by use of solar cabinet dryer was 30 h in comparison to 45 to 60 h required in case of concrete surface drying.

Drying of ginger in an integral type natural convection solar dryer coupled with a biomass stove was reported by Prasad & Vijay (2005). It was found that 18 kg of fresh ginger with an initial moisture content of 319.74% (d.b.) was dried to a final moisture content of 11.8% (d.b.) within 33 h. Drying of the product was

also studied under 'solar-only' and open sun in the same climatic conditions and the results indicated that drying was faster in hybrid dryer. It took only 33 h in hybrid dryer, against 72 h in 'solar-only' operation of the same dryer and 192 h under open sun. The developed dryer was simple, can be manufactured locally and can be used for drying of other agricultural products as well.

Charan (1995) reported mechanical drying of peeled ginger in two stages, *i.e.*, up to 50 per cent moisture content (w.b) at 85°C and then to the required moisture content at 65°C gave best organoleptic and biochemical qualities.

A tray type dryer for drying ginger was reported by Philip *et al.* (1996). The main parts were a drying chamber, plenum chamber and a chimney with butterfly valve. Trays of wire mesh were provided in the drying chamber to keep the materials to be dried. The plenum chamber encloses the burning-cum-heat exchanging unit. Preliminary tests showed that 10 hours of drying at 60°C reduced the moisture content of ginger from 90 to 11%. The product obtained was also of high quality.

c. Polishing and storage

Polishing of dried ginger is done to remove the wrinkles developed during the drying process. It is generally done by rubbing the dried rhizomes against hard surface. Polishing of dry ginger is also done by taking dry ginger in sack and rubbed against itself by moving the sack to and fro by two persons standing on either sides. Hand or power operated mechanical polishers are also employed for this purpose. Kachru & Srivastava (1988) reported a mechanical polisher developed at Sukhadia University, Udaipur, which had a capacity of 15 to 20 kg/h and could give 5 to 7% polish. As far as storage of ginger is concerned it could be stored in dried rhizome form without any significant change in biochemical constituents for over one year period.

d. Cleaning and grading

Once the ginger is dry, it is sorted and graded. For ginger, the grading takes into consideration the size of the rhizome, its colour, shape, extraneous matter, the presence of light pieces and the extent of residual lime (in the case of bleached ginger). The specifications of various grades of Indian ginger and ginger powder under Agmark are given in Tables 6–9. Agmark certification is currently not mandatory for export trade. However, it is still valued as a mark of quality. Indian Standard Specifications (ISS) for ginger are almost in line with the Agmark specifications. The minimum rhizome size of rhizomes as per ISS is 20 mm (IS 1908:1993).

Table 6. AGMARK grade designations of garbled non bleached ginger (whole)

Grade Designation	Size of rhizomes (length in mm) Min.	Organic extraneous matter, % (m/m), Max	Inorganic extraneous matter, % (m/m), Max	Moisture % (m/m), Max	Total ash % (m/m), Max	Calcium (as calcium oxide) % (m/m), Max	Volatile oil % (ml/100g) Min.
Special	20.0	1.5	0.5	12.0	8.0	1.1	1.5
Standard	15.0	1.5	0.5	13.0	8.0	1.1	1.0

Source: Spices Board (2006); Pieces of rhizomes smaller than 15 mm can be graded with the marking 'Garbled Non –bleached Ginger (Pieces)'. It may be marked as 'Garbled Non Bleached Calicut' (NGK) or 'Garbled Non bleached Cochin' (NGC) depending upon the its place of origin

Table 7. AGMARK grade designations and quality of ungarbled non bleached ginger (whole)

Grade Designation	Size of rhizomes (length in mm) Min.	Organic extraneous matter, % (m/m), Max	Inorganic extraneous matter, % (m/m), Max	Very light pieces % (m/m) Max.	Moisture % (m/m), Max	Total ash % (m/m), Max	Calcium (as calcium oxide) % (m/m), Max	Volatile oil % (ml/100g) Min.
Special	20.0	1.5	0.5	4.0	12.0	8.0	1.1	1.5
Standard	15.0	1.5	0.5	6.0	13.0	8.0	1.1	1.0

Source: Spices Board (2006); Pieces of rhizomes smaller than 15 mm can be graded with the marking 'Garbled Non –bleached Ginger (Pieces)' It may be marked as 'Ungarbled Non Bleached Calicut' (NUGK) or 'Ungarbled Non-bleached Cochin' (NUGC) depending upon the its place of origin

Table 8. AGMARK grade designations of garbled bleached ginger (whole)

Grade Designation	Size of rhizomes (length in mm) Min.	Organic extraneous matter, % (m/m), Max	Inorganic extraneous matter, % (m/m), Max	Moisture % (m/m), Max	Total ash % (m/m), Max	Calcium (as calcium oxide) % (m/m), Max	Volatile oil % (ml/100g) Min.
Special	20.0	1.5	0.5	12.0	12.0	2.5	1.5
Standard	15.0	1.5	0.5	13.0	12.0	4.0	1.0

Source: Spices Board (2006); Pieces of rhizomes smaller than 15 mm can be graded with the marking 'Garbled bleached Ginger (Pieces)'. It may be marked as 'Garbled Bleached Calicut' (BGK) or 'Garbled bleached Cochin (BGC)' depending upon the its place of origin

Table 9. AGMARK grade designations of ungarbled bleached Ginger (whole)

Grade Designation	Size of rhizomes (length in mm) Min.	Extraneous matter, % (m/m), Max	Very light pieces % (m/m) Max.	Moisture % (m/m), Max	Total ash % (m/m), Max	Calcium (as calcium oxide) % (m/m), Max	Volatile oil % (ml/100g) Min.
Special	20.0	2.0	4.0	12.0	12.0	2.5	1.5
Standard	15.0	2.0	5.0	13.0	12.0	4.0	1.0

Source: Spices Board (2006); Pieces of rhizomes smaller than 15 mm can be graded with the marking 'Garbled Non –bleached Ginger (Pieces)'. It may be marked as 'Ungarbled Bleached Calicut' (BUGK) or 'Ungarbled bleached Cochin' (BUGC) depending upon the its place of origin.

Cleanliness specification

Cleanliness has always been a major concern for the importing countries. Trade in spices is governed by numerous national as well as regional regulations. For example, dried cardamom and ginger exported to the United States must conform to the specifications laid down by the American Spice Trade Association (ASTA). The specifications of ASTA for cleanliness of turmeric imported to US are given in Table 10**.** Similar specifications have also been laid by other importing countries like U.K, Germany, The Netherlands, etc.

Table 10. ASTA cleanliness specifications for small cardamom and ginger

Cleanliness Specification	Whole insects, dead	Excreta, Mammalian	Excreta, Other	Mold	Insect Defiled/ Infested	Extraneous/ Foreign Matter
	Count	mg. / lb.	mg. / lb.	%, wt.	%, wt.	%, wt.
Small cardamom	4	3	1.0	1.00	1.00	0.50
Ginger	4	3	3	>3	>3	1

Source: Sivadasan & Madhusudana Kurup (2002)

Health requirements

The presence of microorganisms in food products is critical from the point of view of human health. Inadequate and unhygienic drying and storage leads to accumulation of microbial load on the spice. Strict regulations have been specified by the importing countries for the limits of microbial load in spices. The microbiological specification for spices under German law is given in Table 11.

Table 11. Microbiological specification of spices under German law

Parameter	Standard value (per gram)	Danger value (per gram)
Total aerobic bacteria	10^5	10^6
Escherichia coli	Absent	Absent
Bacillus cereus	10^4	10^5
Staphylococcus aureus	100	1000
Salmonella	Absent in 25 g	Absent in 25 g
Sulphite-reducing clostrides	10^4	10^5

Source: Balakrishnan (2007)

Uncontrolled application of chemical pesticides at various stages of plant growth results in accumulation of their residues in spices, sometimes to a levels beyond acceptable limits. With the growing concern on the carcinogenic properties of various pesticide residues, the importing countries are tightening the tolerance limits. Pesticide residue continues to be a serious problem in all the spices for export (Balakrishnan 2007). Pesticide residue tolerance limits for black pepper is given below (Table 12).

Table 12. Pesticide residue tolerance limits fixed by some black pepper importing countries and India (MRL in milligram per kilogram)

Pesticide	Agmark (India)	US	Netherlands	UK	Germany	Spain
Acephate	0.2	4				0.1
Azinphos-methyl	0.5					
Chlorpyriphos	1	1	0.01	-	0.05	0.05
Cypermethrin	0.1				0.05	0.05
Diazinon	0.1		0.05	0.05	0.02	0.05
Dichlorvos	0.1	-	0.05	-	0.1	-
Dicofol	0.1	5	0.05	0.5	0.02	0.02
Dimethoate	0.5	2	0.01	0.05	0.5	0.05
Disulfoton	0.05				0.02	
Endosulfan	5	2	0.02	0.1	0.05	
Ethion	5	1	0.01	-	0.05	0.1
Fenitrothion	1		0.05	0.05	0.05	0.05

Malathion	1	8	0.05	8	0.05

Source: Aarathi *et al*. (2012)

Another major issue in the spice is the presence of aflatoxins. Aflatoxins are a group of secondary metabolites of fungi, *Aspergillus flavus* and *Aspergillus parasticas* and are rated as potent carcinogens. Inadequate and unhygienic drying leads to the growth of these fungi on the spice. Aflatoxins in spices are generally classified into four- B_1, B_2, G_1 and G_2. B_1 and B_2 are produced by *A. flavus*, whereas G_1 and G_2 are produced by *A. parasticus*. Of these, B_1 is the most virulent carcinogen and has received the most attention. Microbial standards adopted by different agencies for black pepper are given in the Table 13.

Table 13. A comparison of microbiological parameters adopted by different countries for import of black pepper: 2010

Particulars	**Agmark (India)**	**ASTA**	**ESA**	**Malaysia**	**IPC**
1. Salmonella	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed
2. Yeast and mold			10^6 No./g absent max	10^2 No. count/ g max	
3. *Escherichia coli*			10^3 No./ g absent	absent 10^1 No./ g max	
4. Aflatoxin B1		2 ppb (max)	5 ppb		
5. Aflatoxin B1+B2+G1+G2	30 ppb (max)	4 ppb (max)	10 ppb (max)		

Note: ppb=parts per billion; 10^6 g=10^6 numbers per gram

Source: Aarathi *et al*. (2012)

Conclusion

Application of current knowledge to improve the handling systems (especially packaging and cold chain maintenance) of horticultural perishables assures their quality and safety. Both quantitative and qualitative losses occur in horticultural crops between harvest and consumption. Our goal is to minimise theses losses, and to do so we must, understand the biological and environmental factors involved in post harvest deterioration, and use the appropriate post harvest technology procedures that will slow down deterioration and maintain quality and safety of the commodities. Qualitative losses, such as loss in edibility, nutritional quality, caloric value, and consumer acceptability of the products, are much more difficult to assess than quantitative losses. Post harvest losses vary greatly among commodities and production areas and seasons.

India is an acknowledged leader in the world of spices and produces 45% of the worlds spices in terms of volume but the storage losses are very high. At micro-level, these losses increase the marketing cost of the products and at macro-level they also reduce the per capita availability. Thus, there is need to reduce these losses to feed the ever growing population. The post harvest losses according to certain estimate in spices and condiments (plantation crops) are in the range of 3.6 - 6.8 and 0.6 - 6.% respectively. The post harvest losses comprise essentially on-farm losses and those that occur during transportation and storage in different marketing channels.

Black pepper and small cardamom are mainly confined to southern states, whereas, ginger is cultivated throughout the country. Each crop needs special harvest and post-harvest operations and many technologies are available and new technologies are also being evolved. The labour availability for agricultural operations is very much limited throughout the country. Harvest of these crops requires trained labourers and non-availability of it is posing great challenges for researchers to develop suitable harvesting machineries. Production of pesticide residue free produce is also another challenging area where one has to

develop suitable pest and disease management strategies to reduce the risk and for more acceptance of the produce. Timely operations in tune with changing weather are also essential to minimise the loss. Also, appropriate adoption of GAP technologies would minimize the post harvest losses and enhance the quality.

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Production technologies to mitigate climate change with special emphasis on cardamom and black pepper

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1. Introduction

Global warming and climate change have emerged as watch- words during the past several decades across the world. The impact of unprecedented changes in the weather pattern experienced in different agro-ecological zones worldwide have been a serious cause of concern especially in agriculture and allied sectors. Climate change and associated impact might differ from region to region across the globe. The probable effects of increase in global temperature include, rise in sea levels and a change in the quantum and pattern of precipitation. Other adverse effects of climate change include frequent occurrence of extreme weather events including heat waves, droughts, heavy rainfall, ocean acidification and even extinction of various life forms due to shifting of temperature regimes. Effects significant to human race include threat to food security and the loss of habitat from inundation. Agricultural productivity is dependent mainly upon the climatic factors and land resources. Climate changes perhaps have both beneficial and detrimental impacts on agriculture sector. However, it is evident from the history that, agricultural enterprises have coped with unpredictable changes in climate through adoption of technologies for crop production and management, often referred as climate resilient agriculture.

In the regime of global warming, agriculture in India and elsewhere is at the cross- roads. Unpredictable and unprecedented variations in the weather pattern have posed threats to agriculture, as it directly or indirectly affects the crops/ cropping system in a particular location or over larger areas. Spices are cultivated under diverse cropping systems and varied agro-ecological systems are also no exception to this vagary. Among the spice crops, cardamom and black pepper, which share a lion part in both production and export, have also been affected by the change in weather pattern. However, by adopting various mitigation measures especially, water conservation measures and judicious use would reduce climate effect to a greater extent and economic production could be achieved in a sustainable manner.

2. Cardamom

Small cardamom (*Elettaria cardamomum* Maton), a member of the family Zingiberaceae, is a perennial plant indigenous to South India, occurring in the moist evergreen and deciduous forests of Kerala, Karnataka and Tamil Nadu. The cardamom of commerce is the dried capsule, which is used as flavouring agent in food, confectionary, beverages, cosmetics and medicine. As cardamom is well noted for therapeutic properties like stimulant, carminative, diuretic, stomatic, aphrodisiac *etc.*, it is used as one of the recipes in native and Ayurvedic medicines.

In India, cultivation of cardamom is mostly concentrated in the evergreen forests of Western Ghats in South India. Besides India, cardamom is cultivated in Guatemala, Tanzania, Sri Lanka, El Salvador, Vietnam, Laos, Cambodia and Papua New Guinea Small cardamom is grown in an area of 71, 012 ha with a production of 10, 380 t. Kerala has maximum area and production followed by Karnataka and Tamil Nadu (Table 1).

Table 1. Area, production and yield of black pepper and small cardamom in India during 2010–11

Crop/State	Area (ha)	Production (tonnes)	Yield (kg/ha)
Black pepper			
Karnataka	21061	18240	866
Kerala	172182	20640	120
Tamil Nadu	3009	9120	3031
Total including others	201381	48000	238
Cardamom (small)			
Kerala	41242	7935	192
Karnataka	25209	1710	68
Tamil Nadu	4561	735	161
Total including others	**71012**	**10380**	**146**

Source: Spices Board (http://www.indianspices.com/pdf/Major_spice_statewise_area_production_2013_new.pdf)
Note: Yield is calculated dividing production (kg) by area (ha)

(i) Climate: Rainfall and Temperature

Cardamom is grown in India under rainfed conditions (75-80% of total area) with the quantum of precipitation ranging from 1500 to 5750 mm per annum. Nearly 75 to 78% of total rainfall is received from South - West monsoon which lasts for three months from June - August. North-East monsoon and pre - monsoon showers (summer rains) are not well distributed and often not dependable. Hence, cardamom suffers from both excessive moisture and moisture stress. Dry spell in these tracts usually occur during December-May. Moreover, the moisture retention in these areas is low due to undulating topography and indiscriminate deforestation. The crop is sensitive to drought as well as change in micro climatic environment (temperature and humidity), hence provision of adequate moisture *i.e.*, irrigation during summer is most essential to realize higher yield.

In India, during 1983 prolonged drought in the first 6 months, when rain was most needed for cardamom plantations, resulted in a significant crop loss especially in exposed and partially shaded areas of Idukki district of Kerala. India's cardamom production came down to 1600 MT, thereby giving a grim pointer to the need for combating recurring drought by proper soil and moisture conservation, mulching, adequate shade management along with provision for life saving irrigation for sustaining yield (Subha Rao & Korikanthimath 1983).

The national average yield of cardamom is only 149 kg ha^{-1} as against 300 kg ha^{-1} in Guatemala and Papua New Guinea. One of the main reasons for the increased yield in Guatemala is the well distributed rainfall. Even though the characters of rainfall were positively correlated with cardamom production, a significant correlation was observed only between total number of rainy days and yield.

Analysis of rainfall and temperature of hill zone (high rainfall tract) of Karnataka (part of Western Ghats) was carried out for 23 years (1986–2008). The analysis indicated that, the tract received a mean rainfall of 2617 mm in 123 rainy days with a maximum contribution (80.94%) from South - West monsoon (June to September). July was the rainiest month (799.6mm) with 28 rainy days. There was no significant trend in mean annual rainfall. The mean monthly maximum temperature (TMAX) ranged between 23.7°C (August) to 31.7°C (March) and mean monthly minimum temperature (TMIN) was in the range of 13.2°C (January) and 18.8°C (May). Temperature trends indicated that annual TMAX was increasing (R^2=0.4903), while TMIN was decreasing (R^2=0.3656). Though the tract receives high rainfall, moisture stress is common between December and March and adequate moisture conservation (or irrigation wherever possible) is essential particularly for perennial crops in the juvenile stage. Based on the analysis, it is suggested that, first dose of fertilizer application, prophylactic plant protection and shade regulation have to be completed during 18th to 21st standard week (30th April-27th May) during pre-monsoon time and second schedule has

to be adopted during 36th (3-9 September) to 39th week (24-30 September). These operations may continue up to 41st week for cardamom depending on rainfall receipt. Beyond 41st week (8-14th November), the rainfall receipt is less and earthing up and mulching for cardamom need to be done preferably before 43rd week (22-28th November) to conserve moisture and reduce the evaporation (Ankegowda *et al*. 2010)

(ii) Water conservation measures

Mulching

Fallen leaves of the shade trees are utilized for mulching. Sufficient mulch should be applied during November - December to reduce the ill effects of drought which prevails for nearly 4-5 months during summer. In a study conducted to assess the relative merits of locally available mulching materials (leaf mulch, paddy husk, phoenix leaves, coir dust and stratified leaf mulch) under uniform shade of coir matting and by using suckers combined with two levels of irrigation (75 % and 25 % available moisture), leaf mulch (19.3) and phoenix leaves (14.9) were on par and significantly superior to other mulches in sucker production.

De-mulching is also equally important during May after the pre monsoon showers for facilitating honey bee movement to obtain better pollination, capsule setting, provide better aeration and minimize incidence of clump rot or rhizome rot. The practice of uncovering the panicles shortly after the commencement of flowering improves fruit set in cardamom.

Trashing

Trashing consists of removing old and drying shoots of plant once in a year with onset of monsoon under rainfed situations and 2-3 times in high density plantation provided with irrigation facilities. Trashing in September onwards may be avoided due to summer. Dried leaves and shoot during this period protects plant from light injury to panicles, flowers and young shoots.

Earthing up

Earthing up of the plant base and root zone with top soil is recommended during October -December. During this operation, care should be taken to ensure that only top soil is used and is evenly spread at the base covering only half the bulb portion of the rhizome. This operation helps to keep the 10 to 15 cm soil loose and friable enabling easy root penetration and water percolation which leads to better growth of new tillers which yield next year. The other operation generally done is cardamom plantations are forking, digging and raking.

Shade management

Cardamom is very sensitive to moisture stress and performs comparatively better in cool and shady environment. The shade canopy provides suitable environment by maintaining humidity and evaporation at suitable levels. Shade requirements vary from place to place depending on the topography of the land, soil type, rainfall pattern, crop combination etc. Gaps in the shade canopy have almost always led to leaf scorching under Indian conditions. It appears that the performance of cardamom plants under Indian conditions depends on their interaction with shade, sunlight and soil moisture. Studies indicated that cardamom does not tolerate direct sunlight at the same time under too much shade metabolic activities of plants are retarded and they fail to grow well and yield. Hence, removal of excess shade is also essential so as to allow sufficient light penetration. Shade has to be regulated based on the topography of the land, moisture content etc so as to get about 50% filtered sunlight for proper growth and flowering.

Shade regulation is one of the important practices in cardamom plantations. It should be attended during summer (March-April) in the new planting areas and during May-June after the receipt of summer showers in the existing plantation. If there is thick shade due to dense branches and bigger leaves, chopping off branches should be done to provide filtered light of 40-60% of the open area. Cut alternate side branches of tree in the lower one third to half portion of the total canopy height. Lopping should not be done on one side only. Cutting branches from all the sides ensures a balanced canopy. South Western slopes should be provided with more shade than North-Eastern slopes.

Cardamom growth is influenced by seasonal conditions, especially rainfall pattern. Vegetative buds emerge from the bases of tillers almost throughout the year. However, majority of vegetative buds are produced after the rainy period. It was observed that linear growth rate of tillers increases with the onset of southwest monsoon and growth rate slows down with cessation of rain. Peak flowering and fruit set period coincide in cardamom and nearly 70-90% of flower production was recorded between May and August. Hence, efficient utilization of fertilizers and time of application is very important. Application of fertilizers in May and later in September is found to be the best. However, under irrigated conditions, tiller initiation and panicle initiation are continuous processes and hence more split application is beneficial.

(iii) Soil and water conservation

Though cardamom tracts receive heavy rainfall (1500-4500 mm), the availability of soil moisture during summer months is a limiting factor due to undulating topography of the plantations and 75% of rainfall is received in three months (June, July and August). In low to medium rainfall areas (1200 to 2000mm), trench system of planting *i.e.*, planting cardamom in 1.5' × 1.5' dimension trenches by filling with farm yard manure, jungle soil and top soil was found to conserve more soil moisture and supplement the plants even during dry spells. In areas having slope of more than 7%, all along the contour, bench terracing of about 5-6 feet width has to be created for taking up cardamom planting. The clearing of fallen shade trees/branches before taking up planting and the removed weeds should be kept between the rows across the slope so as to act as a barrier to check soil erosion and to prevent run off losses for effective soil and moisture conservation. Agronomical practices like shade regulation, trench system of planting, provision of shelter belts, cultural measures like mulching, earthing up, contour staggered trenches, vegetative barriers, intercropping, half moon and continuous half moon terracing help in better growth and development of cardamom (Ankegowda *et al.* 2002; Madan & Ankegowda 2007).

(iv) Water requirement and irrigation management

Cardamom is generally grown as a rainfed crop and cardamom tracts of India experience a dry spell of about 5-6 months. Increased denudation of forests, deterioration in forest ecology, coupled with erratic trends of rainfall, leads to aridity effects, adversely affecting cardamom production. Even if there is no reduction in total rainfall, failure of pre monsoon or post monsoon showers, breaks in rainfall or excesses rainfall, affects the crop adversely. During monsoon, post monsoon and winter months though there is sufficient moisture in the soil, plant growth is rather slow because of low ambient temperature. During summer months, if adequate moisture is available cardamom plant puts forth luxuriant growth.

Under normal conditions, panicles start emerging during January and continue to produce flowers from May onwards. Failure of post-monsoon rains and subsequent stress situation leads to flower and a fruit drop, and under severe conditions causes drying up of panicle tips. Therefore, irrigation is necessary from January to May. Use of drought tolerant genotypes with sustainable yield is another good option.

The yield loss due to moisture stress depends on the intensity and duration of stress. The development of new varieties or cultivars with high yield and tolerance to drought condition is of prime importance in cardamom breeding. In recent years, emphasis has been given to survey problem areas for identifying drought escapes. Such collections made from different centers are under evaluation. Selection of cardamom genotypes were carried out using parameters such as relative water content, membrane leakage, stomatal

resistance and specific leaf weight, and significant variations have been noted among cultivars. Few genotypes are under evaluation for yield under moisture stress condition.

Since the roots of cardamom are shallow, moisture at the root zone does not last long, and hence it is essential to irrigate the crop during January to May. It was also observed that commencement of irrigation from December 15th induces timely production of new suckers and panicles and favors normal maturity of the panicles.

The water collected in the farm ponds from the small and big streams and can be utilized later for irrigation purpose when there is no rain or the gap between two rains is more. The percolation or seepage loss can be prevented by giving cheap lining like cement, polythene sheet etc. Since these ponds may be in the higher elevation, the water can be used for irrigation by gravitational flow. There is a need to provide some more drainage channels to remove the excess water during the heavy rains. But at the same time it should not be allowed to erode the soil and remove all the water immediately. Small check dams or obstruction by stones may be provided in these drainages. But during rainy season the water should be drained quickly and during other seasons, the water could be stored by providing appropriate gates. Wherever necessary the vertical cross drainage may be formed so that the excess water could be drained during the rainy season and stored for giving supplemental irrigation during dry months.

(v) Methods of irrigation

Among the various methods of irrigation *viz*., surface irrigation, sub-surface or trench irrigation and overhead irrigation or sprinkler irrigation, the last one in ideally suited in cardamom plantations.

Sprinkler irrigation

Since cardamom is grown on hill slopes with undulating topography, sprinkler irrigation can provide uniform water supply. Field can be irrigated without wastage water as the rate of application of water can be well regulated with sprinklers. This will also avoid leaching and runoff that are common with other methods of irrigation. The humid atmosphere required for the successful growth and production of cardamom can be created by over head sprinkling. Frequent light sprinkling can be done on soils with poor water-holding capacity. Sprinkler irrigation (25 mm rain) once in 12 days recorded higher yield (396.2 kg ha^{-1}) than sprinkler irrigation once in 15 days (378.72 kg ha^{-1}) and no irrigation (224.03 kg ha^{-1}) (Ankegowda 2011).

Drip irrigation

Most of our cardamom areas are on slopy grounds along the Western Ghats. Availability of perennial water sources in plantation areas is very limited. Even if such sources are available the volume of water required for irrigating large extent even though sprinkler will be too much, making it impossible to cover the entire area during summer months. Drip irrigation has advantages such as minimum labour, maximum irrigation efficiency (80-95%), efficient use of fertilizers, early maturity and higher yield and controlled weed growth. Disadvantages of drip irrigation are clogging of outlets, unsuitable for closely spaced crops and damage caused by ants and rodents etc. In spite of early initiation of panicle and poor setting at early stage, in drip irrigation, 8 litres per plant daily from January 15th onwards recorded significantly higher yield (575.58 kg ha^{-1}) followed by sprinkler irrigation once in 12 days (378.72 k ha^{-1}).

Mini sprinkler irrigation

Many farmers who have taken up intensive cultivation of cardamom with high productive clones are irrigating cardamom by mini sprinkler irrigation. Similar to drip irrigation, in this system small pipe lines are given in the middle of rows. In general, mini sprinkler heads are fixed at height of one and half to two

feet height and this heads sprinkles water to 5 feet radius for an hour daily. They have a discharge rate of 40-50 L/ h. Advantage of this system is that it saves water (Fig. 1). However, the disadvantage of this system is that it cannot wet the leaves.

Fig. 1. Mini sprinkler irrigation

3. Black pepper

Black pepper is generally grown in southern states *viz*., Kerala, Karnataka and Tamil Nadu and is slowly spreading to non-traditional areas such as East and West Godavari districts of Andhra Pradesh, Andaman and Nicobar Islands and North - Eastern states. The optimum temperature for crop growth is in the range of 23-32^{o}C, though it tolerates a temperature range of 10-40^{o}C. It can be grown in altitudes ranging from sea level to 1500 m above MSL. Tropical temperature and high relative humidity with little variation in day length throughout the year and a well distributed rainfall of 2000-3000 mm is required for better productivity. It is susceptible to excessive heat and dryness.

Black pepper growing regions of southern states receive on an average 1500-4000 mm rainfall of which around 75% is distributed during June to October and remaining during November to May. This makes rainfall distribution very uneven and the crop suffers due to lack of soil moisture especially during March to May months which affect nutrient absorption from soil. This phase is crucial as flower primordial initiation takes place during this period. Low soil moisture coupled with high radiation load and high temperature results in severe wilting of vines which affects productivity to a great extent. Basin irrigation of pepper vines @ 40-50 L/vine at fortnightly intervals during this period has been reported to enhance productivity substantially. Rainfall of 70 mm received in 20 days during May-June is sufficient for triggering flowering process in the plant, but once the process is set off there should be continuous showers until fruit ripening. Growth of fruit bearing shoots (laterals) and photosynthetic rate are more during peak monsoon in India. The late commencement of south west monsoon delays flowering. Heavy north east monsoon showers after a spell of dry period after SW monsoon results in high spike drop.

Trends of climatic parameters of black pepper growing regions and the pepper productivity trends of those regions have been studied recently and in most of the regions, the trend is similar, *i.e*., as rainfall decreases and temperature increases, the productivity decreases. As black pepper is valued for its quality, it is very essential to have information on the influence of climate change on its quality parameters. Black pepper is grown in the country in wide range of altitudes ranging from sea level to 1500 m above MSL. Though the rainfall in higher altitudes is less than or equal to the rainfall in plains, the temperature is 6-9 degrees lower compared to lower altitudes. As it is predicted that the temperature is likely to increase by 2-3^{0}C from the present level by 2100 in India, all the crops are likely to suffer from high temperature especially during summer months. Studies on growth of black pepper at 2-3^{o}C above ambient temperature levels may give an indication on the climate change impacts on black pepper with respect to temperature as

this region is predicted to have 2^{0}C rise in temperature by 2050 (Krishnamurthy *et al*. 2011). Implications from past climate trends and its relationship with productivity are that climate change in terms of increase in temperature may negatively influence black pepper productivity especially in plains whereas increase in Tmin may have positive influence in high elevations. Controlled environmental studies on initial growth of ten black pepper varieties at elevated temperatures (3^{0}C above ambient) revealed that most of the varieties showed lower plant height, leaf area and photosynthetic rate when grown under elevated temperature. Quality changes with respect to altitudinal changes were also noticed. The major quality parameters *viz*., oil, oleoresin and piperine were not affected but oil constituents were affected by altitude. Black pepper grown in high altitude had more α-pinene, limonene, sabinene+myrcene and less β- caryophyllene compared to that grown in low altitude.

(i) Spike shedding – one of the production constraints at high altitude misty climate

The mixed crop of coffee and black pepper is a common practice in many coffee growing regions of Karnataka. The performance of the varieties depends on local climatic conditions, management methods, pest and disease complex of that area. In hilly regions crop failure due to spike shedding, anthracnose and moisture stress have been reported particularly in rainfed mixed crop. In rainfed areas, premonsoon rains play a major role in determining the productivity of the crop.

Crop failure due to spike shedding is becoming major production constraint in high elevations of Karnataka. Shedding of spikes is attributed to various factors *viz*., fungal *pollu* (*Colletotrichum sp*.), insects, drought, absence of pollination and inadequate pollination. Predominance of female flowers in the spikes was reported as the major cause for pollination failure and resulted in spike shedding.

One of the reasons for spike shedding is lack of pollination due to the absence / very low frequency of either male or female flowers. An experiment was undertaken at the Cardamom Research Centre, Appangala, Karnataka (1000 m above MSL with annual rainfall of 3000-3200 mm) to study the flower composition during different months of flowering (May to November) using the hybrid Panniyur-1 (9-12 years old) maintained on silver oak standards. The experimental plot was irrigated from 20th March and shade regulation was attended during April second week to give 70% exposure (6500-8500 lux on cloudy day at noon). Ten vines (6-7 m height) per replication were selected for recording observation and number of bisexual flowers per spike was recorded during third week of the month in 50 spikes/vine and expressed in per cent.

The number of hermaphrodite flowers altered drastically between May to November. Maximum percentage of bisexual flowers was recorded in the month of June (90%), while the lowest was recorded in August (4%) which coincided with heavy rainfall and less light availability. Light availability played an important role in pollination which has a direct bearing on productivity of black pepper.

In another experiment, all recommended practices were followed except shade level which was altered to study the influence of shade on flower composition. Panniyur-1 was maintained on silver oak standard. Shade regulation was selectively attended to in April second week to provide different light levels. Ten plants were selected from each exposure level *viz*., dense shade, partial shade and complete exposure for recording bisexual flower status.Observation on the composition of flower was recorded from the representative plots where excessive spike shedding was noticed. Fifty shed spikes were observed in nine locations (7 in Karnataka, 1 each in Kerala and Tamil Nadu).

The data on flower composition in shed spikes during the month of August indicated predominance of female flowers instead of bisexual flowers, highlighting the shift from bisexual flowers to female flowers under low light and the trend was same in all the nine locations. All the locations were heavily shaded and that might be the reason for the flower composition changes towards female flowers. Though irrigation, variety, standard, age of the vine and management were uniform, the quantum of light availability made the difference in the flower composition. In shaded condition, the drift towards female status is pronounced and spikes comprised of only 3.9% hermaphrodite flowers as against 83% hermaphrodite flowers in exposed conditions. High percentage of bisexual flowers is essential for good fruit set. This shift towards female phase leads to pollination failure and spike shedding during July, August and September. The light

availability can be enhanced by proper shade regulation of standards or shade trees in the plantation during May-June for higher hermaphrodite to female flower ratio.

(ii) Pre- monsoon showers and spiking

In order to assess the influence of pre- monsoon rainfall pattern on black pepper setting in coffee mix cropped with black pepper in Kodagu District, the data on monthly rainfall received in different zones of Kodagu District was collected from planter's field. Timing of spike emergence and setting in different regions of Kodagu under different cropping system like Robusta coffee and Arabica coffee mix cropped with black pepper were observed. Number of spike per $0.5m^2$ and spike length (cm), number of berries per spike and shade level were recorded in different locations in Kodagu District.

During 2008, total rainfall received up to May in the district ranged from 139.75 mm to 480.2 mm. Madikeri Taluk generally receives higher rainfall and the pre monsoon rainfall here ranged from 166.75 to 420.75 mm. In Virajpet area, pre monsoon rainfall ranged from 139.75 to 480.2 mm, area generally receives medium well distributed rainfall. In Somwarpet area, pre monsoon rainfall ranged from 240.25 to 287.75 mm, area generally receives less rainfall. Monsoon rain starts in the month of June in Kodagu district.

In general, Kodagu District received good and well distributed pre monsoon rains from Feb-May during 2008. As a result, new leaves and spikes emerged early and crop setting was significantly better (Hebbettageri, Hakathur, Kakabe, Suntikoppa, Chettalli, Sidapur, Anandapur, Pollibetta, Amathi) compared to area that received rains only in March followed by less rains during April and May (Kutta, Madapur). Intensity of black pepper spiking varied between Arabica and Robusta coffee plantations. In Robusta coffee plantation, due to better light availability and in some cases pre blossom irrigation (up to 25 mm), the vines produced spikes in June and uniform setting (69.5 spikes per $0.5m^2$, 13.6 cm spike length and 65.3 berries per spike). In Arabica plantations, on an average, 28.2 spikes per $0.5m^2$ with 13.9 cm spike length and 69.1 berries per spike were recorded under medium shade conditions. Fifty per cent of spikes emerged in June and the remaining fifty per cent emerged in August even in the area where good premonsoon shower was received (Madapur, Suntikoppa).

The data clearly indicated that continuous rains during March, April and May had positive impact on black pepper production in Robusta coffee and shade regulated Arabica coffee mix cropped with black pepper in Kodagu. The areas which received 250-400 mm rain during pre-monsoon period were comparatively better with good crop prospects. This indicates that a minimum of 250-400mm of rainfall during March to May is required in shade regulated pepper gardens for early spiking and setting followed by sufficient rainfall during June for elongation of spikes. Because of early spiking, good berry setting and maturity of leaves, the natural incidence of anthracnose was very less in areas which received more than 250 mm rain during pre-monsoon period. This study clearly indicates the beneficial effect of sufficient well distributed pre monsoon rainfall on spiking and berry setting in Panniyur-1 variety of black pepper grown as mixed crop in coffee plantations. It also helps the planters to apply fertilizers and take up disease control measures (Ankegowda & Krishnamurthy 2008).

(iii) Impact of pre-monsoon irrigation on spike emergence

Due to delayed monsoon the black pepper yield has come down in many plantations over the last few years. However, due to early and well distributed pre monsoon showers, spiking and berry setting were significantly better during 2008. This lead to another experiment to study the influence of summer irrigation during March to May months and management practices on black pepper spike production, berry setting and yield in coffee based cropping systems in Kodagu District, Karnataka.

The experiments were conducted in misty area (during May-June generally mist accumulation is noticed in hill tops) in high altitude (1000 m above MSL) in coffee based cropping system in Kodagu District in two plantations (Sandalkad estate, Boikeri and Fair field estate, Hosakeri) in Kodagu District, Karnataka. The pepper was trained on silver oak (*Grivelia robusta*) and palwan (*Erythrina* sp.) The area was divided into

two blocks, one irrigated and another rainfed. Age of the vine was 12-15 years. The basin irrigation with hose @ 50-60 litres was given to pepper root zone after harvest from March 15th onwards once in 15 days up to May 15th in irrigated block and the quantity of water was adjusted based on the rainfall of preceding week. Shade was regulated in April in both the blocks. The number of spikes per m^2, number of laterals (fruiting branches) per m^2 and number of leaves per m^2, spike length (cm), and the number of berries per spike were recorded at 3 and 6 m height of vine at end of cropping season in both the plantations. The dry yield per vine was recorded. The time of emergence of spike, spike shedding and anthracnose incidence were monitored from May onwards. For the both the blocks recommended package of practices for coffee + pepper cropping system and disease control measures were followed (1% Bourdeaux mixture spray in June and September and drenching with 0.2% copper oxy chloride was undertaken in June). Manures and fertilizers were applied as per the package.

The results from both the plantations clearly indicated that premonsoon irrigation has a significant positive impact on spike production and yield. The yield increase in irrigated block was more than 3 fold compared to the rainfed block. Berry number per spike in rainfed block was half that of irrigated block in Sandalkad estates while it was still less in Fair field estate. The low number of berries per spike in rainfed block is due to partial setting of spikes which implies that delayed spiking may lead to partial setting. Low spike intensity in rainfed situation is due to staggered and delayed spiking, lower bisexual flowers, higher anthracnose incidence and spike shedding (Ankegowda *et al.* 2011).

The results of the study suggest premonsoon irrigation for the control of anthracnose and spike shedding. Unlike other crops, in susceptible black pepper cultivars only tender leaves readily take *Colletotrichum gloeosporiodes* infection. Synchrony in production of new leaves and spiking and early maturity may be the reason for lower disease index in Panniyur-1 under irrigated conditions. This study clearly demonstrates that promoting early spiking and setting is the best strategy to overcome anthracnose infection.

This data clearly indicated that basal irrigation of pepper vine during March-May and shade regulation in April helps in early initiation of spikes and good setting. Thus, based on the results of the study, it is suggested to irrigate black pepper during summer months in years of pre monsoon failure to harvest good crop in high altitude in coffee based cropping system where black pepper is grown as mixed crop. Early production of spikes and new leaves followed by maturity resulted in field tolerance to anthracnose and lower spike shedding.

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Scope of protected cultivation for spices

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1. Introduction

There are about more than hundred spices grown world over and from India alone more than 60 spices exported and Indian spices reach about137 countries around the globe. They are classified as annual and perennial. The annual spices whose seeds or fruits are used as spices are called seed spices. The perennial species include black pepper, clove, cinnamon, nutmeg etc. The perennial spice crops require hot and humid climate where as seed spices are grown in arid to semi arid part of the countries in hot and dry weather. The production status of Indian has been well enough to meet the annual demand. With the accelerating population and opportunity to sell the produce in any corner of the world, the need has arisen to develop technologies to harvest more from per unit area. Annually only 10% of the seed spices produce is exported which meets the 50% of the world demand. There is tremendous scope of protected cultivation in spice particularly seed spices, owing to its annual nature. This technology can also be a boon for other spices crop such as ginger, turmeric, black pepper, cinnamon etc.

Seed spices are all *Rabi* crops of *Apiaceae* family except fenugreek and nigella which belongs to Fabaceae and Ranunculaceae, respectively. These crops are predominantly grown in the states of Rajasthan and Gujarat, altogether these two states forms the 'bowl of seed spices' characterized by its arid and semi arid climatic. Arid and semi arid regions have harsh climatic conditions and also have water scarcity. These two factors offer tough conditions for farmers to raise a highly productive seed spice crops. Since time immemorial these crops are cultivated in the country and in most of the parts they are cultivated following traditional methods of cultivation. The production technologies developed so far has shown slow adoption by farmers, but still there is much to develop in seed spices cultivation.

Considering all these above mentioned facts seed spice crops need due attention, in respect to develop better crop production models to increase the yield with high quality of produce. The model should be so much efficient that it should fit well under the semi arid and arid conditions of the country and should also be cost efficient. The protected cultivation has an answer to the above need which can be rewarding in harnessing more seed spice from per unit area with higher quality. The protected cultivation technology may be applied in the following areas to harness good produce.

2. Solarization by transparent plastic sheets for biotic stress management

Spices are highly affected by soil borne pathogens, as these crops are cultivated in a mono-culturing pattern increases the microbial load over a time which is the main cause of its becoming highly susceptible to various soil born fungal diseases. Hence, it becomes necessary to reduce the microbial load for raising a healthy crop. Sterilization of the soil is can be done by integrating the traditional practice of deep ploughing followed by solarization. A thin transparent plastic film of 25-50 microns laid for duration of 3-4 weeks on a water saturated soil during the critical summer months increases the soil temperature by 10-15°C above the ambient. Solarization has a dual benefit as it also reduces the plant-weed competition, due to high temperature large number of weed seeds becomes desiccated and the weed seeds lose their viability. The technique has given best result in management of wilt and other soil borne diseases in seed spices.

3. Plug tray nursery raising under protected conditions

Seed spices size is small and needs shallow depth for germination. A precise technology intervention is needed to place the seed at a desired depth. Pneumatic seeding is very much possible. This mechanized technology has very high potential and can be applied both for non-pelleted and pelleted seeds. Despite raising crops by seeds, seedling transplanting is also desirable in few of the seed spices like fennel, ajwain, celery and dill.

In fennel transplanting is already a well adopted technology by farmers. An intervention of plug tray nursery raising in fennel can further enhance the plant potential. This will reduce the post transplanting mortality and transplanting shock and can provide healthy, robust, vigorous seedlings and quick establishment. The technology of plug tray nursery raising can be adopted in ajwain, celery and dill. Celery is a sub-temperate crop and needs much time to establish in arid and semi arid conditions of Rajasthan. Being a thermo-dormant crop the seed dormancy can be broken by a snap treatment of seeds at cold temperature and raising them in plug trays in semi controlled conditions, a seedling of 45-60 days old raised a ahead of the cropping season saves time and give opportunity for the plant to establish well in the field. By adopting these techniques a considerable gain in seed yield can be achieved.

4. Plastic mulching

An intervention of raised bed equipped with drip fertigation system can be strengthened by integrating plastic mulching. As weeds are the major problem in these crops, mulching will reduce weed emergence. This will also increase the water use efficiency. A plastic mulching layer will save water by reducing evaporation loss from the soil surface. Hence, there will be reduction in application of weedicides and simultaneously in labour employed in hand weeding. This technology is labour saving, time saving, safer for soil and human health as it reduces residual toxicity of weedicide occurring in the soil and also produces toxic free seeds. The kind of colour of plastic mulches used depends upon the season and objective. Mostly double coloured plastic mulches *viz*., silver + black, yellow + black, blue + black, white + black, only black and only transparent plastic mulches with a thickness of 10-25 microns are mostly used worldwide for different crops in various crops in different seasons with defined objectives. The color of plastic mulch as well as light transmission and reflection affects soil temperature and weed infestation. Plastics are available in several colors, but black has so far been the major mulch used in agriculture.

Benefits of plastic mulches are multiple which includes:

a) *Earliness:* Crops grown on plastic mulch can be harvested 7 to 21 days earlier.
b) *Enhanced yields:* Marketable yield may be up to three times greater.
c) *Improved quality:* Produce is cleaner and has increased quality.
d) *Higher economic returns:* Earliness, high yields and high produce quality may improve economic return to the farmer.
e) *Reduced weed infestation:* Certain plastic mulches prevent light penetration and weed seed germination and growth, and serve as a physical barrier to weed seedlings.
f) *Potential decrease in disease incidence*: Many air borne diseases over-winter in soil and plastic mulch may limit splash onto the plant during rain events.
g) *More efficient use of water:* There is reduced evaporation from the soil surface, and reduced water usage as compared to overhead irrigation due to direct delivery of water to the root zone.
h) *Possibility to double-crop:* The same plastic can be used to grow a second or third crop with minimum inputs.
i) *Reduced fertilizer leaching:* Lower water rates, especially in light soils reduce risk of fertilizer leaching and groundwater contamination.

5. Protected cultivation

Seed spices are cultivated during the winter season and these crops are highly sensitive to abiotic stress more specifically to frost and terminal drought. To save these crops from climatic adversities, protected cultivation techniques can be highly useful. The major protected cultivation techniques which can be deployed in seed spices cultivation are

a) *Temporary plastic walls for protection against frost and low temperature:*
The walls can be erected upto the height of 1-1.5 m depending upon the crop height and transparent plastic can be used for making such temporary walls only during critical winter period (mid December to mid January) under northern plains of India for seed spices

b) *Temporary use of insecticide impregnated walls for protection against insect and frosts:*
The walls can be erected upto the height of 1-1.5 m depending upon the crop height and instead of transparent plastic insecticide impregnated insect proof nylon net of 40-50 mesh can be used for making such temporary walls not only to protect against frost but also to control aphids. Hence these walls can remain for longer time starting from flowering to harvest stages.

c) *Insect proof walk in tunnels/net house:*
Such structures are basically fabricated by using insect proof nylon net which can serve two purposes first, protection against frost and second, protection against insects. These structures are suitable for minimizing the isolation distance criteria in seed spice seed production programmes as it will check the visit of honey bees the chief pollinating agents. Hence, insect proof net houses can help in production of high genetically pure seed and within in the net house apiculture can also help in increases the percent seed set and income from honey production. Such structures can be well equipped with low pressure drip irrigation system. Virus free planting material of perennial spices can easily be produced in insect proof walk-in-tunnel.

d) *Plastic covered walk in tunnels:*
Plastic covered walk in tunnels are advisable for protection against frost. Crops like cumin and coriander can be taken in plastic covered walk in tunnels for high productivity. These structures decreases the crop duration, hence a environmental manipulation can help in having a early seed crop. Such temporary structures are fabricated by using 150-200 microns thickness transparent plastic and have a limitation to be used only in the northern plains of the country where the temperature during winter for a period of 40-60 days goes very low (< 8°C). Such structures can be well equipped with low pressure drip irrigation system.

e) *Shade nets houses for offseason cultivation of seed spices for green leaves:*
The basic objective of this technology is to provide protection to the crop against high to extreme radiation and high temperature during peak summer months. Shade net houses are used for growing offseason crops like coriander and fenugreek for green leaves purposes during critical summer months (April to July). Such structures can be temporary and permanent but the colour and the shading intensity of the shade nets vary based on the specific requirement of the crop. Mostly green or black colour shade nets having a shading intensity of 40-60% are used for offseason cultivation of green coriander and fenugreek.

Spices are entering an era of market competitiveness and hence an integrated approach has to be adopted in spices to make it more sustainable and profitable. Intervention of mechanization and other protected cultivation techniques in spices is imperative.. Seed spices are known for their flavour and aroma, hereby quality stands first than yield, therefore technology which can increase the quality of seed spices are needed.

Post harvest handling and value addition in spices

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1. Introduction

Spices are high value export oriented crops and India is a major exporter of spices and spices products. During 2012-13 India has exported 1,77,625 tons of spices valued Rs.2,71,147 registering 13% increase in and 9% decrease in volume. In the quality front, the major consuming countries like Europe and USA are demanding more and more quality compliance by the producing countries. To meet this challenge we have to equip ourselves to produce, process and market high quality spices, with internationally accepted food safety standards. Hence precautions has to be taken from the harvesting, primary processing which includes, washing, threshing, blanching, drying, cleaning, grading and packaging in order to meet the standards. The improvements in post harvest processing, mechanisation and value addition in spices in major spice crops are presented in this paper.

2. Black pepper

Harvest in Black pepper starts when one or two berries turn yellow (Purseglove *et al*. 1981). The spikes are nipped of by hand and collected in bags. Three models of pepper harvester were fabricated and evaluated on the basis of efficiency in the cutting action and easiness in operation (Aneeshya *et al.* 2013). The most efficient and user friendly was the second model due to its light weight, easiness in operation and minimum loss. Recent advances in product diversification have necessitated harvesting of the berries at different stages of maturity (Natarajan 1981). The primary processing in black pepper involves threshing, blanching, drying (sun drying or mechanical drying), grading and packing.

a) Threshing, Blanching, Drying

Traditional manual processing has given way to mechanization in majority of the processing stages. Mechanical threshers are used now to improve the quality of the product and to increase the efficiency of operations. Threshers developed by various agencies are compared (Amaladhas & Korikanthimath 2003) and given in Table 2.

Table 2. Comparison of black pepper threshers developed by different agencies

Parameter	Model/ make of thresher									
	Gudalur thresher	KAU thresher	TNAU thresher (Improved model)	Malaysian thresher	Indonesian thresher		Vivega thresher		Mohta thresher	Cafex thresher
					Manual	Power	Manual	Power		
Capacity (kg h^{-1})	600	50	200	600	170 – 185	425 – 450	50	200	1200	600
Power source	2 hp motor	0.5 hp motor	1 hp motor	NK	Pedal operated	3 hp motor	Hand operated	3 hp motor	3 hp and 1 hp motor	3 hp motor
Threshing mechanism	Wooden cylinder with aluminium angles	Metal drum with rubber lining	Metal drum with rubber lined rasp bar	Metal drum lined with rubber blades	Metal drum	Metal drum	Metal drum with angles	Metal drum with angles	Metal drum	Metal drum
Max. efficiency (%)	99.5	98.0	99.6	99.8	94.13	92.21	91.5	96.0	Nearly 100	98.0
No. of passes	2 - 3	2 - 3	2	2	NK	NK	3	2	1 - 2	2
Damage (%)	< 0.3	< 0.5	Negligible	NK	3.78	6.13	4.0	> 4.0	Negligible	< 0.5

NK – Not known

Source: Amaladhas & Korikanthimath (2003)

The quality of the black pepper can be improved by blanching, a simple treatment of dipping the mature berries taken in perforated vessel in boiling water for a minute before drying. Sun drying is the conventional method followed in order to bring the moisture content below 10%. The average dry recovery varies between 33-37% depending on the varieties. Recently, various types of dryers such as solar and mechanical dryers have been developed by different agencies which are highly efficient for drying pepper. Solar tunnel drying in a cylindrical tunnel shaped drying chamber of size 2 m × 3 m to a height of 2m for drying 100 kg pepper was reported by Thirupathi & Visvanathan (2008). A natural convection reverse air flow mechanical drier developed by Regional Research Laboratory, Trivandrum are used by the farmers and small scale industries for drying of black pepper. Models of varying capacities operated either electrically or by burning agricultural wastes can also be used for drying. An electrically operated drier of 100 kg capacity has been developed by TNAU, Coimbatore (Sreenarayanan *et al*. 2003).

Fig. 1. TNAU Thresher

Fig. 2. Mechanical black pepper dryer

b) Cleaning and Grading

Cleaning and grading are basic operations that enhance the value of the produce and help to get higher returns. The dried pepper is cleaned to get rid of the extraneous matter such as dirt, stalks, leaves etc. Magnetic separator is used to remove metallic contamination such as iron fillings and stray nails. Vibratory conveyors with inclined decks in combination with air classification are used for efficient de-stoning of spices. Broken pepper and light pepper grades are separated pneumatically. Pinheads which come along with garbled pepper are separated by sieving. Cleaning on a small scale is done by winnowing and hand

picking which removes most of the impurities. Grading of black pepper is done by using sieves and sifting black pepper into different grades based on size. TNAU has developed a hand operated cleaner cum grader suitable for cleaning and grading operations (Thirupathi and Visvanathan, 2008). At an operating speed of 25 rpm, the unit had a maximum effectiveness of 66.4% and capacity of 430 kg/h.

c) Packaging and Storage

Whole pepper is generally packed and transported in gunny bags and polyethylene lined double burlap bags. The bags are arranged one over the other on wooden pallets after laying polypropylene sheets.

3. Cardamom

Cardamom, known as the 'queen of spices', is one of the highly prized spices of the world. As the flowering continues over a long period several pickings are needed. Harvesting should be taken up only at a time when the capsules reached the maturity stage. Immediately after harvesting on each day, capsules are washed to get rid of dirt and treated with 2 % washing soda (Sodium Carbonate) for 10 minutes to retain green colour and reduce mould growth in RCC tanks. The treated capsules are spread in a single layer on portable drying trays for draining of wate and later for drying.

a) Curing

Cardamom curing or drying is the process in which the moisture content of green cardamom is reduced to 8-12%. There are mainly two types of drying *viz*. sun drying and artificial drying. In sun drying it is difficult obtain good green colour and requires 5-6 days or more depending up on the availability of sun light. Artificial drying can be done either by electrical or conventional flue pipe drier.

b) Garbling

The dried cardamom is then subjected to garbling. Traditionally this is achieved by rubbing the cardamom capsules against coir mat or wire mesh and winnowed to remove any foreign matter. An oscillatory type semi mechanical garbling unit developed by Tamil Nadu Agricultural University, Coimbatore has a capacity of 2-3 kg per batch whereas the rotary type garbler will take about 2-3 minutes to garble one batch of about 5 kg. Its capacity is 100kg/h and the efficiency was 98% (Sreenarayanan *et al*. 2003).

4. Ginger

India and China are the world's largest producers and exporters of ginger. In India, domestic market prefers fresh green ginger for culinary use while two other types of dried ginger i.e. bleached and unbleached are also produced for export purpose. The fresh ginger immediately after harvest is subjected to washing, which is performed to remove dirt, residues of farm chemicals and other foreign materials.

a) Peeling and drying

After washing the ginger rhizomes are subjected to peeling operation. Indigenously, peeling of ginger is done by scrapping with sharpened bamboo stick. The scrapped or peeled rhizomes are again washed well and dried in sun for a week or more and then rubbed again to give a polish. A mechanical brush type ginger peeling machine has been developed by Rajasthan Agricultural University. The peeling efficiency of the machine was 85% and the capacity was 200 kg/h (Agarwal *et al.* 1987). Another mechanical ginger peeler was developed with its peeling drum made of diamond cut mesh (Jayashree & Visvanathan 2013) which has a peeling efficiency of 59%. The sun dried ginger is brown in colour, more or less irregular wrinkled surface

and when broken, shows a dark brownish colour. However, it is reported that the quality of dry ginger cured in the brightsun is better than the quality of ginger cured in a closed oven with artificial heat.

b) Polishing

Polishing of dried ginger is done to remove the wrinkles developed during drying process. In the indigenous method the dried ginger is rubbed against a hard surface. However, hand or power operated polishers similar to turmeric polishers are also employed for the purpose of polishing dried ginger. In the case of hand operated polishers an output of 5-6 quintals per day of 8 hours is obtained with the help of two persons. The dried ginger rhizomes are manually graded. The machines of various capacities to pulverize dried ginger from 25 kg per batch to continuous powdering of 2-3 t/ day for large scale production are available.

5. Turmeric

Maturity of the crop is indicated by complete drying of the aerial plants including the base of the stem. The leaves and stem are cut close to the ground. Two days earlier to digging out the rhizomes, irrigation is given. In case of ridge method of planting, plough is used to lift the rhizomes. Otherwise the rhizomes are dug out with manually. he harvested rhizomes have to be cured within 2-3 days after harvest for securing maximum out turn. In the turmeric growing regions of Tamil Nadu, mechanical harvesting of turmeric is being practiced. Tamil Nadu Agricultural University (TNAU), Coimbatore has developed a power tiller operated mechanical turmeric harvester with a capacity to harvest 0.6 ha per day (TNAU, 2009a). Tractor drawn turmeric harvester mounted on 35-45 hp tractor with a capacity to harvest 1.6 ha per day have been developed by TNAU (TNAU, 2009b). The tractor mounted harvester may be adjudged as the best mechanical harvester for saving of time and reduced the percentage of damaged rhizome apart from the removal of drudgery in harvesting of quality rhizome.

Fig 3. Tractor and power tiller driven turmeric harvester

a) Post harvest operations

The harvested turmeric rhizomes before entering into the market is converted into a stable commodity through a number of post harvest curing processes like boiling, drying, polishing and colouring. Curing of turmeric is taken up within 3 or 4 days after harvest. The fingers and mother rhizomes are separated and are cured separately, since bulbs take longer time to cook.

The recommended practice is to use clean water for boiling turmeric rhizomes in mild steel or galvanized iron pans and takes about 60-90 minutes. The cooked fingers are heaped on a cleaned drying floor and left undisturbed for 4-5 hours and later sun dried for 10-15 days by spreading in 5-7 cm thick layers on bamboo mat or on the drying floor. Tamil Nadu Agricultural University (TNAU), Coimbatore, has developed an improved turmeric boiler using steam boiling technique (Visvanathan *et al.* 2002). The

capacity of the boiler is about 200 - 300 kg per batch and 40 q per day of 8 hours. Fuel used is 70–75 kg of agricultural waste materials. Curing of turmeric for 60 min by steam cooking was considered optimum to produce quality dried turmeric with minimum losses The use of large scale steamer for boiling large quantities of turmeric rhizomes at farm level was also available (Visvanathan 2008).

b) Polishing

Poor appearance of dried turmeric is improved by smoothening and polishing the outer surface by manual or mechanical rubbing. Manual polishing gives rough appearance and dull colour in the dried rhizome. A mechanical polisher for turmeric has been developed in the Agricultural University at Andhra Pradesh, India (Sukumaran & Satyanarayana 1999). The unit consists of 88 cm diameter mild steel drum with meshes and is operated by a 2 hp electrical motor. The drum speed was maintained at 30-32 rpm and the capacity of the polisher is about 600-700 kg/h. A pedal operated hexagonal drum having six polishing plates of size 30 × 60 cm has been developed at OUAT (Pal *et al*. 2008). The capacity of the polisher is 100 kg/h and 6% polishing is achieved.

c) Cleaning, grading, packing and storage

Turmeric of commerce is described in three ways- fingers, bulbs, and splits. Very little grading of the spice is done at the growers end. Cleaned and graded material is packed generally in new double burlap gunny bags and stored over wooden pallets in a cool, dry place protected from light.

Fig 4. Turmeric steam Boiler Developed by TNAU & Tractor driven turmeric polisher

6. Chillies

Chilli (*Capsicum annum)* is the most widely cultivated crop among the spices grown in India. Chillies are harvested when the pods are well ripened and partially wither at the plant itself. At this stage they would have superior pungency and colour. Improved drying involves drying of chillies on materials like tarpaulins, cement concrete floor, polythene sheets etc. In mechanical drying, the chillies are dried at a drying temperature of 50^{o} C and at air velocity of 1.5 m/s. Solar cabinet driers developed by CIAE Bhopal with a capacity of 30-50 kg/batch (dry weight basis) can dry chillies in 3-5 days. Waste fired driers developed by PKV Akola is suitable for drying 200 kg of red fresh chillies per batch with in a period of 16 hours for moisture reduction from 73% to 16.6% (Kachru & Gupta 1993). The cleaning and grading are done manually. Pulverizing of chillies is done in hammer mills of various capacities. The whole or powdered chillies are stored in double layer poly propylene bags as it is easily subjected to aflatoxin contamination.

7. Nutmeg and Mace

Fruits of nutmeg are harvested when they split open on ripening. The split fruits are either plucked from the tree with a hook or collected soon after they drop onto the ground. Since this crop is harvested during rainy season in Kerala, sun drying is difficult resulting in improper drying of nutmeg and mace. Drying of medium to large quantities of nutmeg is done in drying rooms. The harvested nutmeg is spread on raised wire mesh floor and heated air is passed through pipes inside the drying room. Continuous drying of nutmeg is not recommended as the oil oozes out without proper drying. The local practice of drying nutmeg at Kalady, a prominent nutmeg growing area is to pass the hot air for one or two days (8 hours each) and then allow to dry at ambient conditions for one week. The heated air is again passed for a day or two and then dried for a week or 10 days. The nutmegs are dried until the seeds inside rattle on shaking. This takes about 15 days or more. The seed cover is removed by breaking the hard seed coat manually or mechanically. Some of the nutmegs are dried improperly by this process have lot of fungal infections and the problems of aflatoxins are also reported by the exporters. Nutmeg samples dried in solar tunnel drier showed a higher reduction in drying time. It took about 8 hours for drying from an initial moisture content of 42.6% to 7.2%, while the conventional drying practice took about 13 days (Joy *et al.* 2000). Nutmeg is usually packed in double layered jute or polythene bags. If other packing materials are used, care must be taken to avoid materials, which might lead to 'sweating' and mould development. Powdered nutmeg is prepared by grinding at ambient temperature.

Mace is detached from the nut carefully soon after harvest, washed, flattened by hand or between boards and then sun dried until they become brittle. Hot air ovens can be used for drying and the colour retention is much better than sun dried mace. Studies conducted at IISR, Calicut showed that blanching of mace in hot water at 75 ^{o}C for two minutes preserved the qualities of mace during drying (Amaladhas *et al.,* 2002). Dried mace is graded and packed.

8. Cinnamon

Cinnamon is obtained by drying the central part of the bark and is marketed as quills or powder. Harvesting for bark is made after the second or third year of planting and the subsequent harvest is made between 12 to 18 months after previous harvest. The finest quality of bark is obtained from shoots of uniform brown colour, thin bark 1.0-1.2m length and 1.25 cm diameter. The ideal time for cutting the stem is when the red flush of the young leaves turn to green**.** Coppicing of cinnamon for extraction of bark, harvesting of 5- 6 cm thick stem is recommended. Production of quills consists of peeling, rolling and piping. The process of producing quills has several by-products (Quillings, Feathering, chips) which are used in further processing.

9. Seed spices

Out of 20 seed spice crops cumin, coriander, fennel, fenugreek, dill and ajwain contribute more than 95 per cent towards area and production. Cumin and fennel are dominant seed spices of Gujarat while coriander and fenugreek are important in Rajasthan. India exports raw as well as value added items to nearly 70 countries in the world and meet around 45% of the global demand and earns 361.5 crores of foreign exchange.

For exporting the seed spices, quality is the most important criterion. The quality of seed spices is assessed by mean of its intrinsic (Moisture, volatile oil, oleoresins content, major chemical constituents) as well as extrinsic (size, appearance, colour) quality. The produce must be safe, free from any health hazards substances and contaminants. The contaminants can be classified into three categories.

1.	Physical contaminants	Immature or shriveled seed, berries, insect infested product, presence of live or dead insect excreta of animals.
2.	Chemical contaminants	Added colour material, preservatives, antioxidants, fumigants, aflatoxin, pesticides/insecticide residue.
3.	Microbial contaminants	Presence of Salmonella, *E. coli*, yeast and mould.

a) Stage of harvest

The crop of coriander matures in 90 to 135 days. The stage of maturity of the fruit at harvest is when central umbels are about to attain yellow colour. Cumin is harvested in about 100-110 days. Fennel takes 170-175 days to mature and harvesting is done before the fruits are fully ripe, umbel attains a slight greenish yellow colour. A good quality fennel for chewing purposes, commonly known as '*Lucknowi saunf*' is produced by harvesting the umbel 30 to 40 days after pollination. In fenugreek, the harvest time is judged when the colour of leaves and pods turn yellow. The right time of harvesting is usually done in the morning hours to avoid shedding losses.

Fig 5. Thresher for fennel and Cumin

Fig 6. Mobile processor for seed spices

b) Threshing of seed spices

Traditionally, threshing of seed spices is performed by treading the crop under the tyre of tractor or by stick beating and then the threshed stocks is cleaned by winnowing in natural air stream or in the artificial air streaming the processed products. The new modified threshers were tested in the adopted villages for threshing of cumin and fennel crop by CRSS, Jagudan and it was found that net return of 3.25 and 3.00 Rs per kg for cumin & fennel threshing respectively can be obtained as compared to traditional method.

c) Drying

Sun drying is usually adequate to dry to produce but there is a chance of contamination of the material by dust and dirt and volatile components will be lost. Mechanized drying could enhance the quality and post harvest losses. At CRSS, SDAU, Jagudan low cost poly solar drying method was the best for faster drying (32 hr) as compared to other drying methods. Shade drying is the best to maintain green colour of fennel. Higher net return (75.50 Rs/ kg) was obtained in low cost poly solar dryer as compared to shade drying method (64.84 Rs/ kg) and open sun drying (58.80 Rs/ kg).

d) Cleaning /Grading

Various machines are used for special functions. Spiral separator is used to separate round seeds and flat seeds. Magnet drum/pulley is used to separate iron particles. Magnet seed separator/ electrostatic seed separator is being used to separate identical weed seed from product. Electronic colour sorters are used to separate discoloured seed to enhance colour value of final product. Gravity separator/destoner is to separate undesirable material on the basis being used of gravity.

e) On farm processing through mobile seed processing unit

Value addition at farm level is urgent need of the time because major deterioration and post-harvest losses occurs at this stage. The Mobile Seed Processing Unit was demonstrated by Centre for research on Seed Spices, Jagudan in adopted villages under NAIP Component-II "Value chain in Major Seed Spices for Domestic & Export Promotion" project for on farm processing of Fennel & Cumin crop. Average higher price of Rs.725 and 491 per quintal, respectively for fennel and cumin was obtained as compared to unprocessed product. The farmers are realizing 10-15% higher prices of their processed produce as compared to traditionally unprocessed produce, such type of processing unit are also established in nearby the villages. A mobile agro processing unit developed at CIPHET on a four wheeled trailer could be used for processing of seed spices at farm level. The different machines suitable for processing of seed spices including cleaner grader, horizontal burn mill, vertical burr mill etc. could be installed and operated by a DG set. These types of mobile processing machine were also tested at Research Farm of NRCSS, Ajmer and at Farmers' fields and the results are encouraging. This machine is very much beneficial for small and marginal farmers as the produce can be processed at their door step.

f) Packaging and storage

To standardize proper packaging materials for coriander an experiment has been tried with following eleven packaging materials for bulk and retail packing at CRSS, Jagudan. For bulk package jute bag, jute bag with LDPE lining, HDPE bag, HDPE bag with LDPE lining, Paper bag each with 50 kg capacity, LDPE, HDPE, PP, PET+LDPE laminate, metalized PET +LDPE laminate. From the above packaging treatment, paper bag is found best followed by jute bag with LDPE lining in case of bulk packages (50 kg bags) while in the case of consumer packages (500 gm), metalised PET + LDPE laminate is found best followed by PET + LDPE laminate. The whole dried seeds are usually packed into jute or poly bags and stored in cool dry places at 25^{0c}-28^{0c} room temperature. Biodeteriration due to storage fungi and storage pests will occur if the moisture of the produce is more than 10%.

10. Value added products from spices

a) Black pepper

A variety of products have been made from pepper like Green pepper based products, Black pepper and white pepper based products and Pepper by- products. The major green pepper based products are Canned green pepper, Green pepper in brine, Bulk-packaged green pepper in brine, Cured green pepper, Frozen green pepper, Freeze dried green pepper, Dehydrated green pepper, Green pepper pickle, Mixed green pepper pickle, Green pepper sauce and Green pepper-flavoured products**.** Black pepper and white pepper based products include Whole black pepper, Sterilized black pepper, Ground black pepper, Cryoground black pepper powder, Pepper oil and Oleoresin, white pepper and white pepper powder. Other miscelaneous products from pepper are Pepper-flavoured products, Pepper extract, curry powder spice blends, peppersal, Pepper mayonnaise, pepper cookies and pepper tofu.

(2) Cardamom

Major products of cardamom are bleached cardamom, Decorticated seeds and seed powder, Cardamom volatile oil and Cardamom oleoresin. In addition to this, CFTRI, Mysore has developed the following products: Encapsulated cardamom, cardamom tea, cardamom coffee and cardamom soft drink mix.

(3) Ginger

Ginger powder, ginger oil, Ginger oleoresins, encapsulated ginger, Ginger preserves and salted ginger are the value added product from ginger.

(4) Turmeric

Major value added products are Ground turmeric, Turmeric oil, Turmeric Oleoresin and curcuminoids.

(5) Chilli

Oleoresin is the main product. Other products from chillies are Dehydrated chilli, Canned chilli, Brined/pickled chilli and Fermented chilli.

(6) Nutmeg and mace

Nutmeg oil and mace oil, Nutmeg oleoresin, Nutmeg butter are the main value added products. By utilizing nutmeg pericarp (rind), many value-added products have been developed viz., Nutmeg (rind) pickle, Nutmeg (rind) preserve from slices, Nutmeg (rind) preserve from shreds, Nutmeg (rind) candy, Nutmeg (rind) sweet chutneyand Nutmeg (rind) powder.

(7) Cinnamon

In addition to cinnamon bark, various other products are obtained from the tree namely, bark oil, leaf oil, bark oleoresin etc.

(8) Seed spices

In seed spices value addition may be adopted in following way:

1. Ground spices.
2. Spices extractives
3. Curry powder
4. Consumer packed spices.
5. Organic spices.

The ground spices can be incorporated in food dishes more uniformly as compared to whole spices. In spite of these attributes they have limited shelf life and are subject to oxidation, flavour loss and degradation on long storage due to microbial contamination. For small scale production up to 100 kg/day manual grinders are adequate. For large scale production a small powered grinding mill needed and models are available that can grind 25 kg/hr. The high heat evolved at the time of grinding (42-95 ^{0} c) resulting in flavor loss. To overcome this, spices are milled at low temperature using liquid nitrogen cryogenic grinding. Coriander powder was prepared by cryogenic grinding at four temperatures – 30 ^{0}C -80 ^{0}C, -120^0 C and -180^0 C at CRSS, Jagudan. By cryogenic grinding at -180 ^{0}C had smallest particle size, more uniformity and high volatile

oil content (0.9%). Coriander powder obtained from cryogenically grinding method is found greener than that obtained from traditional grinding method. The major disadvantage of cryogenic grinding is high cost.

Fig 7. Cryogenic grinding facility for seed spices **Fig 8.** Processing facility for seed spice at Mehsana

(9) Spices extractives

Spices extractives can be categorized into three groups:

Essential oils

These are major flavouring constituents of spices, highly concentrated about 75-100 times than the fresh spice

Coriander: Major component of volatile oil is linalool (67.7%) followed by alphapinene (10.5%), amma-terpinene (9.0%), geranyl acetate (4.0%), camphor (3.0%) and geraniol (1.9%). Minor components include beta-pinene, camphene, myrcene, limonene, p-cymene, borneol etc. Indian coriander oil differs from European oil in Possessing a lower linalool contents and comparatively higher linalyl acetate contents.

Cumin: The main constituent is cuminaldehyde and three other aldehydes up to 70%. Dominant monoterpenes hydrocarbons (total about 50-55%) are b-pinene, g-terpinene and p-cymene, plus myrcene a- and b-phellandrene and limonene, with minor amounts of sesquiterpenes hydrocarbons (Baser et al 1992). Cumin oil is sometimes adulterated with synthetic cuminaldehyde, which is difficult to detect. The oil is a raw material for the production of thymol.

Fennel: Fennel seed oil, usually traded as fennel oil, is mainly obtained by steam distilling whole or crushed fruit with a yield of 1.5-6.5%, and more recently by supercritical carbon dioxide extraction. In general, oil content is greatest in European and lowest in Asian varieties. The main constituents are trans-anethole (60-65%, but up to 90%), fenchone (2-20%) estragol (methyl chavicol), limonene, camphene, a-pinene and other monoterpenes, fenchyl alcohol and anisaldehyde. Oil produced in Nigeria from fennel of Indian origin had 80% anethole content but no fenchone..

Fenugreek: Major constituents are the dihydroactinidiolide,2-3- dihydrobenzofuran and 1-heanol totaling 7-9% with 20 other constituents at less than 3% and the remainder below 1%. The furanone derivative, sotolon, is reportedly mainly responsible for the characteristic fenugreek odour.

Oleoresins

Oleoresin represents the complete flavour and non-volatile resinous fraction present in the spices. The aroma and taste fractions are proportionally blended to constitute the 'true essence' of the natural spice. The oleoresin can be obtained in a single step by elimination of the steam distillation process.

Derivatives of essential oil and oleoresins

They include plated encapsulated forms of spice extractives, seasonings in dry carrier such as dextrose, salt or rusk powder. They impart the strength of good quality freshly ground spices and can be easily incorporated in the food.

(10) Curry Powders/blends and mixes

Curry powder is an indigenous seasoning made from various spices (coriander, cumin, fennel, fenugreek are common) constitute the raw materials used in quality curry powder. The ingredients of curry change according to different needs. The colour, form and taste of various curries are in accordance with the custom of various nations and regions. Consumers all over the world demand different curry powder. The export trade in curry powder at present is dominated by India. Curry powder is made from a blend of several spices, the number vary from a minimum of 5 to more than 20 depending on end uses.

(11) Consumer packed Spices

The exported spices are consumed in three main segments namely, industrial, institutional and retail. Different packaging media are used according to the consumer's preference. The packaging has gained considerable importance as it increases the shelf life of spices. The development of new and improved plastic films, aluminium foil, laminations, high speed film sealing machines etc. has created new opportunities for packaging the spices as instant spices, spices pastes, spices powder etc. By exporting consumer packed spices, higher unit value for the same quantity can be earned. The price of such retail spice packs is higher between 50-100 per cent as compared to prices of bulk spices.

(12) Organic spices

Exporters specializing in organic production have been successful in achieving the international standard prescribed for spices. The growing demand for organic crop products has led to the development of international trade for organic spices**.**

11. Conclusion

Post harvest operations like harvesting, procession, packing, extraction and development of value added products etc play a major role in maintaining quality of spices to the specifications of international trade. In addition to reducing the labour, mechanization helps in maintaining the quality and food safety standards. Improvements in hygiene, packing and storage facilities will not only help in keeping quality of spice flavours but also play a major role in reducing aflatoxin and salmonella contamination of our spices and spice products. The present deficiency in on farm primary and secondary processing of spices need to be bridged for quality up gradation and greater emphasis on product diversification to the newer requirements of domestic as well as global marketing. Thus post harvest processing and management of spices have great scope considering the present international trade scenario.

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Management of mycotoxins in spices- an update

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1. Introduction

India accounts for 25-30% of world's pepper production, 35% of ginger and about 90% of turmeric production. It is estimated that the world trade by 2020 will be around 24.2 lakh tons of spices. To meet this demand, India has to assure the quality of the product. To achieve thisgreater emphasis should be given to post harvest management of spices. Spices are highly hygroscopic in nature and absorption of moisture from air, during rainy season results in mould and insect infestation. Spices need protection against ingress of moisture, light, heat and loss of aroma or flavour during storage. Like all the other agricultural commodities, spices invariably contain high moisture content (55- 85%) at the time of harvest which has to be brought down. Post harvest handling should ensure proper conservation of basic qualities like aroma, flavour, pungency, colour etc.

2. Mycotoxins-present scenario

Mycotoxin contamination in agricultural systems has been a serious concern for human and animal health and has been used as a non-tariff trade barrier. It is a major problem in the tropics and subtropics, where climatic conditions and agricultural and storage practices are conducive to fungal growth and toxin production.The finance and resource burdens on farmers for detection and amelioration of these mycotoxins in ingredient rations and in the production environment are significant. Livestock in tropical countries are especially affected by acute toxicity and consumers are vulnerable to the long-term mutagenic and immuno-suppressive effects of mycotoxins.

With the increasing stringent regulations for mycotoxins, especially for aflatoxins imposed by importing countries such as the European Union, the export industry of agricultural commodities is under constraint. The problem is further compounded by the unorganized structure of the export set up and a general ignorance or inadequate knowledge of both the farmers and processors about aflatoxins. The problem is not obvious like other diseases which produce visible symptoms on plants due to infection.

In agricultural crops, mycotoxin production can occur at various points in the food chain *viz*., at pre-harvest, harvest and drying, and storage. Poor agricultural and harvesting practices, improper drying, handling, packaging, storage, and transport conditions promote fungal growth, increasing the risk of mycotoxin production. After processing, further mycotoxin production is limited especially if the water activity of the product is low enough to prevent mould growth and mycotoxin production. This is the key element for mycotoxin-free products. Toxins can also accumulate in processed products due to increase in the levels of water activity, allowing fungal growth and mycotoxin production (Marin 2013).

3. International limits for mycotoxins in food and feed

Presence of mycotoxins is not only related to the effect they might have on consumer health, but may also have an impact on world trade. According to the annual report of the Rapid Alert System for Food and Feed (RASFF), in 2012, mycotoxins were the main hazard in border rejection notifications in the European Union. In the report, aflatoxins were the primary mycotoxins associated with the commoditties. And herbs, spices,

nuts, nut products, fruits, vegetables, cereals/bakery products, and foodstuffs were the most affected categories (Table1).

Table 1. Mycotoxin notification of EU during 2008–2012

Mycotoxins	2008	2009	2010	2011	2012	Total
Aflatoxins	902	638	649	585	484	3258
Deoxynivalenol (DON)	4	3	2	11	4	24
Fumonisins	2	1	3	4	4	14
Ochratoxin A	20	27	34	35	32	148
Patulin	3					3
Zearalenone	2				4	6
Total	**933**	**669**	**688**	**635**	**525**	**3450**

Importing countries insist mainly on the specification for pesticide residues, aflatoxin, trace metal and microbial contamination. The European Union has set strict limitations on aflatoxin levels in various foodstuffs, such as groundnuts, nuts, dried fruits, cereals, milk and spices including paprika and chilli (European Commission, 2010). Aflatoxin regulations for Foods and Spices (as of December 2003) by European Union [EU] are 5 ppb of aflatoxin B_1 and total aflatoxins to be 10 ppb. For the export of spices and spice products, the most popular specification for spices and herbs is the "ASTA Cleanliness Specifications for Spices, Seeds and Herbs".

The Codex Alimentarius Risk Analysis system comprises a scientifically based Risk Assessment by the FAO/WHO Joint Expert Committee on Food Additives(JECFA), a committee also dealing with contaminants and natural toxins such as mycotoxins, and a Risk Management part by Codex Committee for Food Additives and Contaminants(CCFAC).The principles for laying down Maximum Limits (MLs) for contaminants and toxins in foods and feeds within Codex Alimentarius are agreed and work is in progress to establish MLs for some mycotoxins. In the European Union, a similar process is in progress in particular for spices.

4. Major mycotoxins

Mycotoxins are produced by a number of fungal genera primarily *Aspergillus*, *Penicillium*, *Alternaria*, *Fusarium*, and *Claviceps*. The most relevant groups of mycotoxins found in food are produced by the following five fungal genera: aflatoxins produced by *Aspergillus* species; ochratoxin A produced by both *Aspergillus* and *Penicillium*; trichothecenes (type A: HT-2 and T-2 toxin, and type B: deoxynivalenol), zearalenone, fumonisins B_1 and B_2, and the emerging mycotoxins (fusaproliferin, moniliformin, beauvericin, and enniatins) produced mainly by *Fusarium* species; ergot alkaloids produced by *Claviceps* and altenuene, alternariol, alternariol methyl ether, altertoxin, and tenuazonic acid produced by *Alternaria* species (Barkai-Golan 2008).

5. Aflatoxins

Among various mycotoxins, aflatoxins have assumed significance due to their deleterious effects on human beings, poultry and livestock (Smith & Moss 1985). The aflatoxin problem was first recognized in 1960, when there was a severe outbreak of a disease referred to as "Turkey 'X' Disease" in UK in which over 100,000 turkey poults died. The cause of the disease was shown due to toxins in peanut meal infected with *Aspergillus flavus* and the toxins were named as aflatoxins by virtue of its origin (*A. flavus*--> Afla). Studies revealed that aflatoxins are produced primarily by some strains of *A. flavus* and by most, if not all strains of *A. parasiticus* plus related species, *A. nomius* and *A. niger* (Zain 2010; Iqbal *et al*. 2010; Creppy 2002).

Aflatoxin contamination does not affect crop productivity but it makes the produce unfit for consumption as toxins are injurious to health. The marketability of contaminated produce, particularly in international trade is considerably reduced due to stringent standards of permissible limits on aflatoxin contamination set by the importing countries. The aflatoxin-producing fungi can invade the seed in the field before harvest (preharvest invasion), during harvest, drying, curing, storage and transportation (post harvest invasion).

Aflatoxin producing members of *Aspergillus* are common and widespread in nature. Aflatoxins are toxic and among the most carcinogenic substances known (Hudler 1998). After entering the body aflatoxins are metabolized by the liver to a reactive intermediate, aflatoxin M_1, an epoxide. It is a very powerful hepatocarcinogen and naturally occurring mixtures of aflatoxins have been classified as a class 1 human carcinogen (IARC 1993). The IARC (1993) also concluded that there was inadequate evidence for the carcinogenicity of aflatoxin M_1. Scientists have attempted to isolate genes associated with aflatoxin biosynthesis through cloning of genes, in order to understand the enzymes regulating its biosynthesis, to help develop control strategies through inhibition of these controlling genes (Keller *et al.* 1994).

At least 13 different types of aflatoxins are produced in nature. The species of the *A. flavus* group that produce aflatoxins include *A. flavus*, *A. parasiticus*, *A. nomius*, *A. tamarii* and *A. bombycis.* Some strains of *A. flavus* have been re-identified as *A. parasiticus* and *A. nomius* (Goto *et al*. 1996; Peterson *et al*. 2001; Paterson 2007; Paterson & Lima 2010a, b). Aflatoxin B_1 is considered the most toxic and is produced by both *A. flavus* and *A. parasiticus*. Aflatoxin G_1 and G_2 are produced exclusively by *A. parasiticus*. While the presence of *Aspergillus* in food products does not always indicate harmful levels of aflatoxin, it does imply a significant risk in consumption. Aflatoxins M_1 and M_2 were originally discovered in cow's milk which fed on mouldy grain. These compounds are products of a conversion process in the animal's liver. However, aflatoxin M_1 is present in the fermentation broth of *A. parasiticus*.

Aflatoxins normally belong to the group of difuranocoumarins and are classified into two broad groups according to their chemical structure: the difurocoumarocyclopentenone series (AFB_1, AFB_2, AFB_{2A}, AFM_1, AFM_2, AFM_{2A} and aflatoxicol) and the difurocoumarolactone series (AFG_1, AFG_2, AFG_{2A}, $AFGM_1$, $AFGM_2$, $AFGM_{2A}$ and AFB_3). Aflatoxins are potently toxic, carcinogenic, mutagenic in the order $AFB_1 > AFG_1 > AFB_2 > AFG_2$ as illustrated by their LD_{50} values for day-old ducklings. The dihydrofuran moiety, containing double bond, and the constituents linked to the coumarin moiety are important for producing biological effects.

6. Importance of mycotoxin management

Prime importance has to be given to microbiological safety of spices and their products during storage. Hygiene and storage conditions should be ameliorated for the prevention of aflatoxin contamination in spices. Aflatoxins can be produced only under particular environmental conditions. Therefore, the actual growth of aflatoxigenic fungi on the food does not necessarily mean that aflatoxins are also present. Important factors in determining whether aflatoxins are actually produced as the fungus grows within the seeds or grains are moisture content, temperature, insect or other injury to the crop and the environmental conditions as well as the *A. flavus* isolates (Moore-Landecker 1996; Wilson & Payne 1994). Aflatoxins can be produced in preharvest as well as in stored products. Spores of *A. flavus* can be introduced into the plant through insect wounds or they can germinate on the pistil of the flower. Its spores also contain aflatoxin (Thanaboripat 1988).

The quality of product depends on the quality of raw materials used, the processing methods adopted, the packaging materials used and marketing practices followed. Inadequate storage, transportation and marketing conditions, which contribute to mould growth cause increase in risk of mycotoxin contamination. Therefore, in order to ensure quality of the product, constant care should be maintained from the time of harvest till the time it reaches the consumer. It has been reported that 5–10% of agricultural products in the world are lost to mould and are unfit for consumption by humans and animals (Topal 1993). Most spices are produced in tropical and subtropical regions.

Spice products are usually prepared by drying the raw material whole or coarsely cut. The plant material is commonly spread on the ground and sundried; artificial drying and the use of solar dryers are limited.

Finally, the dried product is ground. The predisposing factors of infection include improper drying, high relative humidity and temperature, farmers' production practices, early and delayed harvesting and poorly constructed storage structures. Spices exposed to some of these factors are likely to have a higher incidence of fungal infection (*Aspergillus* spp.) which might presumably increase the likelihood of the presence of aflatoxins. The hot and humid climate, coupled with simple, unsophisticated production conditions, extended drying times, and often inadequate instructions to farmers can cause considerable hygiene and quality problems (Gerhard 1990). As a consequence, high microbial loads (up to108 cfu/g) may be found in spices as reported in black pepper and paprika (Baxter & Holzapfel 1982; McKnee 1995). Bacterial contamination poses enormous risk, especially when spices are added to food without subsequent preservation, since microbial counts may dramatically increase until consumption. Furthermore, spore forming bacteria may cause spoilage of canned foods and processed meat products. Although yeasts and moulds have generally been found in smaller numbers, *Aspergillus* species may create serious problems in chilli and paprika, as well as in ginger, coriander, and pepper because of their aflatoxin producing potential (Flannigan & Hui 1976; Garrido *et al.* 1992). Since thermal preservation is impossible, inhibition of microbial growth in the raw material by drying is the most efficient way to reduce microbiological and aflatoxin contamination.

Surveys conducted: Survey was conducted in India during March 2005 to July 2005 in different places of Kerala and Andhra Pradesh by collecting samples from farmers, entrepreneurs, traders, co-operative societies, warehouses etc. The methods of storage and packaging materials used for packing of spices were also studied. The samples collected were analyzed for biochemical and microbiological aspects. A survey was also conducted on the incidence and level of aflatoxin contamination on imported spice preparations in the Irish retail market and found to be contaminated (chilli, pepper and turmeric)(Michael *et al.* 2008). Makunl *et al.* (2010) reported that of the 343 samples of five different food commodities from three states in Nigeria, aflatoxins M_1 (AFM_1) and B_1 (AFB_1) contamination were observed. Insufficient hygiene conditions during drying, transport and storage in the production of red pepper could cause microbiological and mycological growth which results in the formation of mycotoxins. Aflatoxin B_1 was detected in 100 samples of powdered red pepper randomly obtained from markets in Istanbul using Enzyme Linked Immunosorbent Assay (ELISA) (Aydin *et al.* 2007).

7. Effective management modules for storage of spices

Elimination or inactivation of aflatoxin by physical or chemical methods bears many drawbacks (Park 1993). Physical approaches involving treatment with heat, UV light or ionizing radiation are not entirely effective. Except ammoniation, chemical degradation by the addition of chlorinating, oxidizing or hydrolytic agents are not widely acceptedas these require expensive equipments and result in loss of nutritional quality of spices.

a) Moisture levels

Natural contamination of food grain is greatly influenced by the environmental factors such as storage structure, temperature, pH, moisture etc. Among the recommendations for solving the mycotoxin problem rapid drying of agricultural products to low moisture content is often emphasized because all scenarios leading to mycotoxin contamination relate to non-maintenance of stored products at safe moisture content. Drying of harvested spices to 10% moisture content or lower within 24 to 48 hours will reduce the risk of fungus growth and consequent aflatoxin production (Govindarajan 1977). In Africa, majority of the farmers sun-dry their harvests which often require longer durations for the product to attain 'safe' moisture level especially in times of cloudy weather. The spices are spread out on polyethylene sheets on the floor and the stirring or turning is done manually till the product is dry. Humidity- moisture relationship studies on

ground turmeric and cumin have revealed that a moisture level above 12.1 per cent (dry weight basis) is critical with respect to free flow characteristics with the product (Balasubramanyam *et al*. 1979).

b) Improved packaging techniques

One of the most important means of reducing post harvest losses is the introduction of improved packaging material together with improved packaging techniques. Proper packaging can reduce not only bruising and crushing but also improves marketing of product, reduces moisture loss, prevents contamination and maintains sanitary environment during marketing. The main purpose of spice packaging is to protect from microbial contamination, oxygen, water vapour, light and loss of aroma. Spice packaging is a critical technology addressing the ever-increasing demands for convenience, freshness, ease, shelf-life, safety and security of the products.

Packaging materials

Packaging has an important effect on improving the shelf life of the product. The packaging requires optimization of physical, chemical and environmental factors. Increasingly, new forms of packaging for processed foods are being produced in India. These include shrink and stretch films, PVC shrink labels, leak proof composite containers, bag-in-box, laminated cartons, tetra packs, multilayer film containers, poly packs and retortable pouches. Most of these involve use of plastic films with specific requirements. The film has very low moisture and gas permeability and therefore ensures prolonged shelf life of the contents with aroma, flavour and taste retention (Motey & Smita 2003). The film is free from additives and therefore does not impart any odour or taint to the sensitive spice product that is packed.

The retail distribution of ground spices in consumer packages is becoming increasingly popular in India as the consumer is assured of the quality product under hygienic conditions. In a study conducted at the Indian Institute of Spices Research(IISR),Kozhikode, five different packaging systems were used *viz.,* PET jar(P1), 75 µ polypropylene covers(P2), 25 µ polypropylene covers(P3), 12 µ metalized polyester+ 40 µ poly LDPE(P4) and 12 µ polyester +12µ metalized polyester+ 80 µ poly LDPE(P5) with control as jute bags. Packing materials P1, P4 and P5 were found to be very effective in retaining the volatiles upto 18 months of storage. Thus, under all conditions of storage, spices packed in consumer packs in 2LMP, 3LMP and PET jars remained safe for 6M without any loss in volatile oil .On the other hand, polypropylene covers (25 µ and 100 µ) are not suitable in offering adequate protection for loss of volatile oil during storage.

Packaging studies have revealed that aluminum foil laminate offers maximum protection against loss of volatile oil and ingress of moisture. Though the polyethylene and polypropylene pouches possess good functional properties, they are reported to be poor in barrier properties like resistance to water vapor, greases and oil. Probably this could be the reason for the loss of volatile oil and resinous material during storage in these pouches.

Modified atmosphere packaging

Modified Atmosphere Packaging (MAP) is a technique used for prolonging the shelf-life of fresh or minimally processed foods. MAP is becoming increasingly popular as a method of food preservation. The shelf-life of the products will be prolonged with MAP since it slows the natural deterioration of the product. In this preservation technique, the air surrounding the food in the package is changed to another composition. This modification usually results in a reduction in the oxygen of the air, while increasing the level of carbon dioxide and nitrogen in the atmosphere.

In spice samples kept at 100% vacuum, no changes in the oleoresin was seen upto 6 months, while samples under 100% N_2 were totally safe. The decrease in oleoresin is more or less a reflection of the decrease in curcumin and volatile oil since these two components constitute more than 80% of turmeric oleoresin.

No decline in the essential oil content was noticed upto 6M under vacuum in all types of packaging materials of black pepper. There was a reduction of 4.2% in the samples after 12 M. Under 100%N_2, the samples did not show any change in the volatiles upto 12 M. In ginger and turmeric stored at 100% vacuum, 100% N_2 and at ambient atmosphere, the reduction in the volatiles was minimal. Samples stored at 100% N_2 was effective and retained the moisture throughout the storage period and all the three packaging material were found to be effective.

In another study using high CO_2 atmosphere, black pepper powder (60 mesh) was stored in consumer unit packs of 100g capacity in low density polyethylene (LDPE) films of 100, 300, and 500 gauge at 27°C and 65% RH, which showed no loss of piperine up to the end of the study (Shanthi *et al*. 2007). Ellis *et al*. (1993) showed that *A. flavus* can grow in a CO_2 enriched atmosphere if headspace oxygen is present. It also emphasized the combined effect of several 'barriers' to either completely inhibit mould growth or to reduce aflatoxin in MAP products containing various levels of headspace oxygen to safe and acceptable levels (<20 ng g^{-1}).

Storage structures

Effect of storage structures on the quality of black pepper has been reported (Giridhar and Reddy, 2002**).** Black pepper was stored in three storage structures (bamboo basket, pot and tin) for one year under laboratory conditions. *A.flavus, A.fumigatus, A.niger* and *A. japonicus* were recorded in all three structures. Some fungal isolates produced different mycotoxins including aflatoxin B_1, gliotoxin , ochratoxin A, patulin etc. The highest weight loss and highest content of total phenols, total nitrogen and free fatty acids were recorded for seeds stored in bamboo basket. Starch content and reducing sugars also recorded decline during storage.

c) Biological methods

Current control measures are aimed at controlling fungal growth and mycotoxins formation in stored products by physical methods, chemical treatments and biological methods. Since most of these control strategies require expensive chemicals they are not economically feasible by the farmers. Plant extracts or essential oils can provide potential alternatives to control post harvest fungal deterioration. Aromatic organic compounds of spice oils possess antifungal activity and control the production of mycotoxin by fungi (Wilson & Wisniewski 1992; Chatterjee 1990). Recently there has been increasing interest in using naturally occurring compounds, especially essential oils, to limit fungal growth and toxin production. Many antifungal materials derived from plants have been identified (Shelef 1984; Beuchat & Golden 1989) and some have been found to inhibit mycotoxin formation (Rusal & Marth 1988).

Biopreservatives

The biosynthesis of aflatoxin B_1 can be inhibited by extracts of certain plants such as garlic and onion that are toxic to fungi and may be useful in controlling the fungal growth and mycotoxin production (Fan & Chen 1999; Steinhart *et al*. 1996). Many essential oils have also been reported as effective inhibitors of aflatoxin production. Allameh *et al.* (2001) reported more than 50% inhibition of aflatoxin production at 50% (v/v) neem extract concentration. Earlier reports confirm the effect of selected combinations of cinnamon extract and sodium benzoate on the growth response of *Aspergillus flavus* (Aurelio *et al.* 2007).

Changes in the oleoresin content after exposure of dry ginger to selected plant products reveal that turmeric leaf oil was very effective in retaining the oleoresin content upto 18 M of storage. In turmeric also, oleoresin content could be maintained for a period of 6 months, when exposed to cinnamon oil, clove oil and turmeric leaf oil. Significant inhibition of fungal growth as well as Aflatoxin B1 and G1 production was exhibited by turmeric leaf oil at 1.5% concentration (Sindhu *et al*. 2011). The economic value of this study lies in the simplified technique for control of aflatoxin contamination in agricultural products and the

benefits derivable from the use of local resources. It seems likely that the activity of the plant extracts results from a synergistic and cumulative effect existing between the plant components but further validation of the mode of action of essential oils is needed in order to ratify a possible synergism.

Bioprotectants

Plants are usually used as storage protectants to control insect pests. Studies at IISR showed that among the various bioprotectants used, curry leaves, neem leaves and garlic were consistently effective in retaining the quality with respect to the biochemical parameters and free from fungal contamination. Garlic is found to be highly effective and retains the quality and prevents fungal contamination upto 12M. *Glycosmis pentaphylla* leaves*, Murraya koenigii* and *Allium sativum* were found to be highly effective in retaining the volatiles in black pepper. *Azadirachta indica*, *Strychnos nuxvomica* and *Allium sativum* too prevented loss of volatiles during the entire period of storage (36 months) at 5% level (Sindhu 2011). Several reports are also available on the inhibitory effect of clove on *A. flavus* and *A. parasiticus* as well (Bullerman *et al*. 1977). Clove effectively inhibited the mycelial growth of *A. flavus* and aflatoxin production (Reddy *et al*. 2004).

Bacterial antagonists

Among the biological control measures for mycotoxins involvement of bacterial antagonists is a potential area. Many attempts have been made to control aflatoxin production using various methods including bacterial isolates in many crops (Nesci *et al.* 2005; Palumbo *et al.* 2007). At IISR, four endophytic and two rhizosphere bacteria were evaluated for their antagonistic potential against three *Aspergillus* species *viz., A. flavus, A. fumigatus* and *A. parasiticus.* Among the bacterial antagonists tested *viz*., IISR6, IISR 853, Bp 35, Bp 25, Bp 17 and TC 10, isolate of *Pseudamonas* spp. (IISR 6) were found highly effective in preventing the growth of the fungus *in vitro.* The overall trend showed that *P. flourescens* is a potential antagonist to *A. flavus* (Sindhu 2011).

However, so far no economical method of preventing *A. flavus* infection has been developed. Hence results on bacterial antagonism arising from present study would help in developing a biological strategy to prevent aflatoxin contamination in spices. New post-harvest strategy for the prevention of aflatoxin contamination of spices is the use of nontoxigenic strains *of A. parasiticus* and *A. flavus* to compete with toxin producing strains. A promising new approach to the prevention or elimination of post-harvest aflatoxin contamination is the molecular regulation of aflatoxin biosynthesis by toxigenic *Aspergillus* fungi. A complete understanding of the molecular regulation of aflatoxin biosynthesis may lead to enhanced food safety through selection of crops that minimize expression of aflatoxin pathway gene.

8. Leads obtained from IISR, Kozhikode

The microbial contamination in spices is mainly due to high moisture content due to improper post harvest handling. It is necessary that the spices should be dried to a safe moisture level of 10% and stored at this moisture level. In actual practice it is found that though spices are initially dried properly, they tend to absorb moisture from the atmosphere due to its hygroscopic nature. In Kerala, with the onset of monsoon, the relative humidity increases to more than 90% and all the dry products tend to absorb the atmospheric moisture if it is not packed properly and stored in a conducive environment for microbial growth. This is a slow process and if not monitored regularly results in aflatoxin production in spices.

The following observations/conclusions were drawn from the research programmes on mycotoxins in spices:

a. Moisture content

The moisture level of 8-10% was critical in retaining the intrinsic quality of black pepper, ginger, turmeric and nutmeg samples and could be stored for a period of 24 months without fungal contamination. The microbial load and aflatoxin levels were also minimum.

b. Packaging materials

PET jar, two-layer metalized polyester and three-layer metalized polyester covers were found effective as best packaging material for storage of black pepper, ginger, turmeric and nutmeg.

c. Modified atmosphere packaging

Black pepper, ginger turmeric and nutmeg packed in consumer packs in 2LMP, 3LMP and PET jars and stored at 100% vacuum and also at 100% N_2 could retain the intrinsic quality and are free from fungal contamination throughout the storage period of 24 months.

d. Plant products

Samples exposed to cinnamon oil, clove oil and turmeric leaf oil (1%) could maintain the quality for a period of 24 months without fungal contamination

e. Bioprotectants

Among the plant materials used, dried leaves of *Glycosmis pentaphylla (Panel), Murraya koenigii (Kariveppu)* and *Azadirachta indica (*Neem*)* at 5% level were found to be highly effective in retaining the quality and preventing fungal contamination for 24 months.

f. Bacterial antagonists

Among the endophytic and rhizosphere bacteria tested for antagonism, isolate of *Pseudamonas* spp. (IISR 6) was found highly effective in preventing the growth of the fungus *in vitro.*

9. Conclusions

Aflatoxin control programmes, if well organized, will result in economic gains as well as health improvement. The new European standards of aflatoxin level in spices means that effective control must be found by developing countries to boost trade.

Since spice and spice products are hygroscopic in nature, highly sensitive to moisture and also contain volatile aromatic principles, inefficient packaging may result in rancidity, mould growth and insect infestation. Deterioration of the aroma, flavour components and pigments is accelerated by heat and light. To avoid these problems, suitable packaging materials like Epoxy lined steel drums, High Density Polythene containers, PET(Poly Ethylene tetrapthalate) bottles, HMHDPE (High Molecular weight High Density Poly Ethylene) containers are to be used.

Precautions are also to be taken for efficient storage of the spice products. An environment with an average RH of 55-60^{0}C will prevent mould growth. It is better to carry out fumigations using safe chemicals prior to storage. Wooden pallets are also suitable to prevent moisture reabsorption and mould growth

Since most of the preliminary processing of spices is done at the farm, it is mostly done by traditional methods. Improved and more scientific methods need to be popularized to get good quality products .Prime importance has to be given to microbiological safety of spices and their products. Measures such as Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP), quality management systems under International Standard Organization (ISO 9000) and Hazard Analysis and Critical Control Points (HACCP) help reduce or eliminate contaminants in spices. In 2005, ISO published a single standard to encompass all the needs of the market place and designated as ISO 22000.This standard ensures a safe food supply chain worldwide. Consumers have now become more quality conscious and hence the quality should be maintained at every stage of production, processing and handling by farmers, traders, processors and exporters. Hence quality assurance has become an integral part of the production strategy of spices in developing countries. The time has already come to improve our package of practices so as to compete in the international market and there is also a great need for value addition of the produce.

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Mechanization to reduce drudgery in post harvest processing of spices

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1. Introduction

Spices play an important role in day to day diet of people. India is considered to be home of spices having favourable climatic and soil conditions. About 95 % of the spices produced are consumed by the domestic market and a meager of 5 % is exported which helps in earning substantial amount of foreign exchange.

Small and medium level gadgets for spice processing will encourage value addition and improve the quality. Some of the gadgets are discussed below:

2. Black pepper

Black pepper is the whole dried fruit of the vine *Piper nigrum*. The fruits or berries are 4 to 7 mm in diameter and have pulpy pericarp and a hard endocarp and is widely used as a condiment due to its characteristics aroma, pungency and biting taste. Two primary products of *P.nigrum* that are internationally traded are black pepper and white pepper.

(i) Threshing

Harvested green spikes are heaped for a day, before threshing for easy separation of the berries. In few plantations mechanical threshers are used for separating and cleaning the berries. However, the threshing efficiency of these machines is only about 90%.

Manual trampling of pepper

Spikes with fully matured and green stage, fully ripened stage and partly dried stage will be available in the harvested lot. The labourer will separate them into various lots, *viz.*, berries, spikes suitable for threshing, ripe ones for production of white pepper and partly dried ones for direct drying. Threshing is done by manual trampling.

Power operated pepper threshers

Mechanical threshers of capacity 200 to 1500 kg/h have been developed at various organizations. The pepper thresher developed at Tamil Nadu Agricultural University consists of a metallic drum provided with rasp bars, concave, an oscillating sieve, power source and power drive. The metallic drum is made of mild sheet and made to a diameter of 330 mm and length of 450 mm. On the periphery of the drum, 8 numbers of rasp bars of size 30 mm × 15 mm are mounted and lined with rubber sheet. This drum is placed inside a concave of diameter 370 mm made of mild steel with an opening at the centre for 12 mm width. The oscillating unit is made to a size of 400 mm × 600 mm and provided with an eccentric of 5 mm and receives the power from a one hp motor and oscillates at a speed of 90 strokes/ minute. The power to the drum is

also transmitted through V pulley arrangement and operated at 300, 360 and 450 rpm speeds of the drum and evaluated at pepper plantations.

Hand operated pepper thresher

This pepper thresher consists of a metallic drum provided with rasp bars, concave, power drive with a handle and a sieve for separating the empty spikes. The metallic drum is made of 1.5 mm thick mild steel sheet and made to a diameter of 250 mm and length of 350 mm. On the periphery of the drum, 8 numbers of rasp bars made of wood of size 20 mm × 15 mm are mounted. The drum is placed inside a concave of diameter 300 mm made of mild steel with an opening at the centre for 12 mm width. The cover of the concave is made to half round and the hopper is fitted to the cover at an inclination of about 35°. The power to the drum is transmitted through a gear wheel and handle and made to rotate the drum at about 250-300 rpm.

(ii) Drying

Pepper has moisture content of 60 to 70% at harvest, which should be brought to safer levels of 10-12 per cent by adequate drying. The green colour of matured pepper is due to the presence of chlorophyll pigment. During drying, enzymatic browning sets in and the phenolic compounds are oxidized by atmospheric oxygen under the catalytic influence of the enzyme phenolase and eventually turn black.

Solar tunnel dryer for pepper

The solar tunnel dryer constructed using pipe frame structure called hoops used for drying of pepper consists of a single drying chamber of size 2 x 3 m to a height of 2 m for drying 100 kg pepper. The floor is covered with black sheet of 200 microns thickness, which acts as absorber for better absorption of solar radiation. The metallic frame structure of the tunnel dryer is covered by UV stabilized semi transparent polyethylene sheet of 200 microns.

Mechanical driers

Natural convection reverse air flow mechanical drier developed by National Institute of Interdisciplinary Science Technology, Thiruvananthapuram are used by the farmers and cottage scale industrial units for drying of black pepper. These driers are widely used for drying of coconut, spices, ayurvedic products, etc. This dryer has a capacity of 200-225 kg of berries per batch and takes 25-28 h of drying time at 55-60°C temperature of drying chamber.

(iii) Cleaning and grading

Cleaning

Inclined belt separator is used for effective separation of foreign material from pepper. Spiral separator is also used for pepper cleaning which is a stationary one and doesn't need any power to operate as it works based on the gravitational force. A hand operated rotary type cleaner cum grader has been developed at Tamil Nadu Agricultural University, Coimbatore to clean the pepper and grade and according to the AGMARK specifications. The unit consists of a rotor for a length of 1.35 m and diameter 400 mm. Along the length of the rotor, it has been divided into three segments of each 450 mm with provision to place any sieves. Outlets below each sieve have been provided. A spiral is provided inside the rotor for easy conveying of the feed materials to the sieve perforations. At the centre of the rotor, a shaft is provided to mount the rotor on two bearings and rotate with a handle. A feed hopper to hold about 15 kg of pepper has been

provided at the feed inlet end with appropriate side slopes for easy feeding of the feed into the sieves. The unit is provided with three sieves of sizes, round 3.5 mm, 3.8 mm and 4.8 mm diameters, which are the sieves as per the AGMARK specifications for the grades, 2, 1 and bold, respectively.

3. Cardamom

Among the various spices cultivated in India, cardamom called "Queen of spices" is the true fruit of *Elettaria cardamom*, a tropical perennial shrub with pseudostem.

(i) Drying

Cardamom capsules should be subjected to drying within 24-36 hours of harvest to avoid deterioration. Drying is one of the important unit operations as it determines the colour of the end product, which is the attractive and most important quality character. There are mainly two types of drying, *viz*., natural (sun drying) and artificial drying using firewood or electricity as fuel.

Natural (sun) drying

Sun drying requires 5-6 days or more depending upon the availability of sunlight. Splitting of capsules is more as they are subjected to frequent turning during drying. Sun dried capsules are mainly converted into bleached cardamom.

Artificial drying

Using the dryers, artificial drying is achieved. Cardamom capsule looses about 70-85% moisture on drying. The normal conversion ratio of green to dry cardamom is 4:1 or 5:1, which varies according to size, moisture level and method of drying. The retention of natural colour is a positive index of quality. The kiln dryers are widely used in cardamom plantations.

Kiln drier consists of a wood-burning furnace, heat exchanger pipe and drying racks in a chamber. The furnace is made of firebricks or ordinary bricks. The hot flue gas escape through the chimney after circulating through 250 to 300 mm diameter flue pipe made of mild steel sheets placed in the centre of the room. The heat is transferred to the chamber by radiation from hot surface of the flue pipe. Racks are kept at 1.2 m height from the flue pipe to avoid over heating. The drying trays of 1 x 1 m each containing about 3 to 4 kg of fresh cardamom are arranged on the racks @ 3 to 5 trays /tier .The roof of the chamber is insulated from inside with wooden planks or asbestos sheets. The capsules kept for drying are spread thin and stirred frequently to ensure uniform drying. The fuel requirement is about 100 kg per 100 kg of fresh cardamom. The drying air temperature is maintained at 45 to 55ºC by controlling the supply of wood in the furnace. The drying time is about 24-36 hours. Exhaust fans are provided to flush out moisture-laden air. The various drawbacks in the existing system are:

(i) The whole process takes about 24-36 hours and the kilns have very low thermal efficiency.
(ii) The average fire wood requirement is 1 quintal per 100 kg of fresh cardamom, which leads to deforestation.
(iii) The construction cost of kilns is very high.

Electrical dryer

Cardamom dryer consists of combuster, blower, chimney, hot air duct, drying chamber, hot air recirculation duct, control panel, combustion blower, thermostat etc. The flue gas is produced by burning fire wood in the combuster in excess of air with near complete combustion of the fuel. The air is supplied by means of blower

which is operated by 0.25 hp motor. A suitable chimney is provided with appropriate height to induce draft for complete combustion of the fuel. A thermostat is fitted at the plenum chamber to control the temperature of the hot air. A perforated wire mesh is fitted at the bottom of the drying chamber to hold the cardamom capsules to a height of 30 cm. An exhaust duct is provided to vent out moisture laden air to prevent condensation. A recycling duct is provided for recirculation of the hot air if the relative humidity of the air drops below 60%. The temperature of the hot air varies from 45 to 80°C during the drying process. The stage of completion of drying is assessed by hearing the sound of the seeds inside the capsules.

(ii) Garbling

Garbling is the process of removal of flower stalks from the dried cardamom. This is achieved by rubbing against coir mat or wire mesh and winnowed to remove any foreign matter. Also power operated garbling drum is being used in the plantations. The unit is powered by 0.5 hp motor and has a batch capacity of 5 kg. Garbling, done using gunny bags or on a wire mesh, is popular in the cardamom plantations. Use of gunny bags to hold and garble the cardamom is cumbersome and also results in dust pollution.

Rotary type garbler

The rotary type garbler developed at Tamil Nadu Agricultural University consists of a feed hopper, rotating drum, discharge chute and handle. A shaft placed at the centre of the drum is provided with 4 numbers of beaters radially mounted. With the help of a suitable handle the beater assembly is rotated. The drum is provided with 10 × 2 mm perforations, for easy discharge of floral parts and dust after garbling. In this garbling unit, about two to three minutes is required to garble one batch of about 5 kg of cardamom.

Oscillating type garbler

The oscillating type garbler developed at Tamil Nadu Agricultural University consists of a concave, oscillating unit, perforated bottom, outlet for the flower stalks and cardamom and handle. The concave is made as a semi circular unit with 39 mm diameter and 22 mm depth for a width of 31 mm. The oscillating unit is made to a width of 28 mm with a depth of curvature of 21 mm. A suitable handle is provided to the oscillating unit for easy operation by rowing the handle. A wire mesh of ISS 320 (2.8 mm opening) is provided at the bottom of the concave for holding the cardamom. Another outlet is provided to collect the cardamom after garbling, separately. On the oscillating unit, iron bars of 8 mm diameter are fixed on the periphery. In the clearance between the iron rods and the concave, the cardamom undergoes rubbing action, thereby it is garbled and the flower stalks are removed.

4. Ginger

Ginger, the underground rhizome of *Zingiber officinale,* is an important commercial crop grown for its aromatic rhizomes which are used as vegetable, spice, medicinal purposes, etc.

(i) Post harvest processing

a. Peeling

Peeling serves to remove the scaly epidermis and facilitate drying. The outer skin of ginger is scrapped off with a bamboo splinter or wooden knife having pointed ends. Iron knife is not recommended as it may leave black stains on the peeled surface, affecting the appearance, or may lead to colour fading. During peeling, it should be ensured that the cortical parenchyma, which is rich in essential oil bearing cells, are not removed or cut as it would cause loss of volatile oil and thereby, decrease the aroma of the peeled rhizome.

Mechanical peeling

A mechanical brush type ginger peeling machine consists of two continuous brush belts being driven in opposite direction with a down ward relative velocity by a variable speed motor. The parameters optimized are brush belt spacing (1 cm) and belt speed (65 rpm) of the driving brush belt resulting in the belt relative velocity of 199 cm/s. Number of passes required was 4 to 5 and the capacity of the machine at the recommended parameter values with 5 passes were 20 kg/h. When operated at its full capacity, the machine has a peeling efficiency of 71% with ginger meat loss of 1.6%.

Chemical peeling

Chemical peeling using Sodium hydroxide, NaOH, (widely known as lye peeling) is one of the most common and the oldest methods for peeling fruits and vegetables but produces a dried product of dark colour in case of ginger.

b) Drying

Traditionally, the partially peeled ginger is sun dried in a single layer in open yard for 7 to 10 days. Rhizomes must be dried to a moisture level of 10% and stored properly to avoid infestation by storage pest. Improperly dried ginger is susceptible to microbial growth. The dried ginger presents a brown, irregular wrinkled surface and when broken shows a dark brownish colour. The drying of ginger usually leads to the loss of volatile oil by evaporation.

c) Polishing

Polishing of dried ginger is done to remove the wrinkles developed during the drying process. It is generally done by rubbing the dried rhizomes against hard surface. Polishing of dry ginger is also done by taking dry ginger in sack and rubbed against itself by moving the sack to and fro by two persons standing on either side. Hand or power operated mechanical polishers are also employed for this purpose. A mechanical polisher developed at Sukhadia University, Udaipur, has a capacity of 15 to 20 kg/h and gives 5 to 7% polish.

(d) Cleaning and grading

Once the ginger is dry it is cleaned, sorted and graded. Grading takes into consideration the size of the rhizome, its colour, shape, extraneous matter, the presence of light pieces and the extend of residual lime (in the case of bleached ginger). Two types of Indian dried ginger entering the International market are Cochin and Calicut ginger, named after the two major production centers in Kerala. Both Cochin and Calicut gingers are graded according to the number of fingers in the rhizomes: grade-B, three fingers; grade-C, two fingers and grade-D, pieces. In addition to these well known types of Indian ginger, another type, Calcutta ginger, is occasionally seen in the market.

5. Chillies

Chilli is the dried ripe fruit of *Capsicum* spp. which is also called *red pepper* and it constitutes an important commercial crop used as a condiment, culinary supplement or as a vegetable. Among the chilli consumed in India, dried chilli contributes the major share.

(i) Drying

Chilli is harvested at a moisture content of around 300–400% and need to be dried to 11% for further preservation and storage.

Traditional method of drying of chilli

The harvested chilli is heaped indoor for 3 to 4 days so that partially ripe fruits, if any, ripen fully and the whole product develops uniform red color. Partially ripe fruits, if dried without curing, develop white patches and such fruits fetch less market value.

The drying of chilli is done by spreading the fruits on dry ground or concrete floor under sun. Mud floor, rooftop or wooden cots are also used for this purpose. In case of cement floor, drying takes 5-6 days for the reduction of moisture content from 60-70% (w.b.) to 10% (w.b.), while in mud floor it takes 3-4 days during sunny days. Usually the chilli is spread in single thick layer for drying and it takes 13-15 days for the reduction of moisture content from 70-80% (w.b.) to 10% (w.b.), depending upon the climatic conditions. In case of cloudy weather and intermittent rains, damages as high as 50 % are reported. Such unfavourable conditions also lead to discolouration with white spots over the surface of final product. Loss of glossiness and pungency are also noticed. In view of its direct exposure to environment, dirt may also get deposited on the chilli besides; this method involves excessive handling and irrecoverable shatter loss.

Improved drying methods

Efforts have been made by various research institutions to develop a process and equipment to speed up the drying process. In the improved drying methods, various pre-treatments and equipment are used for getting better quality of the final dried product.

(ii) Pricking

Each pod is pricked longitudinally along one side by sharp stainless steel nails fitted on a wooden blocks. The drying time in the case of pricked chilli is found to be less by four days when compared to unpricked ones. Pricking does not affect the colour in any way.

(iii) Blanching

Chilli is blanched in hot water at 98.5^{o}C for 3 minutes cooled immediately and dried. The rate of drying is the fastest in blanched chilli and the drying time was seven days. The pods completely flatten due to loss in turgidity.

Chemical treatment

The pericarp of chilli contains a tough waxy layer, which prevents its rapid drying. The chemical method is tried as practiced in case of grapes:

(a) a solution containing 25 g of potassium carbonate per litre is prepared.
(b) to the solution of potassium carbonate, 15 ml of refined and de-odourised olive oil is added.
(c) chilli is dipped in the potassium carbonate solution for 5 minutes and drained.

The chemical treatment reduced the drying time to six days. The sample treated with potassium carbonate and olive oil showed sharp colour and glossy appearance. It appears that presence of oil brings out the colour. The chemical treatment on a whole appears to be quite promising. Chilli smeared with oil of

Mahuwa imparts glossiness. However coconut and gingelly oil are not used for this purpose as they lead to mould growth and discolourisation.

(iv) Solar drying

A solar cabinet dryer was developed at Central Institute of Agricultural Engineering (CIAE), Bhopal. The angle of inclination of collector was kept at 17° from horizontal and the bottom of dryer was kept at 5° inclination from horizontal for draining out the water. The sidewall of the dryer was made out of 3 mm thick plywood and bottom was built with 3 mm thick plywood fitted with 32-gauge aluminium foil for reflecting back the sunrays. On the top, a single glass (4 mm thick) radiation shield mounted on wooden frame into two segments was provided for easy handling of the glass shield.

Solar air heaters having a collector area of 290 m^2 were designed to dry 5.25 tonnes of chillies per day. The air heater was a roof-integrated type and the corrugated aluminum roof of the factory was painted with commercial dull black paint. A 4 mm thick tempered glass cover was fixed over the roof using aluminum support frames. The edges were closed and made air tight with two layers of galvanized iron sheets with 50 mm thick mineral wool insulation. Provisions were made for ambient air entry and it makes five passes over the collector. The lower side of aluminum roof was packed with 65 mm mineral wool using 5 mm thick cardboard support. The collector was divided into six units and area of each unit was 48 m^2. The hot air from each panel was collected through a common insulated duct, which was connected to the inlet port of a 12.5 kW centrifugal blower. The hot air for chillies was introduced at four points in the tunnel dryer. Filters were used at the ambient air entry point in the collector to prevent dirt and other impurities. The spices powder-making factory reported a reduction of 90% in its fuel consumption due to the usage of the solar dryer. A temperature rise of 15-46°C above ambient temperature was observed in solar air collector.

Greenhouse-type solar dryer

A greenhouse-type solar dryer was developed in the Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi to dry punched and unpunched 'jwala' variety of chillies. A continuous air inlet of one feet width was provided on one side of the green house along the bottom of the vertical wall for the entry of natural air. A chimney of 6.06 m height was installed with the green house at the other end of natural ventilation. Natural air entered at one end of the green house and the moisture-laden air escaped through chimney, which provided suitable condition for drying. Drying racks and trays were provided in the greenhouse for drying of chillies. Greenhouse-type solar dryer took 90 h for the unpunched and 66 h for the punched chillies to dry the samples from 300 to 8-9% d.b.

Mechanical drying

A dryer developed by Punjabrao Deshmukh Krishi Vidyapeeth, Akola for drying fresh red chillies consists of mainly four components *viz*., furnace, heat exchanger, drying chamber and blower. The dryer has ten sliding trays in five tiers accommodating 200 kg of fresh red chillies per batch. An average air velocity of 1.22 m/s is maintained through the drying process that is less than the terminal velocity of dried chillies. The heat energy is obtained by burning the agricultural waste material. A blower is operated by a single phase 1.0 hp electric motor to blow the air through the furnace and force the same into the product. Drying air temperature of 53±2°C with 10 cm bed thickness gives better drying and less loss of capsaicin. The chillies in the lowest tier dried after 12 h and successive tiers from below required 12.5, 13, 14 and 15 h respectively to bring moisture content from 252.88 to 20% d.b.

(v) Sorting

At the final stage of drying, the discoloured, spoiled and other damaged ones are manually sorted based on the eye judgment and experience. These sorted ones are collected and separated. This amounts to 4-5 quintals of dry chilli from one hectare. This works out to about 20 to 25% of the final produce. This reject is sold separately at a much lower price of about Rs.600 to Rs.1000 per quintal, while the good ones are sold at about Rs.2200 to 2800 per quintal. During the sorting process itself the dried chilli fruits will be windrowed for easy collection and packaging.

(vi) Destalking

Destalking of dried chilli pod is done after drying and before cold storage/marketing. The export lots are preferred without stalk as required by the buyers. Contract women labour are engaged for destalking and paid @ Rs 4 per kg of destalked chilli. Normally a woman can destalk 12-15 kg of chili. The ratio of stalk in the chilli may be ranging 10 to 15%. The chilli stalks after removal has no commercial value and hence burnt or composted.

6. Turmeric

Turmeric (*Curcuma longa)* is an important spice and cash crop of India. It is used in many culinary preparations to add flavour and colour to foodstuffs.

(i) Post harvest operations

The harvested turmeric rhizomes before entering into the market is converted into a stable commodity through a number of post harvest curing processes like boiling, drying, polishing and colouring. Curing of turmeric is taken up within 3 or 4 days after harvest. The fingers and bulbs (mother rhizomes) are separated and are cured separately, since the latter take a little longer to cook.

a) Boiling

Boiling essentially involves cooking of fresh rhizomes in water until soft before drying. Boiling destroys the vitality of fresh rhizomes, avoids the raw odour, reduces the drying time and yields uniformly coloured product.

Boiling of turmeric rhizomes is carried out till froth forms and white fumes come out of the boiling pan with a characteristic odour. Boiling is considered complete by pressing a pointed stick in to the rhizomes with slight pressure. The other indications for completion of boiling process are softness and easy breaking of rhizomes when pressed between the fore finger and thumb and a yellow interior instead of red one. Tamil Nadu Agricultural University (TNAU), Coimbatore, (India) has developed an improved turmeric boiler using steam boiling technique. The unit consists of a trough, four inner perforated drums and a lid. The outer drum is placed with more than half of its depth below the ground level by digging a pit, which serves as a furnace. This furnace is provided with two openings, one for feeding the fuel and the other one for removing the ash and unburnt. The capacity of the boiler is about 200 - 300 kg per batch and 40 q per day of 8 hours. It takes about 25 minutes after boiling for the initial batch of rhizomes to cook and15 minutes for the subsequent batches. In the commercial large scale steamers, of capacity 1 tonne /batch, steam released from the boiler at a pressure of 2 kg/cm^2 is used for boiling rhizomes by open steaming and the time taken for boiling / cooking is 10-15 min. The fuel required for steam production is about 18-20 kg of crop residues/wastes per batch.

b) Drying

The cooked fingers are dried in the sun by spreading in 5-7 cm thick layers on bamboo mat or on the drying floor. It may take 10-15 days for the rhizome to become completely dry. The fingers and bulbs are dried separately as the latter takes more time to dry. Drying using cross flow hot air at 60^{o}C gives a satisfactory product. Solar dryers can also be used for drying of turmeric. The yield of the dry product is about 20 per cent depending upon the variety and the location where the crop is grown.

c) Polishing

Dried turmeric has poor appearance and rough dull outer surface with scales and root bits. The appearance is improved by smoothening and polishing the outer surface by manual or mechanical rubbing. Polishing is done till the recommended polish of 7-8 per cent is achieved. Usually 5 to 8 per cent of the turmeric (by weight) is the wastage during full polishing and 2 to 3 per cent during half polishing. Polishing of dried turmeric also helps in removing the wrinkles. Manual polishing consists of rubbing the dried turmeric fingers on a hard surface or trampling them under feet wrapped in gunny bags. Mechanical turmeric polishers of holding capacity, 250 to 1000 kg are commercially available and it takes about 45-60 minutes per batch to obtain the required polish.

7. Conclusion

Spices, like all other agricultural commodities invariably contain high moisture (55 to 85%) at the time of harvest, which must be brought down to 8 to 12%. Also, spices vary considerably in shape, texture, size, colour etc. as they may be fruits, berries, barks, seeds, leaves, rhizomes, roots, unopened flower buds (cloves) or other floral parts (saffron). Hence their pre-treatments, curing, cleaning, and methods of processing also vary considerably. During their post harvest processing, they are subjected to different unit operations, such as washing, peeling, curing, drying, cleaning, grading and packaging, until they are ready for the consumer or for the market. Such post harvest processing technology should ensure proper conservation of the basic qualities of spices for which they are valued, *viz*., aroma, flavour, pungency, colour etc. The quality specifications for spices are continually becoming more stringent. Hence, only efficient usage of machinery and technology will reduce the drudgery and improve the quality of spices.

Trends in production and processing of banana

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1. Introduction

India is the largest producer of banana in the world, producing 28.45 million tons from an area of 7.96 lakh hectares with a productivity of 35.7 MT/ha. Banana is grown almost in all the states of the country. However, the major banana growing states are Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu and West Bengal. Tamil Nadu has the largest area (1.30 lakh ha) under banana cultivation, followed by Karnataka (0.91 lakh ha), Andhra Pradesh (0.83 lakh ha), Maharashtra (0.82 lakh ha). Tamil Nadu also holds the top position in production of banana and plantain (6.73 million tons), followed by Maharashtra (4.31 million tons) and Gujarat (4.05 million tons). With respect to productivity, Gujarat (62.30 t/ha) registers the highest productivity, followed by Madhya Pradesh (55.60 t/ha), Maharashtra (52.6 t/ha) and Tamil Nadu (51.70 t/ha) (NHB, 2013).

2. Climate

Banana is essentially tropical plant requiring a warm and humid climate. However, it can be grown from sea level to an altitude of 1200 metres. It can be cultivated in a temperature range of 10°C and 40°C with high humidity but growth is retarded at temperatures less than 10°C and more than 35°C. Yields are higher when temperatures are above 24°C for a considerable period. In cooler climate, the crop requires longer time to mature. Plants exposed to low temperature and humidity during active growth stage show reduced growth and yields. Hot winds blowing in high speed during the summer month's shred and desiccate the leaves. It requires on an average, 1700 mm rainfall distributed throughout the year for its satisfactory growth. Stagnation of water is injurious and may cause diseases like Panama wilt.

3. Varieties

In India banana is grown under diverse conditions and production systems. Selection of varieties therefore is based on various kinds of needs and situations.Around 20 cultivars *viz*., Dwarf Cavendish, Robusta, Monthan, Poovan, Nendran, Red banana, Ney Poovan, Rasthali, Karpuravalli, Grand Naine etc. are more important.

Grand Naine is gaining popularity and may soon be the most preferred variety due to its tolerance to biotic stresses and good quality bunches. Bunches have well spaced hands with straight orientation of fingers bigger in size. Fruit develops attractive uniform yellow colour with better self life and quality than other cultivars.

Udhayam (ABB) is a promising new variety released by NRCB, Trichy for commercial cultivation during 2005. This belongs to Pisang Awak subgroup. The average bunch weight is 37 kg having a potential up to 45-50 kg, which is 40 per cent higher than local Karpuravalli. Crop duration is 13 months and produces high yield in ratoon also. Exhibits field tolerance to Sigatoka leaf spot diseases and nematode infestations. Its cylindrical bunch with well spaced hands are ideal for long distance transportation and less prone to fruit damage during transit. The fruits are high in sugar with 31°B with good blend of acidity and sweetness, hence suitable for processing into value added products like figs, banana juice, wine, etc. It performs well in Tamil Nadu, Kerala, Andhra Pradesh, Karnataka, Bihar and Tripura.

4. Propagation

a. Vegetative method

Commercial bananas are seedless and propagated exclusively by vegetative means using suckers of two types *viz*., sword suckers and water suckers. Sword suckers have a well developed base with narrow sword-shaped leaf blades at the early stages. The weight of the rhizomes should be 1000 -1500 g. It should be 3-4 months age at planting. Small rhizomes will give bigger size fruits with late flowering while bigger size rhizomes flower early but bear small size fruit/bunches The suckers/ rhizomes should be selected from plants, which are healthy, having all the desirable bunch qualities and high yielding ability possessing at least 10 hands in a bunch.

b. Tissue culture

Now-a-days banana plants are also propagated through tissue culture. Varieties like Shrimanti, and Grand Naine are commonly produced using tissue culture technique. Normally disease free plantlets with 3-4 leaves are generally supplied in pots for raising secondary nursery. Plants are initially kept in shade [50%] and as they harden, shade is reduced gradually. After 6 weeks, plants do not require any shade. Normally two months of secondary nursery is good enough before the plants to be planted in the field

Advantages of tissue culture planting material:

- True to the type of mother plant under well management.
- Pest and disease free seedlings.
- Uniform growth, increases yield.
- Early maturity of crop - maximum land use is possible in low land holding country like India.
- Round the year planting possible as seedlings are made available throughout the year.
- Two successive ratoons are possible in a short duration which minimizes cost of cultivation.
- No staggered harvesting.
- 95% - 98% plants bear bunches.
- New varieties can be introduced and multiplied in a short duration.

5. Planting and spacing

Planting can be done in May-June or in September – October at suitable spacing (Table 1).

Table 1. Spacing of different varieties of banana

	Method of Planting	Spacing (m)	Plants/ ha
	Conventional method		
i)	Dwarf Cavendish	1.5 × 1.5	4440
ii)	Robusta and Nendran	1.8 × 1.8	3080
iii)	Rasthali, Poovan, Karpuravalli, Monthan	2.1 × 2.1	2260
	High density planting		
	Paired row planting system		
a)	i) Dwarf Cavendish	1.2 × 1.2 × 2.0	5200
	ii) Robusta, Grand Naine, Poovan, Rasthali and Ney Poovan	1.5 × 1.5 × 2.0	3800
b)	3 suckers/hill (Robusta, Nendran)	1.8 × 3.6	4500

Pits of size 45 cm × 45 cm × 45 cm are dug at the recommended spacing. The pits with equal quantities of top soil, well decomposed FYM and sand in 1:1:1 proportion. Poly bag may be slit and removed and the plant be inserted into the centre of the filled pit without disturbing the roots. The soil level must be maintained at the same level as in the poly bag.

Methods of planting

Pit method: Pits of 0.5 m × 0.5 m × 0.5 m are dug for planting. The only advantage is that no earthing up is required as planting is done at the required depth. This practice is not very popular at present.

Furrow method: This is a very common method in which furrows of 20-25cm depth are opened by a tractor or ridger at a distance of 1.5m and suckers are planted in the furrows. In this method earthling up needs to be frequently done to cover the exposed rhizomes.

6. Manure and fertilizers

The fertilizer dose depends upon the fertility of soil and amount of organic manure applied to the crop. For a good yield, 40-50 t/ha of well-decomposed FYM is incorporated into the soil.

The recommended fertilizer dose for optimum yield is as follows (Tables 2 & 3).

Table 2. Recommended fertilizer dose for banana

Variety	Quantity of fertilizer (g/plant)								
	3rd month			4th month			5th month		
	Urea	SSP	MOP	Urea	SSP	MOP	Urea	SSP	MOP
Poovan, Rasthali & Karpuravalli	140	155	130	230	155	320	90	-	175
D. Cavendish, Robusta & Nendran	150	155	130	250	105	320	150	-	225
Other varieties	110	110	130	155	110	300	90	-	160

Table 3. Fertilizer dosage for tissue culture banana

Days after planting	Fertilizer dose (g/plant)		
	Urea	SSP	MOP
30	45	125	50
75	90	125	85
110	110	125	85
150	110	125	100
180	90	125	100
At bunch emergence	- / -	-	85

7. Water Management

Banana, a water loving plant, requires a large quantity of water for maximum productivity. But Banana roots are poor withdrawal of water. Therefore under Indian condition banana production should be supported by an efficient irrigation system like drip irrigation.

Water requirement of banana has been worked out to be 2000 mm per annum. Application of drip irrigation and mulching technology has reported improved water use efficiency. There is saving of 56% of water and increasing yield by 23-32% under drip.

Irrigate the plants immediately after planting. Apply sufficient water and maintain field capacity. Excess irrigation will lead to root zone congestion due to removal of air from soil pores, thereby affecting plant establishment and growth. And hence drip method is must for proper water management in banana. Water requirement for different stages of banana has been standardized (Table 4).

Table 4. Water requirement at different growth stages of banana

Crop stage	Duration (weeks)	Quantity of water (l/week)
After planting / Ratoon	1-4	4
Juvenile phase	5-9	8-10
Critical growth stage	10-19	12
Flower bud differentiation stage	20-32	16-20
Shooting stage	33-37	20 and above*
Bunch development stage	38-50	20 and above*

* Depending on the season

Fertigation has been standardized at weekly interval. Fertigation with 75% RDF resulted in higher yield in 'Robusta' and 'Grand Nain' (Table 5).

Table 5. Weekly fertigation schedule (g/ plant/ application)

Weeks after planting	Urea (g/plant)	Total (g/plant)	MOP (g/plant)	Total (g/plant)
9 to 18 week (10 weeks)	15	150	8	80
19 to 30 week (12 weeks)	10	120	10	120
31 to 40 week (10 weeks)	7	70	12	120
41 to 46 week (5 weeks)	Nil	Nil	10	50
Total	----	340	----	375

8. Nutrient deficiency

Major deficiency symptoms and recommendations to rectify the problem are given below

Age of leaf	Symptoms on blades	Additional symptoms	Element	Remedial measure
All ages	Uniform paleness	Pink petioles	N	Immediately apply 100 g Urea per plant
		Midrib curving (weeping, drooping)	Cu	Apply 2g copper sulphate (or) foliar spray 0.1 % copper sulphate
Young leaves only	Leaves yellow to almost white		Fe	Apply 5 g Ferrous sulphate per plant (OR) Foliar spray 0.2 % Ferrous sulphate
	Leaves, including veins, turn pale green to yellow	Thickening of secondary veins	S	Apply 40 g Bentonite sulphur per plant (OR) Apply 100 g Gypsum.
	Streaks across veins	Leaves deformed (blade incomplete)	B	Apply 5g Borax per plant (or) give foliar spray 0.1% Borax solution

	Yellow strips along veins	Reddish colour on lower side of youngest leaves	Zn	Apply 5 g Zinc sulphate per plant (or) Foliar spray of 0.5 % Zinc sulphate
	Marginal chlorosis	Thickening veins; necrosis from margins inward	Ca	Apply 100 g Calcium carbonate per plant
Old leaves only	Saw-tooth marginal chlorosis	Petiole breaking, dark green-purple colour young leaves	P	Apply 100-200g super phosphate per plant
	Yellow discoloration in mid blade; midrib and margins remain green	Chlorosis limit not clear. Pseudostem disintegrating	Mg	Apply 100 g Dolomite per plant (OR) Foliar spray of 0.5 % Magnesium Sulphate
	Yellow-orange Chlorosis and brown scorching along margins	Leaf bending. Quick leaf desiccation	K	Apply 100 g of MOP/plant (OR) Foliar spray of 2% potassium Sulphate

9. Intercultural operations

(i) Weed control

Regular weeding is important during the first four months. Spading is commonly used and normally four weeding in a year are effective in controlling weeds. Integrated weed management by including cover crops, judicious use of herbicides, intercropping and hand weeding wherever necessary will contribute in increased production.

Pre-emergence application of Diuron (1kg a.i./ha) or Glyphosate (2 kg a.i./ha) is effective in controlling grasses and broad-leaved weeds without affecting the yield and quality of banana. Double cropping of cowpea is equally effective in suppressing the weed growth.

(ii) Intercropping

Intercropping can easily be raised in banana plantation at the early stages of growth. Vegetable and flower crops like radish, cauliflower, cabbage, spinach, lady's finger, marigold, and tuberose can be successfully grown as intercrop. Mixed cropping with arecanut, coconut and cassava is a common and widely adopted practice in South India.

(iii) Desuckering

During the life cycle, banana produces number of suckers from the underground stem. If all these suckers are allowed to grow, they grow at the expense of the growth of the main plant and hence the growth of the sucker should be discouraged. Removal of unwanted suckers is one of the most critical operations in banana cultivation and is known as desuckering. Such suckers are removed either by cutting them off or the heart may be destroyed without detaching the sucker from the parent plant. Removal of suckers with a portion of corm at an interval of 5-6 weeks hastened shooting and increased the yield.

(iv) Earthing up

In case of furrow planting earthing up should be done during rainy season to avoid water logging while during winter and summer the plant should be in the furrow.

(v) Propping

Propping operation is carried out in areas with high wind speeds. Pseudostems are propped up with bamboo, especially, at the time of bunch emergence.

(vi) Leaf removal

Pruning of surplus leaves helps to reduce the disease from spreading through old leaves. Leaf pruning can change light and temperature factors of microclimate. Pruning of leaves before bunch initiation delays flowering and harvesting cycle. For maximum yields a minimum of 12 leaves are to be retained.

(vii) Bunch covering

Bagging (bunch covering) is a cultural technique used by planters where export quality bananas are grown. This practice protects bunches against cold, sun scorching, against attack of thrips and scarring beetle. It also improves certain visual qualities of the fruits. Bunch covering with dry leaves is a common practice in India.

Pre-harvest spraying of bunches with 2% potassium sulphate (20 g/liter of water) solution along with wetting agent immediately after the emergence of the last hand, followed by a second spray 30 days later and covering the bunches with 100 gauge thick polythene covers with 6% ventilation enhances bunch weight, fruit quality and appearance, besides advancing fruit maturity by 7-10 days and fetches better price.

(viii) Removal of male flower bud

Removal of male bud after completion of female phase is necessary. Once the process of fruit setting is over, the inflorescence rachis should be cut beyond the last hand otherwise it grows at the cost of fruit development. This helps in early maturity of the bunch.

10. Pest and disease management

A large number of fungal, viral and bacterial diseases and insect pests and nematodes infest the banana crop and reduce production, productivity and quality. Summary details of major pest and diseases of banana along with control measures are given below:

	Name	**Symptoms**	**Control measures**
	Pests		
i)	Corm weevil (*Cosmopolites sordidus*)	a) Large network of galleries in rhizome and weakens the plant.	a) Use healthy planting material b) Sanitation in orchard c) Trapping of adult weevils using pseudostem or corm pieces and d) Soil application of Carbofuran @.20gm/plant
ii)	Pseudostem weevil	a) Small holes on pseudostem with	a) Management approach is identical to

	(*Odaiporous longicolis*)	exudation of transparent gummy substance	corm weevil
		b) Existence tunneling in leaf sheath and inner core of the stem	b) Injection of Monocrotophos 150 ml in 350 ml water using stem injector 4 ft. above the ground level at 30º angle is recommended.
		c) Abortion of bunches	c) Use longitudinal split (30cm length) @100/ha and smear the trap with bio control agent, B*eauveria bassiana* (10 ml/ trap) and keep the cut surface facing the ground or keep pheromone trap @ 4 traps/ha.
iii)	Thrips (*Chaetanaphotrips signipennis, Heliaothrips kodaliphilus*)	a) They scrap from attacked plant organs and render them brown and discolored especially the fruits.	a) Spray or inject Monocrotophos @ 0.05% on the inflorescence before the unfurling of top most bract.
iv)	Fruit scarring battle (*Besilepta subcostatum*)	a) Adults feed on tender unfolded leaves and fruits and cause scarring of skin b) Plant losses its vigour and quality of bunch is poor)	a) Sanitation spray of 0.05% Moncrotophos or 0.1% Carbaryl on the heart of the plants immediately after the emergence of new foliage and during fruiting season.
v)	Aphids (*Pentalonia nigronervosa*)	a) They are vectors of banana bunchy top virus (BBTV) and can be seen as congregation under the leaf base of pseudo stem	a) Spray of 0.1% Monocrotophos or 0.03% Phosphomidon on the leaves
vi)	Nematodes	a) Stunted growth b) Small leaves c) Rotting of roots d) Purple black lesions on roots and their splitting.	a) Apply Carbofuron @40 gm per plant at planting & 4 month after planting. b) Use neem cake as organic manure. c) Use Marigold as trap crop.
	Fungal Diseases		
vii)	Panama wilt (*Furarium oxysporium*)	a) Yellowing of old leaves progressing b) Affected leaves collapse near petiole and hang. c) Pseudo stem splitting is common. d) Reddish brown discoloration in cross-section of root & rhizome	a) Cultivation of resistant cultivar b) Trim and treat the suckers in 0.1% Bavistin before planting. c) Apply bioagents like Trichoderma and Pseudomonas fluorescence with organic manure d) Keep good drainage and apply lot of organic manure in field.
viii	Head rot (*Erwinia carotovora*)	a) Rotting of collar region and epinasty of leaves) b) On pulling out of affected plant, the plant topples from the collar region leaving the corn with root in soil c) On opening up of collar region of affected plants, yellowish to reddish ooze can be seen.	a) Use healthy planting material b) Drench plants with 0.1% Emisson followed by another drenching after 3 months.

		d) In early stage of infection, dark brown or yellow, water soaked areas in critical region which may decay to form cavities surrounded by dark spongy tissues.	c) Avoid planting in poorly drained soils and hot summer.
ix)	Sigatoka leaf spot (*Mycospharella spp*.)	a) It is characterized by small lesions on the leaves, the lesion become pale yellow to greenish yellow streaks visible from both the surfaces of leaf	a) Remove infected leaves and burn
		b) Thereafter linear brownish to blackish streaks appear.	b) Keep proper drainage and avoid water logging.
		c) Some times premature ripening is observed	c) Spray Propiconazole/ Carbendazim 1 gm/ litre of water + mineral oil 10 ml/ per litre on upper and lower surfaces once in 20 days.
	Viral Diseases		
i)	Banana Bunchy Top Virus (BBTV**)**	a) Appearance of irregular, dark green 'Morse code' streaks along secondary veins on leaves on underside of the leaves.	a) Use virus free planting material i.e. Tissue Culture.
			b) Survey and eradicate infected plants regularly.
		b) Leaf size is reduced and leaves remains abnormally erect, brittle and results.	c) Control insect vectors especially aphids and mealy bugs.
			d) Indexing should be followed in the case of mass multiplication
		c) Leaves short, close to each other, and bunched at the top	e) Prohibit movement of any plant part from diseased area to healthy area.
		d) The tips of the bracts in male buds have greenish.	f) Use resistant cultivar.
		e) Virus is spread through aphids.	g) Avoid growing of alternate lost as mixed crop or in near by areas.
ii)	Banana Cucumber Mosaic Virus (CMV)	a) Chlorosis with mild chlorotic streaks along the veins they never turn necrotic as in BSV.	a) Elimination of affected plants and maintenance of disease free plantation through the use of disease free planting material i.e. Tissue culture seedling.
iii)	Banana Bract Mosaic Virus (BBMV)	a) Presence of spindle shaped pinkish to reddish streaks on pseudo stem, mid ribs, petioles and lamina.	a) Use of disease free planting material i.e. Tissue culture seedling.
iv)	Banana Streak Virus (BSV)	a) Presence of inconspicuous chlorotic flecking to small lethal systematic necrosis, and includes yellow, brown and black streaking, cigar leaf necrosis, based pseudo stem splitting internal internal pseudo stem necrosis and formation of small deformed bunches.	a) Use of disease free planting material i.e. Tissue culture seedlings.

11. Harvesting

Banana should be harvested at the physiological maturity stage for better post harvest quality. The fruit is climacteric and can reach consumption stage after ripening operation.

(i) Maturity indices

These are established on the basis of fruit shape, angularity, grade or diameter of the median figure of the second hand, starch content and number of days that have elapsed after flowering. Market preferences can also affect the decision for harvesting a slight or full mature fruit.

(ii) Removal of bunch

Bunch should be harvested when figures of second hand from top are 3/4 rounded with the help of sharp sickle 30cm above the first hand. Harvesting may be delayed up to 100-110 days after opening of the first hand. Harvested bunch should generally be collected in well padded tray or basket and brought to the collection site. Bunches should be kept out of light after harvest, since this hastens ripening and softening. For local consumption, hands are often left on stalks and sold to retailers.

For export, hands are cut into units of 4-16 fingers, graded for both length and girth, and carefully placed in poly lined boxes to hold different weight depending on export requirements.

12. Post-harvest operations

At collection site injured and over mature fruits are discarded and for local market bunches should be delivered through lorries. However, for more improved and export market where the quality is predominant, bunches should be dehanded, fruits are cleaned in running water or dilute sodium hypochlorite solution to remove the latex and treated with carbendazim, air dried and graded on the basis of size of fingers, and packed in ventilated CFB boxes of 14.5 kg capacity with polythene lining and pre-cooled at 13-15ºC temperature and at 80-90% RH. Such material should than be sent under cool chain at 13ºC for marketing

a. Yield

The crop gets ready for harvest within 11-12 months of planting. First ratoon crop would be ready by 8-10 month from the harvesting of the main crop and second ratoon by 8-9 months after the second crop. Thus over a period to 28-30 months, it is possible to harvest three crops i.e. one main crop and two ratoon crops. Under drip irrigation combined with fertigation yield as high as 100 T/ha can be obtained with the help of tissue culture technique, even similar yield in the ratoon crops can be achieved if the crop is managed well.

b. Processing and value addition

In banana and plantain, the value addition through processing have resulted in development of various value added products such as fig, juice, bar, jam and sweet chutney from pulp of ripe banana; flour, baby food, health drink, sauce, pickle and chips from pulp of unripe banana; pickle from flower (male bud) of banana; candy and pickle from centre core stem of banana and fibre from pseudostem sheath of banana, which involves a certain degree of sophistication. Most of these processes do not require very heavy investment in machinery. It can be set up in cottage to small scale sector. Besides banana fruit, other parts of plant like flower and true stem are also used traditionally for cooking in south and east India. Leaves are

used as hygienic bio-plates and pseudo stem for making threads and fibers. Banana fibre and fibre-based products are gradually picking up as commercial products in south India. The major products are:

(i) Banana chips

Chips is the only processed banana product widely manufactured on commercial scale in India. Banana chips/crisps are made by deep-frying of raw banana slices in a suitable cooking medium. 'Nendran' banana is widely used for preparation of banana chips. Banana chips manufacturing have been developed into a cottage industry in the states of Kerala and Tamil Nadu with an estimated quantity of more than 2.0 lakh tonnes of banana chips every year.

(ii) Banana flour

Banana flour/powder can be made from both ripe as well as unripe fruits of plantain and banana. Even, immature fruits of banana can be converted into flour that would form raw material for other value added products such as Banana baby food, health drink and soup mix which could fetch a premium price in the market. 'Nendran' is the best variety suitable for flour preparation.

(iii) Banana fig

Banana fig is a dehydrated banana product prepared from ripe fruit. 'Karpuravalli' is the best variety suited for fig-making although other sweet varieties like Neypoovan, Rasthali, Poovan (Palayankodoan) can also be utilized. Banana fig can be eaten as such or can be incorporated as pieces in cakes, biscuits, payasam, kesari and ice-creams as a substitute for raisin. It can provide employment generation to rural population, particularly to women sector. The products can be stored up to three months with good taste.

(iv) Ready-to-serve (RTS) beverage

RTS is a beverage prepared from clarified banana juice. The nutritive value of real fruit beverages is far greater than that of synthetic products, which are at present being bottled and sold in large quantities throughout the country. It is a nutritious drink packed with high energy, vitamins and minerals. It can provide good source of employment as well as back ward support to farmers by providing remunerative price. There is a great scope in the country for the production of fruit juices and other fruit based beverages.

(v) Banana wine

Banana wine is a delicious beverage with low alcohol content (12-14%). It is obtained by fermenting clarified juice with wine yeast for a period of 2 – 3 weeks at controlled temperature. The cost of production of banana wine is much cheaper than other fruit wines.

(vi) Banana jam

In the market today, one cannot find jam exclusively made from banana. Banana, as an ingredient in mixed fruit jam is common. Hence, there is scope for jam if it is manufactured exclusively from banana. Pectin present in the fruit gives it a good set. Appropriate combination of pectin, sugar and acid is essential to give a 'proper set' to the jam and to obtain T.S.S of above 68^0 Brix in the finished product. The product would be cheaper than any other jams available in the market. The product can be stored up to one year without deterioration in quality.

(vii) Banana sweet chutney

Banana sweet chutney is prepared by adding sugar, vinegar and spices to ripe pulp. Blending sweet and sour with spice is much preferred by north Indians. The chutney imparts very good taste with chappathi, dosa, idly, bread, samosa, etc., which also aids in digestion. It is suitable for all age groups and can be stored up to six months for better taste. It can generate rural employment, particularly for women sector.

(viii) Banana flower pickle (Thokku)

The banana male bud is a waste material produced during crop production with less economic value, which can be converted into a high value added product by making pickle (*Thokku*). The process involves removal of pistil, chopping, blanching, grinding and addition of spices and oil by frying. The product is tasty and stable for a year at room temperature, however the best in taste up to six months. It can be ideal choice with idly, dosa, chappathi and with rice items. It provides employment generation to rural enterprise, particularly to women sector.

(ix) Banana central core candy and pickle

Central core (true stem), a component of pseudostem, is commonly used in kitchen for culinary preparations. The part is rich in dietary fibre and believed to have the properties to dissolve the kidney stones. It can be converted into value added products namely Central core candy and pickle. The product will be ready for consumption after allowing two weeks for curing process.

(x) Banana fibre

Fiber is a non-edible product obtained from the sheath of pseudostem of banana plant, which yields high quality fibre. With multifarious utilities of banana fibre, it can be an additional source of income for banana ferments. While the coarse fibre is used for tying garlands, the fine fibre is used for making handicraft items and textile fabric. Banana fibre can be extracted manually or by using fibre extraction machine (Decorticator). A wide array of handicraft items made from banana fibre are bags, table mats, wall hangings, tea coasters, photo frames, etc. Other uses of banana fibre are making products like marine cardages, high quality currency papers, cardboards, tea bags, string threads and fabric material.

Production technologies for cultivation of fruits in Kodagu

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1. Introduction

The challenges of overcoming biotic and abiotic stresses and enhanced profitability to farmers continue to get focused attention, as they can meet the food and nutritional security needs and sustain under changing climatic conditions. Kodagu region is located in the hilly areas of the Western Ghats with elevation up to 1700 m and receives on an average, about 1000 to 2500 mm rainfall annually. The temperatures range from 10° to 35°C. The climatic conditions of Kodagu show mild temperature and high humidity which favour cultivation of many tropical and subtropical fruits. There is a huge potential for cultivation of fruits crops like Coorg mandarin, sapota, papaya, guava, pineapple and banana in this region. The Central Horticultural Experiment Station (IIHR) at Chettalli, though initially was carrying out research mainly on Coorg mandarin, from mid 1980s onwards ,diversified into other fruit crops like sapota, guava, papaya and other underutilized humid-tropical fruits. This was necessitated in view of the different problems faced by Coorg mandarin crop in the region which severely affected its productivity. The Station has contributed to development of improved crop production technologies for high potential crops, viz. Coorg mandarin, Coorg Honey Dew papaya, Kaveri hybrid passion fruit, Kew pineapple, Cricket Ball sapota, Allahabad Safeda guava. In a few pockets of Kodagu namely, Somwarpet, Kushalnagar and Balale, farmers have taken up cultivation of these fruit crops particularly when coffee growing became a low profitable venture. The Station has plans to integrate these crops in the prevailing cropping system of coffee, pepper and orange. Commercial production and processing technologies for value addition of these crops would enhance the socio-economic status of the small growers in this region. A brief account of various advanced technologies for important fruit crops suitable for the region is provided.

2. Coorg mandarin (*Citrus reticulata* Blanco)

It is a famous ecotype of mandarin orange grown in the region. The crop is largely raised as rain fed, under multi-storeyed coffee-based cropping system. The fruits have a relatively tight skin compared to that of Nagpur mandarin. Ripe fruits have an excellent blend of sweet and acid taste, pleasant aroma and keeping quality. High intensity and duration of rainfall in Coorg and surrounding regions coupled with a hilly terrain and well-drained soils, render unique taste, aroma and keeping-quality to this cultivar. Coorg mandarin is grown in an area of approximately four thousand ha in Kodagu. Performance of this crop in the region has steadily declined since several decades due to severe biotic stresses such as *Tristeza* and *Phytophthora* enhanced by changes in abiotic environment and ecology. This general decline of the crop is referred to as decline or die-back and a number of factors are attributed to this problem *viz*., faulty nursery practices, unsatisfactory nutrient, water, pests and diseases management. In recent years, the citrus greening disease has also caused serious losses and is one of the major factors contributing to the reduction in Coorg mandarin cultivation. Some of the critical areas which, needed utmost attention to revive Coorg mandarin in order to render its cultivation commercially viable in the coffee growing areas include efficient utilization through promoting its culture in open sunny situations, use of healthy and disease free budded plants,

efficient water and nutrient management and adoption of integrated pests and disease management strategies.

Coorg mandarin is a sun-loving plant. Such ecology, besides influencing the normal growth and development, also favours the incidence of a large number of pests and diseases. Use of healthy disease free citrus budded plants in the prevailing situation of high incidence of transmissible disorders is an absolute necessity for establishing successful citrus orchards with high productivity. Bulk of the active absorbing roots in Coorg mandarin budded plants are located in the top 10 cm of the soil, confined to a radial distance of 120 cm. This is the critical zone for the utilization of natural resources like water and nutrients in Coorg mandarin. Any unfavourable crop interaction in this critical zone will introduce competition affecting the performance of the crop. Multi-storied cropping in the coffee growing tracts was adopted a long time ago in the region in order to ensure higher land use efficiency. Two rows of robusta coffee spaced at 2.8 × 2.8m for every row of Coorg mandarin on Rangpur lime rootstock planted at a spacing of 2.8 × 5.5m was found satisfactory for growth and viable yield as a companion crop. The excess shade in the cropping system of arabica coffee however reduced the vigour and productivity of Coorg mandarin and shade regulation in this cropping system affected coffee productivity. In pure mandarin orchards, intercropping with papaya and pineapple during pre-bearing period is economically feasible.

a) Nutrient management

Coorg mandarin requires judicious application of fertilizers for better growth and sustained production of high quality fruits. Maximum growth and productivity of Coorg mandarin plants budded on Rangpur lime can be obtained with the application of 25 kg of well decomposed farm yard manure along with 5 kg neem cake and 600g N, 200g P_2O_5 and 400g K_2O per tree/year during the early bearing years. The recommended doses of fertilizers are to be applied in two split doses during the pre monsoon ((May-June) and post monsoon (September-October) periods. In order to have favourable nutrients balancethe index leaf should contain 2.91 to 3.15% N, 1.51 to 1.61% K and 0.32 to 0.36% Mg. The deficiencies of micronutrients especially Zn and Mg are widespread in Coorg mandarin. The soil application of 500g to 1.0 kg zinc sulphate along with 200g calcium chloride per tree is recommended once in 3-4 years. In case of severe deficiency, two foliar sprays of 0.3 per cent zinc sulphate are recommended. For magnesium deficiency, soil application of 500g to 1.0 kg of dolomite or 250g magnesium sulphate per tree every year followed by two foliar sprays of 0.5 per cent magnesium sulphate is advocated.

The role of efficient nutrient management along with pests and disease management are important for rejuvenation of Coorg mandarin**.** The old and declining trees should be pruned by removing of dried, dead wood and symptomatic shoots to a level free from such symptoms followed by pasting of cut ends with 10 % Bordeaux paste. This is important for stimulation of production of vigorous new growths. Soil application of 25 kg FYM + 5kg neem cake + 150g *Trichoderma harzianum* + 400g N, 125g P_2O_5 and 275g K_2O in two splits (pre and post-monsoon) + 1kg dolomite twice (June and October) should be done. Foliar application of 200g N, 75g P_2O_5 and 125g K_2O through soluble fertilizers, zinc sulphate (0.2 %), magnesium sulphate (0.5%) and calcium chloride/calcium nitrate (0.5%), once in a month coupled with integrated management of *Phytophthora*, powdery mildew and citrus vectors result in improving the tree vigour and yield of declining Coorg mandarin orchards. In order to avoid moisture stress during reproductive phase, application of water either through blossom shower by sprinklers or drip irrigation @ 18-20 litres per day per tree for one week during March-April is recommended.

b) Diseases (foot rot, gummosis and root rot)

Coorg mandarin plants cultivated mainly as an intercrop have been affected by a number of fungal, bacterial and viral diseases. As a result, it has become difficult to grow a healthy crop in the region without proper disease management strategies. *Phytophthora* is the most serious soil borne disease of mandarin accounting for more than 20-30% losses. Avoidance of water logging and pasting the tree with a copper fungicide is

recommended as preventive measures. Pasting of 10% Bordeaux paste and drenching the soil with 1% Bordeaux mixture or 0.2% Foltaf is found to be helpful in reducing the intensity of the disease. In severe cases applications of metalaxyl + mancozeb (0.25%) as spray and drenching besides spraying with 0.3% Phosetyl-Al were found helpful in controlling root rot and increase root volume. Application of 50-100 g of *Trichoderma* culture along with 5kg neem cake per tree is recommended for the biological control of *Phytophthora*.

c) Virus and virus like diseases

(i) Greening

Greening disease has assumed an alarming situation in the region and has threatened the mandarin cultivation in Kodagu. Green patches in yellow background, manganese and zinc pattern deficiency and corking vein are also induced by greening. The disease affects all the scion cultivars irrespective of the scion-rootstock combination. The disease is transmitted by citrus psylla. Although the disease can be identified tentatively by symptoms its confirmation through indexing is essential. There is no chemical control measure available for this disease. The reduction in the incidence of this disease can be effected by removing all the affected plants and use of disease free nursery plants -both rootstock and scion mother plants- propagated and grown in vector proof net house environment using disease free bud wood and management of psylla. Effective management of citrus psylla can be done by using systemic insecticides such as imidacloprid (0.003%) during the flushing on tender growth.

d) Insect pests

Over 50 species of insect pests have been recorded on Coorg mandarin in Coorg. The major pests are soft green scale, citrus leaf miner, citrus butterfly, mites, orange shoot borer, aphids and citrus psylla. Aphids and psylla are very important as vectors in transmitting tristeza and greening disease, respectively in the region. These vectors can be controlled by Methyl demeton or Dimethoate (0.025%) or Thiamethoxam (0.05%) or Imidacloprid (0.003%) or Acetamiprid (0.005%) or Fenvalerate (0.005%) or Acephate (0.1125%) or Profenophos (0.1%) or Phasalone (0.05%).

(i) Fruit fly

Fruit fly attack is a major menace in Coorg mandarin cultivation. The adult fruit fly makes small punctures on fruits and lay eggs and fruits become yellow and fall down. The control of fruit fly can be achieved by applying baits containing malathion 2ml/litre + carbendazim (0.1%) with 10g of jaggery or sugar. Pheromone traps (10/ha) using methyl eugenol have been found successful in controlling the fruit fly.

e) Harvest and storage

In Coorg, the main crop is harvested in December to April. A small off season crop is obtained during July to September. Fruits attain maturity after about 36-38 weeks of fruit set. About 400 to 800 fruits per year per tree can be expected from well-managed ten-year old trees. Post harvest losses usually range between 15-30 percent due to microbial decay, harvesting injury, defective handling, exposure to unfavourable temperatures and humidity. Dipping the fruits in 6 percent wax emulsion containing 250ppm benomyl and 1000ppm thiobendazole reduces the post harvest losses. Waxed Coorg mandarin fruits can be stored for 90 days at 4-5^{o}C with a relative humidity of 85-90 % as compared to 75 days for unwaxed fruits. The fruits are widely consumed as fresh fruit but can also be used for producing canned segments, juice, juice concentrate, squash, jams and marmalades etc. The peel of mandarin is a source of essential oil and pectin.

3. Acid lime (*Citrus aurantifolia* L.)

It is another important potential fruit crop in this region because of high revenue generation potential. The trees are not grown on commercial scale though seedless varieties are popular and confined to homestead garden in parts of Kodagu.

4. Sapota (*Achras zapota* L.)

Sapota popularly known as *chiku*, is an important fruit in Kodagu and can be grown profitably under rainfed conditions. Trials also have indicated that it could be an ideal inter crop with coffee for the region from the point of view of ease of cultivation and higher revenue generation potential. It is devoid of any major pests and diseases problems. In subtropics or higher elevation region, it gives only one crop from summer flowering in March and April. Under moisture-stress also, it produces one crop only. There are about 41 varieties spread all over the country. However, commercially sapota cultivation is limited to a few varieties. Some of the popular varieties are Kalipatti, Cricket Ball, Kirtibarthi, DHS 1 and DHS 2 and PKM 1.

a) Planting and nutrient management

Since sapota tree makes uniform all round growth, square system of planting is recommended. However, in lands with 5-15% slope, contour planting is recommended. Depending on growth habit sapota orchards are planted at 10 × 10m, but being slow in growth it takes longer period to occupy allotted space. Therefore high-density plantations having 5 × 5m spacing up to the age of 13 years are very remunerative. Sapota is eminently suitable for multi tier cropping system as prevalent in Kodagu. Two rows of robusta coffee spaced at 2.8 × 2.8m for every row of sapota planted with a spacing of 2.8 × 5.5 m is the usual practice. Under rainfed conditions, nutrient application should be done at the onset of monsoon. A fertilizer combination of 500g N, 250g P_2O_5 and 250g K_2O per tree in two split applications produced the best yield of good quality fruits of cricket ball. Total quantity of organic manure and half the dose of chemical fertilizers should be applied at the beginning of monsoon and remaining half in post-monsoon period (September-October). Since most of the active roots are distributed within the depth of 30cm, nutrients should be applied under tree canopy.

Sapota is affected by a limited number of insect pests and diseases. The major pests are bud borer, leaf webber and fruit borer and necessary plant protection measures (lambda-cyhalothrin @1ml/L or dimethoate @ 2ml/L) should be taken up in time. The main diseases observed are leaf spot and flat limb in sapota.Spraying with mancozeb @2.5 g/litre or copper oxychloride @ 2.5 g/litre would provide adequate control. In an experiment on varietal screening for resistance to leaf spot caused by *Phaeophleospora* , observations on disease index of eleven varieties planted at CHES, Chettalli, CHES Selection showed considerably less disease index. Other varieties viz. CO-1, DHS-2 and PKM-1 also indicated high resistance to leaf spot disease (Ravishankar 2008).

b) Harvesting and postharvest management

Sapota takes around 7-10 months from flowering to maturity depending on variety and climate. Maturity is decided on the basis of ease with which brown scruff gets off the fruit surface and development of yellowish streak instead of green streak on the surface of the fruit. At this stage, practically no green tissue and milky latex are seen on fruits when scratched with nails. Harvested fruits are graded according to size and stage of maturity and washed in 500 ppm carbendazium, shade dried and packed in cartons of 20.5 ×20.5 ×5.5 cm for distant transport. Depending on proper management, 15-20 tonnes fruits are harvested from a hectare. Fruits are highly perishable and they undergo rapid ripening changes within 5-7 days after harvest. Unripe fruits can keep for about 5 weeks satisfactorily between 12-14º C . For early and uniform ripening exposing to ethrel @ 1000ppm is recommended. Post harvest biochemical changes can be regulated through

chemicals, temperature and storage gas composition under CA storage. Under optimum storage temperature of 20º C, the storage life could be increased by removing ethylene and adding 5-10 % CO_2 to storage atmosphere.

5. Papaya (*Carica papaya* L.)

Papaya is highly nutritious and rich in vitamins and minerals. Coorg Honey Dew is one of the earliest gynodioecious selections made in the country (Aiyappa and Nanjappa, 1959). Gynodioecious variety of papaya "Coorg Honey Dew" was developed by this station which became popular throughout the country. The most salient feature of this variety is that the flowers are either hermaphrodite or female. The fruits are large each weighing 2 to 3.5 kg. Pulp is yellow in colour, but with poor keeping quality. It can be used for both table purpose as well as papain extraction. Each plant bears 40-60 fruits and an average yield of 200 tons/ha over a three year cropping period can be expected. Few pockets of Coorg region in Somwarpet and adjoining areas and Kushal Nagar are suitable for cultivation of papaya.

Papaya requires well-drained fertile soils of uniform texture. Under water stagnated conditions and in soils with poor drainage, foot rot disease may cause heavy mortality. Hence, heavy clay soils should be avoided, as papayas cannot withstand water stagnation for more than 48 hours. Depending on the pH, 2 to 4 tonnes of lime per hectare may be applied in acid soils or gypsum in alkali soils to bring the soil to desired pH (6.5 to 7.0) for papaya cultivation. It is suited to a wide range of rainfall conditions ranging from 35 cm to 250 cm per annum. Seeds should be procured only from reliable sources. About, 500g seeds will be required (200g/acre) for planting one hectare.

To control nematodes at the nursery stage, application of neem cake at 100 g/bag is recommended and also Carbofuran 3G @3g/ poly bag at nursery stage. Seeds can be treated with a solution containing 100 mg of gibberellic acid dissolved in one litre water for 2 hours to enhance germination. Seedlings should be drenched with 2g/liter of copper oxychloride to prevent fungal rots at nursery stage. Seedlings will be ready for transplanting when they are 45-60 days old or when the seedlings attain 30-45 cm in height.

a) Manuring and fertilization

Papaya is a heavy feeder and adequate manuring of young and mature papaya tree is essential to maintain the growth and vigour of the tree so as to obtain regular high yields. Before planting 10 kg of well decomposed farmyard manure or compost, 20 g of each *Azospirillum, Paceilomyces* and *Phosphobacterium* or a consortium of microbial cultures should be applied per pit. The inorganic fertilizers may be applied at 2 months interval starting from the 3rd month of planting (250:250:500 g NPK/plant/year in 6 splits) per plant. Soil drenching of humic acid @ 2ml/L may be carried out at monthly intervals after planting. Foliar sprays of zinc sulphate 0.5% and boric acid 0.1% at 4th and 8th month after planting increase the yield and quality of fruits. Under, intensive farming, a fertilizer dose of 250:250:500 g NPK/plant/year recorded maximum growth and yield parameters.

b) Plant protection

(i) Insect pests

Papaya is not a preferred host for many species of insects. But, few insects like scales, mealy bugs, aphids and thrips have been reported infesting it. Mealy bugs have become a major threat to papaya cultivation in recent years which can be ameliorated by biological control measures.

(ii) Diseases

Collar rot and wilt

Wilting of young seedlings and grown up plants in the main field is a common problem in papaya. Prior to the commencement of heavy monsoon rains, the soil around the plants in the main field may be drenched with 1% Bordeaux mixture or 2g of COC at the rate of 2 liters per plant. Metalaxyl @ of 2g/litre can also be drenched 2-4 times at 15 days intervals. Water stagnation should be avoided.

Anthracnose

It is one of the major diseases of papaya affecting fruits and leaves in most of the papaya growing areas. The disease affects the petioles of lower leaves leading to their shedding. Papayas grown in dry areas are usually less affected by than those grown in high rainfall areas. Good control of anthracnose can be achieved by spraying the fruits in the tree with COC or Mancozeb @ 2g/litre.

Viral diseases

Three major virus diseases namely mosaic, leaf curl and ring spot are commonly found in most of the regions of papaya cultivation. Of late, ring spot has become a major threat to papaya production in several tracts. The virus is usually transmitted by the winged forms of aphids in a non-persistent manner and these vectors should be controlled by employing insecticides such as Methyl demeton 25 EC or Dimethoate 30 EC @2ml/litre.

Nematodes

Root knot and reniform nematodes can damage the root system and cause yield reductions. Nematodes can be controlled by the application of carbofuran 3G @3g/poly bag at nursery stage and 15-20g per plant in the main field. Neem cake 250g+ *Pseudomonas fluorescens* formulation @4g can be applied per pit at the main field.

(iii) Papain extraction

Cultivation of papaya for producing papain is a profitable proposition. Substantial quantities of papain can be extracted by adopting correct techniques. Papain enzyme is exclusively exported and there is a great demand in the international market. The latex should be tapped from 75 to 90 days old immature papaya fruits early in the morning. On the selected fruit, four longitudinal incisions should be given using a razor blade attached to a bamboo splinter. The depth of the cut should not be more than 0.3 cm. Tapping has to be repeated four times on the same fruit at an interval of four days. Latex should be collected in aluminum trays and shade dried. The dried latex is then powdered and packed in polythene bags. Before drying, potassium meta-bi-sulphite (KMS) @0.05% has to be added to the latex for better colour and keeping quality. The latex can also be dried in oven at a temperature of 50 to 55^{o}C.

(iv) Post harvest management

Papaya fruits ripen quickly and become soft if not properly stored or handled. It is also susceptible to post harvest rot and decay, especially if it is infested with anthracnose disease in the field. The post harvest shelf life of papaya can be improved by storing the fruits after they attain uniform colouration at 7^{o}C. Modified atmospheric storage at a temperature of 11-13^{o}C with 1 to 1.5% oxygen and 9-10% CO_2 can also prolong storage. Immediately after harvest, the fruits may be given a hot water treatment i.e. dipping in hot water

(55°C) for 30 min to kill the eggs of fruit fly that may have been present under the skin. The fruits can be wrapped individually in newspaper and packed in CFB cartons. Bruising of fruits during handling can also make them susceptible to post harvest diseases.

(v) Value added products

After extraction of the latex (papain), the raw fruits are used for making candy (Tuty-fruity) and also used as vegetable, pickles, chips etc. The ripe fruits are obtained about 130 days after fruit set and used as raw materials for making jam, jelly, toffee, bar, squash, soft drinks, pulp powder etc as the fruit is rich in pectins.

6. Guava (*Psidium guajava* L.)

Guava is available almost throughout the year except the summer months. Being very hardy, it gives an assured crop even with very little care. Guava is also grown as a backyard fruit to a great extent in Kodagu. Few locations of Coorg region *viz*., Somwarpet and Kushal Nagar areas have taken up cultivation of guava in recent times. The most popular guava cultivars are Sardar (Lucknow 49) and Allahabad Safeda. IIHR, Bangalore has developed soft-seeded superior varieties Arka Mridula and Arka Amulya (white pulp) and Arka Kiran (red pulp). High density plantation (HDP) is one of the new strategies in guava cultivation. This includes adoption of appropriate plant density, canopy management and management system with appropriate inputs. It has been attempted in several crops such as guava, banana, mango and pineapple etc. Many guava farmers have been adopting this technology successfully. HDP technology results in maximization of yield in unit area and the availability of the fruits in the market early fetches better price.

Guava is commercially planted at a distance of 6 × 6m. The exact planting distance is, however, decided according to variety and location.

a) Establishing ultra high density orchard

In this system, planting is done at 2.0 m (row to row) × 1.0 m (plant to plant), accommodating 5000 plants/ha. Initially, trees are pruned and trained to allow maximum production of quality fruits during first year. A single trunk tree with no interfering branches up to 30-40 cm from the ground level is desirable to make dwarf tree architecture. After a period of 1-2 months of planting, all the trees are topped at a uniform height of 30-40 cm from the ground level for initiation of new growth below the cut ends. No side shoots or branches should remain after topping. This is done to make a single trunk straight up to 40 cm height. After 15-20 days of topping, new shoots emerge. In general, 3-4 shoots are retained below the cut point after topping. The emerged shoots are allowed to grow for 3-4 months before they are again pruned by 50%. After pruning, new shoots emerge on which flowering takes place. It is emphasized that pruning of shoot is done thrice a year. This leads to desired canopy development. Fruiting starts in the same year but every shoot will not carry fruits. Pruning is however continued so that plants remain dwarf. After a year, pruning operation is done especially in May-June, September-October and January-February (Singh, 2010).

Guava is very responsive to the application of inorganic fertilisers along with organic manures. For guava, a manuring schedule of 900g N, 600g P_2O_5 and 600g K_2O has been recommended. At Bangalore, full K and 70%N are applied in June and full P and 30% N in September. Since 48% of feeder roots of guava are found in the surface soil up to 25 cm depth, fertilizer should be placed in 25 cm trenches 1 m away from the trunk for better uptake. For HDP, NPK may be applied @100, 40 and 40 g per plant year of age, with stabilisation in the 6th year. They may be applied in two equally split doses in January and August. Pre-flowering sprays with 0.4% Boric Acid and 0.3% Zinc Sulphate increase the yield and fruit size. Spraying of copper sulphate at 0.2 to 0.4% also increases the growth and yield of guava. Bronzing is another common problem in guava. It is caused by the deficiency of B, Zn, N, P and K. Lucknow 49 is more susceptible then Allahabad Safeda for bronzing. It can be reduced by improving the soil pH and treating the soil with N, P, K

and Zn at 200, 80, 150 and 80 g/ year respectively, or fortnightly foliar spraying of these nutrients each at 2% for 4 months.

In Coorg, guava normally flowers during February-March and only one crop matures during the rainy season from August-November. The practice of increasing winter crop and by removing rainy season crop is known as crop regulation. The rainy season crop can be removed by spraying of urea (10%) on Allahabad Safeda at the time of peak flowering in summer season. Growth regulators like NAA 100 ppm, NAD 50ppm, or 2,4-D 30 ppm are also reported to be effective in thinning the flowers and manipulating the cropping season.

b) Harvesting and postharvest management

The plants begin bearing at an early age of 2-3 years but they attain full bearing capacity at the age of 8-10 years. A 10 yearold plant yields about 100kg of fruits every year. Shelf life of guava can be extended up to 20 days by keeping them at low temperature of 5°C and 75-85% relative humidity.

c) Insect pests and diseases

Tea mosquito bug and fruit fly are the major pests in guava and most damaging diseases in guava are wilt and anthracnose. Suitable chemical sprays and pheromone traps would control the insects. The planting material should not be obtained from a wilt infected region or nursery.

7. Pineapple (*Ananas comosus* L.)

Pineapple requires a high amount of humidity in atmosphere for better growth and yield. In Coorg, pineapple cultivation has seen a downward trend owing to high cost of labour. Crop production technology for 'Kew' pineapple under rainfed conditions has been standardized. A plant population of 45,000 plants per hectare was found to be optimum producing an yield of 60-70 tonnes/ha. Application of 16g N and 10g K_2O plant/crop in a single dose was found to be the best. Uniform induction of flowering under the humid climate of Coorg could be obtained by application of 10ppm NAA during December-January, while 25 ppm ethrel in combination with 2% urea and 0.04% sodium carbonate was effective during the rest of the year. Optimum stage for induction of flowering was found to be 35-40 leaves. At Hessaraghatta, rate of ratooning was compared in traditional and high-density planting of 55,555 plants/ha. In the study, two successive ratoon crops harvested at 12 monthly intervals amounted to 50.7% and 53.8% of the plant crop yields.

8. Litchi (*Litchi chinensis* Sonn.)

It is another potential tree crop suitable for the region particularly during the off season and fruits are available during November-December compared to May-June in Northern India. Litchi is liked very much as a table fruit; dried and canned litchies are also popular. A large number of varieties are grown in different parts of India. Litchi trees are usually planted in a square system, 10m apart. The distance can be reduced to 7.5m both ways where ever litchi plants need protection either from frost or from the desiccating winds. Litchi trees are good sources for foraging honeybees.

9. Passion fruit (*Passiflora edulis* Sims.)

Passionfruit is cultivated in several parts of the country. In South India, it is grown in Kerala (Wayanad and Munnar), Tamilnadu (Kodaikanal) and Karnataka (Kodagu). Passionfruit prefers moderate rainfall of 100-250 cm. There are two types of passionfruit; yellow and purple. The former requires low tropical conditions while the purple comes up well in higher elevations. Several hybrids between these two have been

developed in many countries. A hybrid Kaveri was developed at CHES, Chttalli in 1986 which is very popular among the farmers of Kodagu and the North East. The most suitable soils would be with a pH of 6.5-7.5.

Passionfruit is propagated through seed, stem cutting, grafting as well as serpentine layering. The spacing followed is 3 × 2 m. Planting is done in the months of June-July. Passionfruit is a woody vine requiring support for good growth and fruiting. For commercial cultivation, the crop is grown on wires or trellises under Kniffin system. The crop needs pruning for fruiting; once in March-April and again in October-November. A fertilizer dose of 110g N, 60g P_2O_5 and 100g K_2O per vine per annum is recommended. Drip irrigation is very useful; 12-15 l/day/vine in summer and 6-8l/day/vine in winter. Passionfruit is affected by several diseases such as collar rot, fusarium wilt, phytophthora root rot, anthracnose and viral diseases. Fruit flies, thrips and mites are the pests that affect the vines. The average yield ranges from 15 to 20 tonnes/ha.

10. Conclusion

The region of Kodagu is the home of several plant species with edible fruits and vegetables. There are quite a large number of indigenous and underutilized fruit crops, which are being used by local inhabitants. These crops are very important in terms of nutraceutical values, their feasibility in crop diversification and adaptability to changes in prevailing agro-climatic conditions. Many of the indigenous tropical and subtropical fruits have still remained underexploited due to the lack of awareness of their potential. Commercial production and processing for value addition of these crops would enhance the income of growers. The increase in area and production of these major and underexploited fruit crops will not only provide nutritional security to the people but also boost the region's economy.

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Production technologies of minor fruits with special emphasis on Kodagu

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1. Introduction

The area and production of major horticultural crops have increased rapidly during last three decade. However, many of the indigenous tropical and subtropical fruits have still remained underexploited due to the lack of awareness of their potential, lower availability and location specificity. The diversity of these fruits is also facing threat of extinction due to climate change, large-scale urbanization and deforestation. To safeguard the existing diversity of underutilized fruits and to achieve sustainable development based on the use of available genetic wealth under various ecosystems, promotion and conservation of these species are of great importance. Commercial production and processing for value addition of these crops would enhance the income of small and marginal farmers and tribal and also help in on-farm conservation of valuable germplasm.

Lots of underutilized fruits were collected at various research stations and developed production technologies for these crops. At the Central Horticultural Experiment Station, Chettalli more than 500 collections of mangosteen (17 accessions), durian (8 accessions), rambutan 150 accessions), avocado (32 accessions), passion fruit (25 accessions), kokum (45 accessions), malabar tamarind (85 accessions) ,macadamia nut (three accessions), pummelo (65 accessions) and longan (two accessions) were collected. The efforts have been initiated to develop promising cultivars and production technologies for the important crops. The detail of the some of these fruits is as follows:

2. Rambutan (*Nephelium lappaceum* var*. lappaceum*)

Rambutan is a popular fruit of Indonesia, Malaysia and Thailand. It has been widely cultivated throughout Southeast Asia. In India, rambutan cultivation is limited to some parts of South India. The fruits of rambutan are red to yellow in colour. These are similar to litchi except long hair like structures on fruits. The edible portion in rambutan is aril, which is attached to seed. Rambutan fruits are rich in carbohydrates, vitamin C, calcium, magnesium and potassium. The fruit contains 82 per cent water, 0.9 per cent protein and 0.3 per cent fat. Rambutan fruits are mostly used as fresh fruit. The aril can be mixed with other fruits for various preparations. The fruits are also used for making jam and jelly and also for canning after removal of rind and seed. Rambutan seed contains high amount of fat. This fat is similar to cocoa butter and can be used as edible oil or making soap and candles. In India, rambutan is cultivated in home gardens of Thrissur, Pathanamthitta, Kottayyam and Ernakulum districts of Kerala; Nagercoil, Courtralam and The Nilgiris districts of Tamil Nadu; Dakshina Kannada and Kodagu districts of Karnataka. The actual area and production of rambutan in India are not available but it is estimated that the area under the crop is less than 500 acres. There is good potential of expansion of this crop in Kerala, Tamil Nadu and Karnataka.

Rambutan tree is an evergreen tree which may grow op to a height of 12–20 m and is adapted to warm tropical climate. It requires around 22–30°C temperature for optimum growth. It is very sensitive to temperature.Higher temperature (>40°C) also affects the growth and development of plants .Lower temperature causes defoliation and affect panicle emergence and fruiting.Lower humidity affects the development of fruits. The tree grows well up to 700 metre above sea-level. The plant requires good rainfall of 200-500 cm well distributed through out the year but a short spell of the dry period is essential for initiation of floral bud function.

Rambutan is grown successfully in wide range of soils. Well drained sandy loam to clay loam soils with organic matter are most suitable for optimum growth and yield. It can be grown successfully in red laterite soil if adequate organic and inorganic fertilizers are applied. The optimum soil pH is 4.5 to 6.5. Rambutan is sensitive to water logging. The orchard in slight sloppy land has been found performing better. The soil should be rich in zinc and iron otherwise yellowing of leaf as a result the nutrient deficiency is commonly observed.

The tree is propagated by seed or by vegetative methods such as budding, grafting and layering. Seed propagation is easy but is not recommended for commercial multiplication as more than 50 per cent seedlings can be male trees. Seedlings are used for rootstocks purpose only. Seeds lose their viability very soon .Thus it should be sown immediately after removing the aril. Germination of 2-day-old seeds is 87% to 95% as compared to 50-60% in one week old seed. Seedlings become ready for grafting in 9-10 months. Vegetative propagation is essential as rambutan seedlings take long time for fruiting . Approach grafting is found successful but it is more labour intensive and cumbersome .Experiment conducted at CHES, Chettalli with ten month old seedlings in the month of November and December gave 42% success while success was 75 % in the month of September –October.Other grafting methods such as cleft and veneer have also been tried for propagation of rambutan. But most of them were not successful or very less successful. The success rate in cleft grafting in the shade house was low (10%).Air-layering may at first appear successful, but many air-layers die after being transplanted into field nursery or poly bags or later in the field, long after separation from the mother tree. Among the various budding methods, patch-budding is preferred as having a higher rate of success. Budding is done on well-grown rootstocks of 8 to 12 month old in month of May or July. The success rate is reported to be as high as 83.6% in other countries. Experiment conducted at CHES, Chettalli revealed that higher humidity and moderate temperature are essential for higher success, at temperature less than 20 ^{0}C success rate was low. Bud wood selection is an important for the success of the budding.

There are several commercial varieties of rambutan grown is south eastern Asian countries. CHES (IIHR) Chettalli have recently released two varieties of rambutan namely Arka Coorg Arun and Arka Coorg Peetabh. Arka Coorg Arun is an early maturing variety with red colour fruits. The fruits mature in the month of September- October and average fruit weight is 40 to 45 g. Arka Coorg Peetabh is a high yielding, yellow colour variety. The average fruit weight is 25-30 g.

Seedling trees of rambutan are vigourous and spreading type and require more space for growth and generally are planted at 10 × 10 to 12 × 12 meter distance. Vegetatively propagated trees are smaller in size and they should be planted at a spacing is 8 × 8 or 8 × 6 m. The most appropriate spacing is 200-250 plants/ ha. The planting is done in pits of 1 × 1 × 1 m size which are done 2 to 3 week ahead of planting and filled with a mixture containing three parts of top soil and one part of compost. Planting is done preferably during June-July after the onset of monsoon so that the plants are well established at the end of the monsoon. Rambutan trees exhibit strong apical dominance and have a tendency to produce long, upright growth. Early pruning and training to form an open center tree is recommended. After harvesting, fruited twigs are pruned back to stimulate new growth.

A fertilizer dose of 200g nitrogen, 25g of phosphate and 100g potassium per tree per year of age is recommended for rambutan. For the first four years, the fertilizers should be applied in four equal dressings, every three months. For fruiting trees, 200g N, 25g P and 130g K per tree per year of age are recommended. Maximum fertilizer rate is reached at 12 years and should remain constant thereafter. Irrigation is given as needed in dry seasons. In order to induce flowering of full-grown plants, there is a need to allow the rambutan plant to pass through a period of drought for about 21-30 days.

Rambutan is a cross pollinated crop. Among the pollinating insects, *Apiscerana* was found to be the predominant followed by A. florea, Trigona Spp., ants and wasp. The peak hours of visit by the pollinating insects to the flowers was between 7:00 a.m to 10:30 a.m. Rambutan grafted trees start bearing fruits from fourth year onwards. It may take up to five months for the fruits to develop into ripe fruits after fruit set. In South Eastern Asian Countries, rambutan produces fruits twice a year, the first and the main crop is in June and a lesser one is in December. But in India it gives only one crop per year. The fruits ripe in month of July to October. Harvesting is done by shears or sharp knives by cut the inflorescence stalk. The fresh fruits are

easily bruised and have a limited shelf life. An average tree may produce 5,000-6,000 fruits (60–70 kg) per tree. Under Chettalli conditions, higher number of fruits were harvested from CHES-26(1801.3) while 50kg fruit per plants was recorded in CHES -29 for a eight year old plant. But the average yield for a 10 year plants for Chettalli condition was 25 kg. The fruits must be sold immediately to avoid shrinkage and decay. Studies conducted at CHES, Chettalli revealed that physiological Loss in Weight (PLW) of fruit increased gradually with the days of shelf life. The fruits may be used for making squash, jam, canning etc.

3. Passion fruit (*Passiflora edulis* Sims)

Passion fruit is a perennial, vigorous, climbing, woody vine that produces round or ovoid, yellow, purple coloured fruits .It is a native of Brazil belonging to the family Passifloraceae, grown mostly in tropical and sub-tropical part of the world from South America to Australia, Asia and Africa. Brazil and Ecuador are the largest passion fruit producing countries. In India, though passion fruit was introduced in early part of twentieth century its cultivation was limited to few districts in Karnataka, Kerala and Tamil Nadu. Since last one decade it's cultivation again started in some parts of northern India, especially North East states. The area under this crop is rapidly increasing in Mizoram, Nagaland, Manipur and Sikkim. and there is a great potential for its cultivation in these states. Presently passion fruit is cultivated in Kerala, Tamil Nadu, Kodagu (Coorg) region of Karnataka and parts of Mizoram, Nagaland, Manipur and Sikkim. The estimated area and production of passion fruit is 9.11 thousand ha and 45.82 thousand tones, respectively. The average productivity of passion fruit in India is around 5.02 tons/ha which much lower than countries like Brazil, Australia, Colombia etc where productivity is 30-35 tons/ha.

Passion fruit prefers a tropical and sub-tropical climate with moderate rainfall ranging between 100 and 250 cm. It is found growing at an altitude of 800-1500m above sea level. Passion fruit is grown on many soil types but light to heavy sandy loams, of medium texture are most suitable. Soil with a pH of 6.5 to 7.5 is the most suitable

Fruit contains orange coloured pulpy juice with large number of small, hard, dark brown to black seeds. The fruits possessed unique flavour and aroma and high nutritional and medicinal properties. They are processed to make fruit juice and concentrate. Fruits are rich in Vitamin A (1300-2500 IU/100 g pulp), Vitamin C (30 –50 mg/100 g pulp) and minerals such as sodium, magnesium, sulphur and chlorides. Passion fruit is good for urinary infections and as a mild diuretic, digestive stimulant, and heart tonic and to treat asthma, whooping cough, bronchitis, coughs, gastric cancer etc

There are two distinct forms of *Passiflora edulis* Sims , the standard yellow *(Passifloraedulisf. flavicarpa*Deg.) and the purple (*Passiflora edulis f. edulis*). The yellow type is more acidic and less starchy while the purple one is less acidic and more starchy. The hybrids of these two have also been developed. A hybrid namely Kavery was developed at Central Horticultural Experimental Station, Chettalli in 1986. Fruits of Kaveri are ovoid to round, big (100g) and purple dotted colour. Each plant bears 40-60 fruits per annum and produces 200 tonnes yield/ha over a three-year cropping period In India, there is no released variety of purple and yellow coloured passion fruits. The local purple lines such as Ooty Purple, Coorg Purple, Moodabidri Purple, Thrissur Purple, Cherapunji Purple, Thaliparamba Purple and Ambalavayal Purple and local yellow colour lines such as Ooty Yellow, Coorg Yellow, Munnar Yellow are cultivated by the growers.

Passion fruit is propagated through seed, stem cutting as well as grafting. Seedlings and grafted plants are more vigorous than the plants raised by cuttings. Passion fruit propagated through cutting or grafting starts fruiting much earlier (7-6 months) than those from seeds (10-12 months). Stem cuttings is most popular method of multiplication of passion fruit. Passion fruit is not a easy to root but rooting is satisfactorily under favourable conditions. Rooting may be hastened by treatment of 200 ppm NAA for very short period (3-5second). Rooting takes place within a month and can be transplanted to the field in about three months. Grafting is used to multiply hybrid varieties on disease resistance rootstocks. Cleft graft, whip graft or side wedge graft methods are used for grafting. Serpentine layering is also used to multiply the vine. The method has been found highly successful with 90-95 percent success.

Planting is done in pits of 45 × 45 × 45 cm at at a spacing 3x2m during June-July. Passion fruit is a woody vine which needs support for good growth and fruiting. For commercial cultivation, the vines are

trained on a frame of wires and poles at1.5 to 2 meter above the soil surface. Among the different types of trellising, Kniffin system is the most economical. Passion fruit vines bear fruits only on current season's growth and systematic pruning of vine encourage new growth resulting in regular and higher yield of fruits. Pruning is generally done twice in a year, first in March and April and another in October-November depending upon the harvest of the crop. Indiscriminate and drastic pruning of inactive or dormant vine may lead to a setback in growth and reduction in yield.

A fertilizer dose of 110g N, 60g P_2O_5 and 110g K_2O per vine per annum is recommended for a 4 year old orchards in South India while 80g N, 40g P_2O_5 and 50g K_2O per vine per annum is recommended for the 4 year old orchards for North Eastern States. For Kaveri hybrid 100g N, 50g P_2O_5 and 100g K_2O per vine per annum is recommended. Prolonged dry spell during January-March may reduce main summer crop and may also affect adversely the development of flowering laterals. If there is no rainfall during the dry months, supplementary irrigation may be given at fortnightly intervals. On an average, passion fruit requires irrigation of 12-15 litre /vine/day in summer and 6-8 litre /vine/day) in winter. Passion fruit is shallow rooted thus deep digging should be avoided. Mulching with dried leaves or grass is done to conserve moisture and check weed growth.

Passion fruit flowers and fruits throughout the year under favourable conditions. However, there are two main periods of fruiting i.e. August to December and March to May. The first fruiting is obtained from the ninth month. Harvesting is done when fruit turns slightly purple. Fruit should be harvested along with the stem. On an average, anyield of 10-12 tonnes per hectare per year can be obtained. The vines are perennial and can produces yield for 10 to 15 years but maximum production can be obtained up to six years after which the yield declines. Fruits harvested should be disposed off quickly to prevent the loss in weight and appearance. About 10-20% loss in weight results from storage, and fruits wrinkle and give a bad appearance. To avoid this they can be stored in polythene bags and for transport to distant markets polythene-lined crates may be used. Fruits are generally used for juice and squash.

Brown rot and root rot diseases cause considerable damage to crop. The rotting of the root starts and ultimately the plant dies. To control the disease, water logging should be avoided by providing proper drainage. Drenching with Bordeaux mixture (1%) may be done and affected plants should be mounded with soil to encourage new root formation. Among the Insect-Pests, fruit fly, thrips, mites are major. Suitable pesticides should be used to control these pests.

4. Avocado

Avocado is a native of tropical America. It originated in Mexico and Central America. In India, avocado is not a commercial fruit crop. It was introduced from Sri Lanka in the early part of the twentieth century. In a very limited scale and in a scattered way it is grown in Tamil Nadu, Kerala, Maharashtra, Karnataka in the south-central India and in the eastern Himalayan state of Sikkim.

In Kodagu, a avocado is grown as one of the mixed crops in coffee-based cropping system.

Avocados can be grown on a wide range of soils, but they are extremely sensitive to poor drainage and cannot withstand water-logging. The tree is in tolerant to saline conditions. Optimum range of pH is 5 to 7. Depending on the race and varieties, avocados can thrive and perform well in climatic conditions ranging from true tropical to warmer parts of the temperate zone. It can not tolerate the hot dry winds and frosts but it may be grown in tropical or semitropical areas with some rainfall in summer.

Avocado is the most nutritive among fruits and is regarded as the most important contribution of the New World to human diet. The pulp is rich in proteins (up to 4%) and fat (up to 30%), but low in carbohydrates. Avocado is mainly used fresh in sandwich filling or in salads. It can also be used in ice creams and milk shakes and the pulp may be preserved by freezing.

All three horticultural races i.e. West Indian, Guatemalan and Mexican of avocado have been tried in India. Mexican and Gautemalan races are grown successfully in humid mid hills of Himalaya. The cultivars of West Indian race are grown in localized pockets in Maharashtra, Tamil Nadu and Karnataka. Several varieties such as Purple, Green, Fuerte, Pollock, Peradeniya Purple Hybrid, Trapp, Round and Long are grown in India.

In India, avocado is commonly propagated through seeds. Seeds should be shown immediately after extraction from fruits. Seedlings are also used as rootstocks. T budding or cleft grafting has found successful for vegetative propagation of varieties and selected clones. Cleft grafting was found most successful during March and September under Chettalli conditions. Avocado plants multiplied from seeds start bearing five to six years after planting while grafted plants start bearing in 4-5 years. Avocado is planted at a distance of 6 to 12 metres depending on the vigour of variety and growth habit. Pits of 1 × 1 × 1 m are dug before the onset of monsoon and filled with farmyard manure and top soil (1:1 ratio) before planting. Planting is done in the month of June -July. Training is done to give a proper shape to the plants. Pruning of the dried branches of mature trees is needed. Heavy pruning has been found to promote excessive vegetative growth and reduces yield.

Irrigation at intervals of three to four weeks during the dry months is beneficial for growth and yield of avocado. To avoid moisture stress mulching with dry grass/dry leaves is desirable. Avocado is heavy feeder. In general, about 1.2 kg nitrogen, 0.8 kg phosphorus and 1.0 kg potassium per tree should applied from the 6th year onwards. Micro nutrient deficiency particularly iron is common. Basal or foliar application of micro nutrient is essential.

Avocado flowers twice in year in Coorg region. The fruits ripe in July - August and December-January. At maturity, fruits of purple varieties change their colour from purple to maroon, whereas fruits of green varieties become greenish-yellow. The yield ranges from about 100 to 500 fruits per tree. Fruits do not ripen on the tree and soften only after 5-10 days storage. Fruits need to be picked carefully. They should be harvested at the correct stage of maturity.

Among insect pests, scales, mealy bugs and mites are the important ones, and may be controlled by suitable insecticides. Root rot, fruit spot, anthracnose and stem-end rot and scab are main diseases of avocado. Root rot which is caused by *Phytophthora cinnamon* is most serious disease of avocado. This may be control by application of suitable fungicides such as metalyxil (2g/l).

5. Mangosteen (*Garcinia mangostana*)

Mangosteen is a broad-leaved, medium-size, ever-green tree. It is considered by many to be the most delicious fruit of the tropics with a universal appeal and considered 'the finest fruit of the world' or 'queen of fruits'. Mangosteen cultivation is popular in Indonesia, Philippines, Burma, Sri Lanka and Malaysia. The tree was introduced more than a century ago in India but currently it is successfully grown only in selected places on slopes of The Nilgiris& Kanyakumari (Tamil Nadu), Waynad&Kozhiokde, (Kerala) and Kodagu (Karnataka). The mature tree reaches a height of 10 to 15m with a dense pyramidal crown and glossy bright leaves. Mangosteen fruit resembles small-sized orange with a smooth reddish purple cortex (rind) which is about 0.6 cm in thickness. Inside the fruit, 4–6 segments are found but only 1–2 of them contain seeds. The pulp is white, soft and juicy that it almost melts in mouth with an indescribably sweet and pleasant flavour.

Mangosteen requires humid tropics with 180–250 cm rainfall. It is found growing in an altitude of 400–900 m in south India. Generally, frost-free regions with equatorial climate that lie at the foothills are suitable for cultivation. Elite mangosteen varieties are unknown, though the fruit has been cultivated for centuries. The occurrence of natural variability is also limited by the fact that 'seeds' are of asexual origin; they are formed from the nucellar tissue in the parthenocarpic fruit. Mangosteen maybe grouped in two types, one with large leaves and fruits of variable size and the other with small leaves and small fruits. In Philippines, a variety called Jolo produces fruits that are larger, with big seeds but more delicious pulp than the common cultivated type.

Mangosteen, aslow growing tree, is commonly propagated through seeds. Planting distances vary from 8 to 10 m between trees, depending on soil fertility. Pits of 1 × 1 × 1 m are dug before onset of monsoon and filled with farmyard manure and top soil (1:1 ratio) before planting. Planting is done in month of June -July. Training is done to give proper shape to the plants. Pruning is done to thin out andfor the removal of dried branches in themature trees. Mangosteen requires good soil moisture and higher humidity for better growth and yield. Regular irrigation is required in dry season to sustain the growth of the plants. Mulching is recommended to avoid moisture stress. Much works has not been done of the nutriment demand of

mangosteen. But adequate amount of farmyard manures should be applied. The fruits ripe in July - August under Coorg conditions. The fruits are sold in market immediately after harvesting.

6. *Garcinia indica* (Kokum)

Kokum (*Garcinia indica*) is originated in the Western Ghats. It is found growing naturally in Konkan (Maharashtra), Goa, Western Ghats region of Karnataka and Waynad area of Kerala. A product, Kokum, is prepared from this species by drying the outer rind and used to garnish curries and for preparing cooling syrup (Amrit kokum). Besides kokum, nector, juice, squash are also prepared from rind. 'Kokum butter' is obtained from the seed, used in soap and candle manufacture and suitable for ointment (used for local application to ulceration, fissure of lips, chopped hands and feet etc.), cosmetics and other pharmaceutical preparation.

Kokum requires high rainfall and moderate climate for optimum growth and fruiting. It is hardy tree and can be grown on a wide range of soils, with pH of 5 to 7.In India, kokum is gaining popularly in part of Maharashtra and Karnataka. Some high yielding varieties are developed by Konkan Krishi Vidya Peeth, Dapoli (Maharashtra). Few high yielding lines have been identified at CHES, Chettalli, also.

Kokum is generally propagated by seeds. Recently cleft grafting has been found successful in kokum. Kokum is a slow growing tree, planting may be done at 6 to 10 m distance. In most of the orchards in Karnataka, it is planted at the border of plantations. Pits of 1 × 1 × 1 m are dug before onset of monsoon and filled with farmyard manure and top soil (1:1 ratio) before planting. Planting is done in month of June -July. The fruit ripe during May to June. A high yielding mature tree may yield 500 to 700 fruits. Fruits are harvested manually when the outer skin tuned red and used for preparing juice.

7. Malabar tamarind (*Garcinia gummigatta*)

It is also known as *Kodumpuli* or Cambogia. A small or medium sized tree found in Western Ghats, fruit rind of which is used as spice in curries and an anti obese drink .The rind of ripe fruits are processed and used as a condiment in fish and prawn preparation to impart flavour. Seed contain edible fat and used as garcinia butter. The tree require high rainfall and moderate climate for optimum growth and fruiting. It is hardy tree and can be grown on a wide range of soils.

It is generally propagated by seeds and of slow growing nature, planting may be done at 6 to 10 m distance. There are no commercial plantation of the spice in Karnataka. Trees are planted at the border of plantation. Pits of 1 × 1 × 1 m are dug before onset of monsoon and filled with farmyard manure and top soil (1:1 ratio) before planting. Planting is done in month of June -July. Fruits ripe during July-August. A high yielding mature tree may yield 500 to 700 fruit. Fruits are harvested manually when the outer skin tuned yellow. Fruit are used for preparing veneer and rind is dried.

One high yielding line has been identified at CHES, Chettalli.

8. Karonda (*Carissa carandas)*

Karonda is a medium-sized, wild, thorny shrub of family Apocynaceae. It is a very hardy, drought tolerant plant that thrives well in a wide range of soils and grows naturally at elevation of 300 to 1800 meters in the Western Ghats and several parts of our country. It is grown on a limited scale in Rajasthan, Gujarat, Bihar and Uttar Pradesh.The tree flourishes well in hot and dry climate. Karonda fruit is a rich source of iron and contains a fair amount of Vitamin C. It is antiscorbutic and very useful for the cure of anaemia. Mature fruit are used for making pickle, jam, squash, syrup and chutney

Recently CHES Chettalli has identified two promising lines namely CHES K-II-7 and CHE K-35 which can be used as table purpose. The fruits of these lines are comparatively bigger in size (12-15 g), dark red in colour and with high TSS.

The plant is propagated through seed. Cuttings can be practised for vegetative propagation of selected promising clone. Planting can be done as hedge on the border of orchard at 60 cm to 1m distance. Commercial planting of selected big fruit size clones may be done at 3 × 3 m distance. Pits of 60 × 60 cm should be dug in May-June andplanting in the month of July. The plants start bearing in two-three years after planting. Regular pruning is required to control the size of plants in high rainfall conditions of Kodagu. Pruning is generally done in the month of October. The fruits of karonda mature in the month of April –May in Kodagu. Fruit are harvested manually. All fruits do not mature at one time Thus harvesting is done three - four times at regular intervals. A mature tree may yield 1000 -3000 fruit.

9. Jamun *(Syzygium cumini)*

Jamun is a tall and evergreen indigenous to India.Jamun fruits are a good source of iron and are said to be useful for heart and liver problems. The seeds of jamun are also an effective medicine against diabetes.

Jamun is a hardy tree and it can be grown under adverse soil and climate conditions and thrives well under both tropical and subtropical climate but requires dry weather at the time of flowering and fruit setting. Early rains are beneficial for better growth, development and ripening of fruit. Young plants are susceptible to frost. Jamun trees can be grown on a wide range of soils-calcareous, saline sodic soils and marshy areas. Deep loam and well-drained soils are the most ideal.

Several promising lines of jamun have been identified on the basis of colour, size and seedlessness. Jamun is propagated both by seeds as well as by vegetative method. Patch budding and forkert budding were found most successful for vegetative propagation. Patch and forkert budding in the month of March give more than 70% success. In low rainfall area, July –August is ideal time for budding. Planting should be done in pits of 1m x 1m x 1m size , dug 10 m apart for seedling trees and 8m apart for budded plants. Seedling trees start bearing at the age of 9-10 years, whereas budded ones take 5-6years. Fruits ripen during June- July or with the onset of rains. It takes about 3-5 months to ripen after full bloom. Fruits change their colour from green to deep red or bluish black at maturity. Fully ripe fruits are harvested daily by hand picking or by shaking the branches. Jamun trees need a number of pickings, since all fruits do not ripen at a time. The average yield of fully grown budded tree may yield 60 –every year. Jamun fruits are highly perishable. They can be stored only up to 2 days at ambient temperature. Precooled fruits packed in perforated polythene bags can be stored for 3 weeks at 8-10 C and 85-95% humidity.

10. Pummelo *(Citrus grandis)*

Pummelo has the largest fruit among citrus fruits. In India this is grown on a limited scale, in few parts of Karnataka, near Kanya Kumari region of Tamil Nadu and lower hills of Uttarakhand and Himachal and parts of Bihar. There is no commercial variety of this fruit in our country. Several local lines are grown in different region. These are Red Flesh, white flesh, Devanahalli, Kanapara, Triumph, Royal etc. Several promising lines of pummelo have been identified on the basis size, colour and less number of seed by several institutes. Pummelo performs well in subtropical climate. The trees grow in almost any soil that is well drained, sufficiently aerated. Traditionally pummelo is propagated by seed but it is also propagated by budding. Rangpur lime and Cleopatra Mandarin may used for rootstock for pummelo**.**

Pummelo is planted at 6 x 6 m distance. Pit of 1x1x1 m size should be dug 2 to 4 week ahead of planting in May-June. Pits should be filled with a mixture farmyard manure and soil. Planting is done in the month of June –July. Regular fertilizer is required for better growth and yield of pummelo. Recommended doses for Coorg mandarin (25 kg farm yard manure along, 5 kg neem cake and 600g N, 200g P_2O_5 and 400g K_2O per plant per year) maybe used for pummelo under Coorg condition. The fruits mature in month of December – January. A tree may yield 100-300 kg per year.

11. Soar sop (*Annona muricata* L)

Soap sop is a native of South America belonging to the family Annonaceae. It is found both wild and cultivated throughout the West Indies and from southern Mexico to Peru and Argentina up to an altitude of 1100 m msl. It is grown mostly in tropical region of the world from South America to Australia, Asia and Africa. In India, the exact detail of the introduction of this plant is not known. Presently it is found growing in the tropical humid part of Karnataka, Tamil Nadu and Kerala.

Sour sop is an evergreen, slender, low branching and bushy tree. The tree is grown primarily at altitudes lower than 900 m at temperature ranging from 21 to 30ºC. Sour sop can be grown on many soil types but sandy to sandy loam soils of medium texture are most suitable. The fruit is ovoid or ellipsoid and usually irregularly shaped weighing 500g to 1.5 kg. The skin is dark green, pulp and has an agreeable sub-acid taste with a distinct flavour. Fruits are harvested when fully mature and turned yellowish green. The ripe fruit are usually consumed fresh as a dessert or snack item.Pulp is an excellent source of vitamins B and C, potassium, riboflavin and niacin. Fruit pulp is thick and requires dilution before use as juice or squash. The fruit also makes excellent preserve, jam or jelly. Sour sop has some medicinal uses and now it is believed to be a potent anticancer agent.

Studies done at CHES Chettalli revealed that the fruit contains 62 to 85 % pulp, 25 to 30% skin and 2 to 3% seed on weight basis. Efforts are also going on at CHES, Chettalli to find out, promising line having higher yield, medium sized fruits (600-1000g), less acidic taste and fiber less pulp from the seedling population available in Coorg and adjoining areas.

Sour sop is usually propagated by seed. Seeds should be planted as soon as possible after removal from the fruit for better germination. Propagation by cuttings or air layering is not very common. Selected types can be multilplied by cuttings, grafting or by shield-budding. A spacing of 4 to 6 meters distance is recommended depending on the climate and soil type. Pits of 60 × 60 × 60 cm size are dug and filled with a mixture containing three parts of top soil and one part of compost. Planting is done during June-July after the onset of monsoon. The tree can be trained to a mushroom shape by topping at 2.0–2.5 m height. Little pruning is required after training of trees. In Coorg condition it flowers through out the year with two main flowering peaks in April- May and October- November. As far as fertilizer does is concerned, 40g nitrogen and 60g potassium should be applied to one year old plant. 180 g Nitrogen, 120 g phosphorus and 180 g potassium is recommended for a tree from fourth year and onwards. Water stress should be avoided during flowering fruit set and fruit development as fruit are more sensitive than leaves. If there is no rainfall during the dry months, supplementary irrigation may be given at fortnightly intervals.

Anthracnose, black canker and diplodia rot, leaf scorch, leaf spot are main diseases of soar soap. No major pests have been found infecting sour sop in Coorg conditions but mealy bugs and fruit fly incidence are noticed. The fruit is picked when full grown and still firm but slightly yellow-green. The usual yield is 12 to 24 fruits per tree per year.

12. Amla (*Emblica officinalis*)

Amla or Indian gooseberry is an indigenous fruit of India. This fruit is hardy and suitable to even waste-lands. The tree is small to medium sized, reaching 8 to 18 m in height, with a crooked trunk and spreading branches. The fruits are used for pickles and murabba (preserve) besides in traditional medicne. Fruits contain high amounts of ascorbic acid (vitamin C- 445 mg/100g) and have antioxidant properties.The main varieties of amla are Banarasi, Francis Chakaiya, Kanchan, Krishna,NA 6, N-10 etc. Amla is raised through seeds and vegetative methods (budding and grafting). The plants raised from seed have prolonged juvenility and wide variability. Vegetable propagation of amla is done by patch/modified ring budding and veneer grafting. Planting is done at6–10m apart during July–August. Established amla orchards in general do not require irrigation particularly in normal soils. A budded/grafted amla tree starts bearing third year onwards after planting, whereas a seedling tree may take 6–8 years. An amla tree may bear 100–300 kg/tree, giving 15–20 tonnes/ha.

13. Pulasan (*Nephelium mutabile* Blume)

Pulasan originated in South East Asia, is a tropical fruit closely related to rambutan but sweeter than the rambutan and litchi. Pulasan is orthodox tropical fruit and thrives only in very humid regions at an altitude of 110-350 m above msl. In India, pulasan plants are grown in kitchen gardens in some parts of Karnataka and Kerala.The name *pulasan* comes from the Malay word *pulas* (twist). The tree attains a height of 10-15 m and has a short trunk to 30-40 cm thick. The fruit is ovoid, 5-7.5 cm long, dark red, short blunt-tipped 1-2 cm long spines. The aril is white or yellowish white and clinging to greyish-brown seed. These are eaten fresh. Fruits mostly have dark red skin, but a rich diversity in skin colour such as yellowish green, yellow, and purplish red is found. The fruit is ovoid, oblong or ellipsoid, light brown and 2 to 3.5 cm long. A long dry season is required for the induction of flowering. The trees are susceptible to cold.

There is little information on the soil requirements of the pulasan but good soil moisture is essential. Fertile soil with good water holding capacity is required for higher yield and superior quality fruits. Two forms of pulasan, one having dark red fruits with crowded tubercles, very sweet and juicy flesh and other having small light-red fruits with sparse tubercles and clings stone are there. In India, only seedlings are grown.Plants produced from seed s can be either male or female and they may notbe true to type. Various grafting and air layering have been tried for propagation of pulasan. But as in the case of rambutan, air-layers are very short-lived. Budding is successful if it is done in the rainy season.The trees require less space than rambutan trees and can be planted at 8 to 10 m apart each way. As a rule, they receive little or no fertilizer or other cultural attention. The yield is similar to rambutan.

14. Longan (*Dimocarpus longan* Lour.)

Longan is a highly esteemed fruit species in Asia grown in Thailand, China and Vietnam. Longan is evergreen tree which can grow up to 20 m. The tree grows well in the tropics but requires a short winter season for satisfactory flowering. However, longan is sensitive to frost and is likely to be killed or badly injured by prolonged low temperature. Fruits are fleshy, very sweet, translucent with a white aril which surrounds a red brown to black seed from which it separates easily. Fruit can be eaten fresh, frozen, canned or dried. There are many cultivars of Longan cultivated in China, Thailand and other south Asian countries. In India longan is found in some of the backyards in south India. There is no recognized variety of Longan in India.

The best temperatures for flowering and fruit set are 20–25°C. Sufficient soil moisture is needed from fruit set until maturity. Suitable annual precipitation is about 1,500 mm. Drought and excessive rainfall adversely affects the growth and yield. Heavy, fine textured red loamy soils with high fertility and good water holding capacity are preferred soils for longan cultivation. Longan can be propagated from seed, air-layering, budding, grafting, cutting and inarching. Among the vegetative propagation methods, air layering is the most popular method and has been widely used for a long time. This is usually carried out during rainy season. Beside air layering it can also be propagated by whip-and-tongue grafting. Trees should be planted at the beginning of the rainy season. Planting distance ranges from 6 × 6 m to 12 × 12 m depending upon the varieties and the soil conditions. Longan takes about 5 months from blooming to harvest. The fruits are non-climacteric and have to be harvested when ripe. Maturity is determined by fruit shape, skin colour and taste. Longan fruit has a short shelf-life. Under ambient temperature (25°-31°C) harvested longan fruit rind turns brown within 3-4 days. Longan fruits can be processed into canned longan, dried longan nuts, longan nectar and frozen longan.

Apart from these, there are many indigenous and exotic fruits which may be grown successfully in Kodagu and adjoining districts. Among them dragon fruit, durian, litchi, macadamia nut etc are important. These fruits are rich in many vitamins, mineral, antioxidants and have nutritional and medicinal properties.

Post harvest management of horticultural crops especially banana and fruits of Kodagu

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1. Introduction

Post harvest technology including value addition is a key component in horticultural industry. Harvesting the fruits at appropriate maturity, sorting, grading, packing and preparation for market are important aspect to be looked into in Post harvest management of fruits and vegetables. On farm preparation of produce for market like trimming, sorting, grading and bulk packaging in packages can add value to the produce besides avoiding transportation of unwanted residue and waste into market. Post harvest ripening of tropical fruits like mango, banana, papaya and sapota is an essential operation to get a produce of uniform taste and quality. Present method of ripening of fruits with calcium carbide is illegal and banned. Fruits ripened with ethylene, though takes slightly longer time for ripening, the quality and shelf life is better when compared to any other method of ripening.

Storage of fruits needs specific conditions of packing, temperature and humidity. Farm storage structures like evaporative cool chambers can extend the life of fruits for 5-15 days. Long term storage and export trade needs cold stores or controlled atmosphere conditions to retain the quality close harvest freshness. Shrink wrapping coupled with low temperature can give better results with lesser cost involvement for storage fruits and vegetables.

For highly perishable produce like litchi, processing can be a best option to make available the product for longer time. Processing can also add value to the produce by making it stable and creating variation in its form. In most of the developed countries and some developing countries like Thailand, Philippines and Malaysia the level of processing in fruits and vegetables is 60-70% while in India it is 2.2%. With changes in priorities and policies of government it is expected to reach 15% by 2015. The improved methods of post harvest handling, packaging, storage and value added products of fruit crops mainly grown in Kodagu area is elucidated below.

2. Banana

Bananas have to be harvested at appropriate maturity depending upon the market destination. Based on the variety it takes from 90 to 120 days after shooting to mature. Some varieties like Yelakki Bale have longer yellow life while varieties like Robusta and Grand Naine have shorter yellow life. In order to maintain a longer green life for catering to distant markets, banana fruits have to be harvested at 75 to 80 per cent maturity. While for local markets it can be harvested at 90 to 100 per cent maturity.

Several signs are used as maturity indices like specific gravity, pulp to peel ratio, total soluble solids, solids to acid ratio, starch content, and even instrumentally measured skin colour and fruit firmness. These methods are difficult to follow practically by farmers and are destructive methods of determining maturity. Farmers mostly follow ingeniously developed methods based on their experience. Some of the practically adopted methods of judging maturity in most part of the world are easy separation of flower ends, age in days after shoot emergence using colored ribbons, angularity of the fruit and caliper grade.

a) Harvesting and field handling

The size of peduncle retained on the bunch varies depending on the size of the bunch. In some cases the harvested bunches are carefully placed on 10-12 cm thick bed of banana leaves on ground, to allow the latex to flow from the cut ends. After latex flow ceased they are to be carried to the packing shed one or two at a time on a prototype of medical stretchers 150 cm long and 75 cm wide, made of thick smooth cloth or in a basket on head. For weighing the bunches, a heavy string is tied to the stalk near the distal end and is weighed on a spring balance in field.

Dehanding of bananas is done by cutting off the hands from bunch stem. In order to avoid crown rot and finger drop it is essential to cut the hands with crescent like pad of tissue, which attaches the hand to main stem. Care has to be taken not to inflict slightest knife wound on the fruits or stalk of banana. The hands may further be cut into required number of fingers based on the size and shape of the packaging cartons. The cut hands or fingers are to be placed on the banana leaves or rexin sheets on tables or ground in such a manner that the tips of the fingers and cut end portion of the hand rest directly on the floor or table. The latex from the cut end should not be allowed to drop or stain the fruits. The delatexing can be done physically by allowing the latex to ooze out or it can be floated in a tank containing detergent or sodium hydro chlorate solution where the latex gets washed out. In India for domestic market, dehanding is practiced mostly Cavendish variety only. However, for export trade dehanding is essential during which defective, damaged and under developed hands are culled out. Selected bigger hands are then washed in tanks containing 10 ppm chlorine and treated with 500 ppm benomyl solution for 5-10 minutes as preventive measure against crown rot and anthracnose during transport and storage. After washing and fungicidal treatment the hands are dried under the blast of air from pedestal fans or blowers. Care should be taken not to leave any droplets of water on the surface or in between fruits.

b) Packaging

In the modern systems of handling and transport, quality control and good container design, have made carton packing feasible. First the hands are graded for size and quality and then packed in layers in special ventilated cartons with plastic (PUF) padding to minimize bruising. In Indian banana marketing system the concept of packaging is yet to be practically adopted. A major quantum of bananas is traded either naked or just wrapped with banana leaves. No systematic grading and packaging is followed in bananas while it plays a very important role in marketing of the produce. As the consumer preference and buying behaviour is towards a standardized and fresh looking produce, appropriate packaging can lead to high price realization. The CFB box is a carton of two-piece telescopic type made of virgin, 5 ply corrugated fibreboard with the dimensions of 65 × 30 × 25 cm. Each carton is provided with ~6% ventilation holes equally distributed on all four sides and side grooves for easy lifting of the carton. The banana hands are packed into the cartons in a lengthwise fashion with their cushion resting on the bottom of the carton and fingertips of the fruits pointing towards the lower side. The cartons are packed with 6 to 7 hands (Cavendish variety), without any bruise. Between each layer of fruits a polyurethane foam sheet is provided as cushion, which avoids rubbing of hands against each other.

c) Pre-cooling

Rapid cooling after harvest is generally referred to as pre-cooling and particularly benefits rapidly respiring fruits like banana. Pre-cooling is essential as refrigerated ships, land vehicles and containers are not designed to handle the full load of field heat but are designed to merely maintain pre-cooled produce at the selected carriage temperature. Out of various methods of pre-cooling air cooling is widely practiced in banana. Banana after packaging in carton should be pre-cooled in pre-cooling chambers till the core temperature of banana attained the storage temperature (13-14^{o}C). Care should be taken to ensure that pre-

cooling should be done gradually for a period of 4-6 hours to avoid internal damage of the tissue. Pre-cooling or storage below 13°C predisposes the banana fruit to chilling injury.

d) Storage

Storage life of banana can be extended by packaging in sealed polyethylene bags with ethylene absorbent. The objective of using polyethylene bags is to maintain high humidity and create a modified atmosphere around the produce in the package. Though banana release a remarkable level of ethylene, inclusion of an ethylene-absorbing compound such as potassium permanganate on an inert carrier in the package can reduce accumulation of ethylene considerably. Harvesting of bunches at 75-80% maturity, storage at reduced temperatures, modified atmosphere storage, packaging in film bags of 400 gauge thickness to create package modified atmosphere and pre-treatments with fungicides and chemicals are highly useful for extending the storage life of bananas up to 2-3 months.

Studies were conducted to determine the suitable thickness of films used to extend the shelf life of banana revealed that physiological loss in weight (PLW) was least for fruits packed in 300 or 400 gauge, non-perforated polyethylene packs and fruits remained in marketable condition up to 90 days after harvest when stored at 13.5°C. These fruits ripen normally with ethylene treatment following storage. Storage in, on-farm storage structures like evaporative cool chambers have found to extend the shelf life up to 10-12 days. Cool chamber storage significantly slowed down the rate of increase in PLW and decrease in firmness of banana Cv. Dwarf Cavendish fruits compared with rapid changes in fruits stored in ambient conditions. Storage of banana bunches in sealed polyethylene tubes and storage at 13°C have been reported to increase the shelf life 2- to 3-folds over control.

e) Ripening

Like most tropical climacteric fruit banana shows a pronounced increase in respiration that is coincident with ripening. Ripening in plantains is usually accompanied by complex biochemical and physiological changes in colour, flavour and textural parameters. Textural changes of bananas and plantains showed that when fruits were treated with ethylene 100 ppm for 24 hours and then stored at different temperatures had reduced levels of textural profile analysis parameters as compared to untreated control. Ethylene spray or dipping at 500 ppm was found equally effective in inducing the ripening of banana cv. Champa. In respect of storage conditions, the results clearly showed that banana treated with ethylene when stored under conditions with adequate oxygen availability registered better colour development and required softness.

Ripening temperatures are very important for proper colour and flavour development. Unripe bananas treated with 10-ppm ethylene gas for 1 hour and stored at 28°C showed the characteristic climacteric peak after 6 days and ripened normally after 8-9 days. Commercially viable and legally accepted method of ripening banana is by exposing the fruits to 400-600 ppm ethylene gas in an airtight chamber for a period ranging from 12-18 hours followed by ventilating the ripening chamber and maintaining the temperature at 18-20°C has resulted in proper colour development and quality attributes.. Further storage of ripened fruits at refrigerated super markets at 22-25°C can give a yellow life of 4-6 days. By adopting scientifically improved methods of post harvest handling of banana, the losses can be reduced, quality improved and farmers can get a better remunerative price for his produce. Of late, establishment of ripening chambers for bananas has become a profitable business venture, particularly where bananas are grown in large quantities.

Processing in banana is an area having high potential for commercialization with several value added products like chips, fig, powder, puree, pickles, juices and squashes, health drink, biscuits, fruit bar etc.

3. Mango

Mango exhibits an erratic ripening behaviour due to wide variation in the maturity of fruits on trees. Even selective harvested fruits do not ripen uniformly. Therefore artificial ripening is practiced commercially using calcium carbide which is prohibited. The safe method of ripening mangoes uniformly is by using ethylene gas @ 100 ppm. Alternatively etherel can also be used as a dip@ 500 ppm. Depending upon the variety and its market price, CFB boxes can be used for packing to reduce post harvest losses and maintaining the quality.

For export of mangoes which requires a storage life of 3 to 4 weeks either at low temperature storage or controlled atmosphere storage at the temperature above critical level is essential. Research at the Indian Institute of Horticultural Research (IIHR), has shown that mangoes stored with MA packaging at 8°C had a shelf life of 4-5 weeks with good post storage ripening quality. Harvesting of fruits with 8 to 10 cm peduncle and de-sapping prevents discolouration due to sap injury/ burn as well as stem end rot in mango.

Several value added products can be prepared from mango like beverages, pulp, canned slices, dehydrated products and pickles. Mango pulp is one of the largest export earners among the processed fruits.

4. Guava

Guava is the fourth most important crops grown in India. More than 70% of the fruits are consumed in fresh form while 10 to 15% is processed into beverages, canned fruits, and jelly. The skin of guava being very thin is susceptible to bruises and damage fast during handling and transportation. Harvesting of guava at optimum maturity with stalk and one or two leaves intact has maintained its quality better during transit marketing. Generally, packaging of guava is not widely practiced. However, wrapping the fruits in news paper and packing in CFB boxes with 5% ventilation has resulted in enhancing the shelf life and maintaining quality. In order to obtain uniform quality it is suggested to harvest the fruits at full mature stage. The maturity of fruits can be ascertained based on its specific gravity. Most of the varieties exhibit a specific gravity of less than 1.00 at full maturity. The shelf life of guava fruits can be extended upto two weeks with modified atmosphere packaging. Cold storage of guava at 5 to 8°C can extend life upto 3 weeks. The prominent processed products of guava are squash, RTS beverage, blended beverages, jelly and mixed jam.

5. Oranges and mandarins

Oranges and Mandarins are important fruits occupying large tracks of area in several parts of the country including Coorg. Coorg mandarin is famous for its distinct quality. To reduce the post harvest spoilage and maintain the quality oranges have to be packed in CFB boxes. Waxing improves the appearance and extends the shelf life of the fruit. Wrapping the fruits with special kind of shrink wrap films and packing in CFB boxes followed by storage at low temperature (7^{o}C) extended the storage life upto 60 days. Orange squash is the most widely marketed processed products besides, marmalade, and juice concentrate.

6. Sapota

Sapota is one of the widely cultivated fruit crop in tropics including Coorg. Harvest maturity is an important aspect for proper ripening and quality of sapota. After ripening it has a short shelf life of 2-3 days. Handling of fruits after ripening is extremely delicate as the impact damages make the fruit spoil fast and the quality deteriorates. It is suggested to pack the sapota fruits in CFB boxes with cushioning so that the losses are reduced and the quality is maintained. Normally artificial ripening of sapota is not practiced commercially. However, the ripening of fruits can be hastened using 50 ppm ethylene gas. The optimum temperature recommended for storage of sapota is 15^{o}C. The shelf life of sapota can be increased upto 12 days under ambient conditions by exposing the fruits to 500 ppb. 1-MCP for 18 h. Though, not many processed products

are sapota is available, good quality juice and wine can be prepared from sapota. Sapota can also be processed into flakes and powder through dehydration.

7. Papaya

Papaya is also one of the important crops grown in Coorg region. The appropriate stage of harvesting the papaya is two streak stage. Though no scientific packaging is adopted for papaya, commercially, paper wrapping or naked loading into the truck or tempos is followed. The losses due to bruises and impact damage during transportation leads to 5 to 10% losses which manifest during ripening of fruits. This can be controlled by either wrapping the fruits with foam net cushion or packing in CFB boxes or plastic crates. Proper packaging of papaya can reduce the losses and spoilage besides maintaining better firmness. The optimum temperature recommended for storage of papaya is 16-18^{o}C. Papaya pulp is one of the important processed products exported from India. Papaya is also used for other processed products like tuti-fruti, jam, and for blending with other beverages. Osmotically dehydrated papaya slices have better nutrition, energy and longer shelf life.

8. Passion fruit

Passion fruit is one of the fruits having great potential for cultivation in Coorg and South Canara. Improved methods of handling the fruits involve harvesting at proper maturity and packaging in CFB boxes. The ripened fruits are highly acidic but has enormous amount of vitamin A. Passion fruit juice and concentrated beverage are the potential value added products having very exotic taste and flavour.

9. Anonaceous fruits

Custard apple is a fruit delicate to handle after ripening but having excellent aroma and taste. Besides, being suitable for table purpose, it is also highly useful for making value added products like beverage and pulp. While beverage is useful in making an excellent drink, pulp is highly useful in the ice cream industry. Other important fruits having great potential for cultivation in Coorg are the following which have immense scope for converting into value added products besides serving as desert fruit (Table 1).

Table1. Potential fruit crops for Coorg

Sl. No.	Fruit	Uses
1.	Litchi	Eaten fresh, canned, processed into squash, wine etc.
2.	Pineapple	Eaten fresh, canned slices, juice, squash, jams etc.
3.	Avocado	Eaten fresh, frozen pulp used for sandwiching and spread in ice creams, juice and milk shake
4.	Jamun	Dessert, Jellies, jam, squash, wine
5.	Tamarind	Essential ingredient of Indian cuisine
6.	Karonda	Jam, jelly, vinegar, wine, candied product etc.
7.	Aonla	Murabba, candy, chips, jelly, pickles, powder etc.
8.	Mangosteen	Novel fruit, eaten fresh
9.	Carambola	Novel fruit, eaten fresh
10.	Kiwi fruit	Novel fruit, eaten fresh

Production technologies of ornamentals

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1. Introduction

The floriculture industry comprises of the cultivation and trade of cut flowers, potted plants, foliage bedding plants and dried flower under open field as well as under protected environment conditions. Other segments *viz*., fillers, seed and planting material, turf grass industries and value added products also contributes a share in the overall growth the floriculture sector. The traditional flower crops *viz.*, rose, marigold, tuberose, chrysanthemum, jasmine, china aster are grown for loose flowers under open field conditions and cut flower crops like rose, carnation, gerbera, chrysanthemum, orchids, lilium, Anthurium, etc. are grown under protected conditions.

India is one of the leading countries in floriculture with an area of 2.54 lakh ha producing 7507 million cut flowers and 16.52 lakh MTs of loose flowers during 2011–12 (Table 1). The major loose flower growing states are Andhra Pradesh, Tamil Nadu, Karnataka, Madhya Pradesh Gujarat, Maharashtra, Haryana, West Bengal, Himachal Pradesh, Chhattisgarh, Uttar Pradesh, Orissa, Sikkim etc. (Fig.1). The states like West Bengal, Karnataka Maharashtra, Andhra Pradesh, Orissa, Uttar Pradesh, Uttaranchal, Arunachal Pradesh, Himachal Pradesh, Jharkhand etc. have emerged as major cut flower growing states (Fig.2). North Eastern and other Himalayan states in the recent times have become major hubs for growing quality flowers. The Anthurium from Mizoram, the carnations from Himachal Pradesh, Orchids from Sikkim, gerbera from Uttrakhand have made a significant impact in recent times.

Table 1. Area and production of flower crops in India

Year	Area (in lakh ha)	Production	
		Loose (in lakh MT)	Cut (Million Nos.)
2006–07	1.44	8.80	3717
2007–08	1.66	8.68	4365
2008–09	1.67	9.87	4794
2009–10	1.83	10.21	6667
2010–11	1.91	10.31	6903
2011–12	2.54	16.52	7507

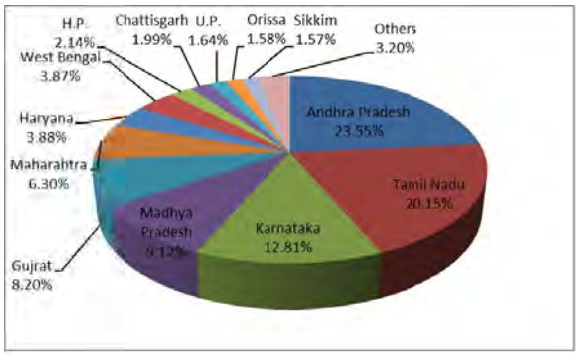

Fig. 1. Major loose flower producing states

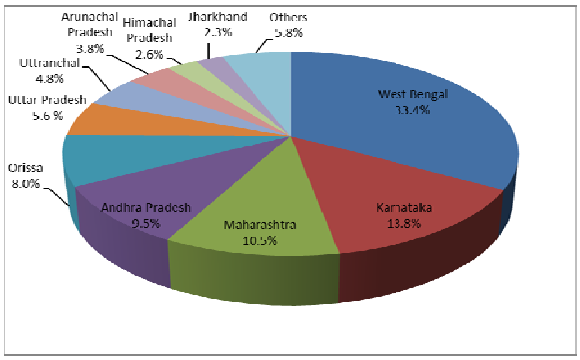

Fig. 2. Major cut flower producing states

Floriculture sector is generating higher income and employment opportunities, promoting greater involvement of women and enhancement of exports. India has now emerged as the second largest grower of flowers in the world. India is exporting flowers and flower products to different countries *viz*., United states, Germany, Netherland, United Kingdom, Japan, United Arab Emirates, Italy, Canada, Belgium, Ethiopia, etc. (Fig. 3).

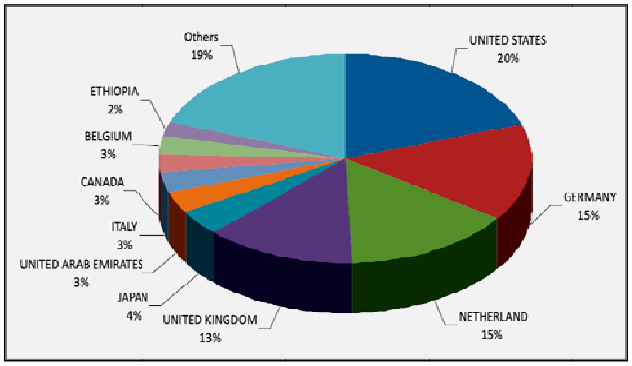

Fig. 3. Country-wise share of exports of flowers from India

2. Open field cultivation of flowers

The traditional flower cultivation, comprising of growing loose flowers mostly for worship, garland making and decorations forms the backbone of Indian floriculture, which is mostly in the hands of small and marginal farmers.

a) Rose

Climate: It requires 28-30°C during day and 15-18°C during night. Temperature less than 3°C may cause darkening of petal colour to black. Higher temperature (40°C) often fades the petal colour.

Varieties: Happiness, Gladiator, Arjun, Bhim, Raktagandha, Mrinalini, Raktima, Pusa Ajay, Pusa Arun, Pusa Shatabdi, Pusa Muskan, Pusa Pitambar, Mother Teresa.

Soil: Requires well drained sandy loams for best performance. It does not prefer black cotton soils with poor drainage and aeration.

Propagation: Propagated commercially through T or inverted T- budding.

Planting: Budded plants are planted at 40 × 45 cm during June in 30 cm deep pit filled with 3 kg FYM, Leaf mould and sand in 1:1:1 ratio.

Inter-culture: Requires periodical weeding and earthing up to remove the weeds and aerate the soil. Removal of shoots from the rootstock is essential to maintain the plant vigour.

Pruning: In North India conditions, pruning is done during October 2nd -3rd week whereas in places like Bangalore and Pune it is pruned twice during June and November.

Irrigation: Once in a week during winters and twice in a week during summer months.

Nutrition: Apply a mixture of urea, single superphosphate and potassium sulphate in the ratio of 1:3:2 at 50 g per plant or 10 kg per 100 sq. m. for three times i.e. first at pruning, second at the end of December when the first flush is over and third at the end of February when second flush of blooms is over. In foliar feeding, spray 3 gram mixture of urea, di hydrogen ammonium phosphate, potassium phosphate and potassium nitrate (2:1:1:1) along with 1.5 gm of teepol at 10 days interval until last flush in March.

Insect pests: Red scales-Can becontrolled by using 1.5 ml/l Monocrotophos; *Thrips* –Can becontrolled by using 1.5 ml/l Monocrotophos; *Red spider mite*-Can be controlled by using 1.0 ml/l Abamectin; *Chaffer beetle*-Spray 1.5 ml/l Monocrotophos

Disease: Die back –Can becontrolled by using 1.5 g/l Carbendazim; *Black spot* -Spray 1.0 g/l Chlorothalonil; *Powdery mildew*-Can be controlled by using 1.0 g/l Wettable sulphur

Harveting: Half open flowers are harvested so that they are fully open by the time they are in the retail market.

Yield: 1.25-1.50 lakh cut flowers/ha are produced when cv. Gladiator is planted and 6-7 tonnes of loose flowers are produced when other varieties are planted.

b) Gladiolus

Climate: Requires 15-20°C during day. Temperature less than 3°C may cause frost damage.

Varieties: Some of the important varieties are Spic and Span, Peter Pears, Priscilla, Pink Friendship, Rose Supreme, Friendship White, American Beauty, Mayur, Dhiraj, Pusa Suhagin, Urmil, Sindhur, Sapna, Shobha etc.

Soil: It can be grown in sandy soils to clay loam soils. Corm development is good in well drained light soils when compared to clay soils.

Propagation: It is commercially propagated through corms of 3-5 cm diameter. Cormels have to be grown for one season to get the suitable size corms for commercial flower production.

Planting: Plant corms at 30 × 20 cm or 30 cm to accommodate 1.5 to 1.80 lakh corms /ha. Plant the corms during October-November at a depth of 3-9 cm.

Earthing up: At 3rd and 6th leaf stage.

Irrigation: Once in ten days during winter months. During hot months it should be irrigated twice in a week.

Nutrition: N, P, K each @ 200 Kg/ha. Nitrogen may be applied in 3-4 split applications i.e. before planting, at 2-3 leaf stage, at spike emergence and after completion of flowering.

*Insect pests: Thrip*s- can be controlled by using 1.5 ml/l Monocrotophos; *Red spider mite*-Can becontrolled by using 1.0 ml/l Abamectin

Diseases: Fusarium wilt- dip corms in hot water at 52°C for 30 min. Corms dipping in Thiram isalso very effective.

Harvesting: When 2-5 florets showing colour

Yield (Flower): 2.5-3.0 lakh spikes/ha.

Yield (Corm): 200000-300000 corms/ha.

c) Tuberose

Climate: Requires 20-30°C during day. Temperatures less than 10°C reduce the spike length, weight and quality.

Varieties: Mexican Single/ Double, Suvasini, Vaibhav, Shringar, Prajawal, Hyderabad Single/ Double, Kolkata Single/ Double, Sikkim Single/ Double.

Soil: Loam and sandy loam soils are ideal for tuberose cultivation.

Propagation: Propagated through bulbs of 2-3 cm diameter. The mother bulb produces a number of daughter bulblets which need to be grown for one year to attain the flowering size bulbs.

Planting: In plains bulbs are planted in flat bed during March at 20 × 25 cm and April-May in hills.

Irrigation: Irrigated once in 8-15 days interval during winters and at weekly interval during summer.

Nutrition: FYM @ 3-4 t ha^{-1}; 100-250 kg N, 100-150 kg P_2O_5 and 75-100 kg K_2O per hectare.

Insect pests: *Aphids*-can becontrolled by using 1.5 ml/l Monocrotophos; *Thrips* –can becontrolled by using 1.5 ml/l Methyl O demeton

Diseases: *Stem rot* –can be controlled by using 1.0 g /l Carbendazim); *Botrytis blight* –can be controlled by using 1.5 g/l Tridemorph (Calixin)

Harvesting: 1-2 florets are fully open for cut flower purpose. Fully opened flowers for loose flowers.

Yield: 10-12 ton/ha (loose flowers) and 5-6 lakh cut flowers/ha.

d) Marigold

Climate: It can be grown ideally at 15-29 °C for good vegetative and subsequent flowering.

Varieties: Pusa Narangi Gainda, Pusa Basanti Gainda, Pusa Arpita.

Soil: Shallow soils are suitable for growing of marigold. Sandy loam soil with a pH range of 7.0 -7.5 having good aeration and drainage is ideal for growing marigolds.

Propagation: Widely propagated through seed. However ,vegetative propagation through softwood cuttings is also commercialized in India in recent times.

Planting: Seeds for summer season crop are sown in the second week of February, while for rainy season crop, sowing is done in the first week of June. Second week of September is the best time for sowing of the seeds for taking winter season crop. The seedlings are transplanted in the field after one month of seed sowing. The seedling should have 2-3 functional leaves prior to transplanting. A spacing 40 × 40 cm for African marigold and 30 × 30 cm for French marigold has been found to be optimum for commercial cultivation.

Building up of plants: The terminal portion of the plants should be pinched as and when they establish in the field. This will help in the axillary proliferation of the branches and would allow production of more side shoots. Such pinching of side shoots is recommended to make the branches denser.

Irrigation: During summer months, plants should be irrigated at an interval of 2-3 days. In rainy season crop is irrigated as per the atmospheric conditions whereas in winter crop needs watering at 8-10 days intervals depending upon the water requirements of the plants.

Nutrition: It requires 200 kg N and 80 kg P and K per hectare for good vegetative growth and flower yield. Full dose application of P and K is done at the time of land preparation. N in two split doses i.e. 1st at the time of land preparation and 2nd one month after transplanting.

Insect pests: Leaf miner –Spray Monocrotophos (1.5 ml/l) or Methyl O demeton or Phosphomidon (1.5 ml/l); *Red spider mite*-Spray Kelthane (2 ml/l) or 0.8 ml/l of Cascade or Vertimec; *Hairy caterpillar* -Spray Endosulfan or Quinalphos at 2 ml/l;*Leaf hopper*-Spraying with Malathion or Rogor (2 ml/l)

Diseases: Damping-off-Apply 1 g/l Copper oxychloride; *Collar rot* -Give 1 g/l Copper oxychloride; *Leaf spot and blight*-Spraying Carbendazim 1 g/l; *Powdery mildew* **-S**pray Calixin or Sulfex will minimize the disease infestation

Harvesting: The flowers are harvested when they are fully open

Flower yield: A yield of 20-22 tonnes of fresh flowers can be obtained from one hectare plantation in case of African marigold, while for French marigold it is 10-12 tonnes per hectare.

3. Protected cultivation of flowers

The cultivation of commercial cut flowers need special attention with regards to the management of the climate if grown out of the season at most otherwise a small care for management of the light, humidity and temperature can help to produce good quality flowers for both domestic as well as export market. The brief description of cultivation of popular flowers under protected environment is being given as under.

a) Rose

Varieties: First Red, Grandgala, Kiss, Prophyta, Nobles, Sonia, Lambada, Mercedes, Golden Time, Golden Gate, Frisco, Confetti, Vivaldi, etc.

Growing environment: Deep sandy loam having pH 6.0 -6.5 with 1.2 to 1.5 EC soils are suitable for cultivation. A temperature of 28/14°C, light of 6000-8000 ft candle, 1000-3000 ppm CO_2 and50-60% RH is required for rose growing in protected conditions. Environmentally controlled polyhouse, especially built for the off season cultivation by controlling the temperature, light, relative humidity and CO_2 as per rooting media are used for rose cultivation.

Planting: Two row systems of 30 cm a part with a width of path 60-100 cm is commercially used for planting in protected conditions. The bed should be ridged to the extent that the roots are aerated. Depending upon the types and varieties 7-14 plants/m^2 can be planted to cover the population of 70,000 to 1,40,000 plants per ha.

Fertigation:

Fertigation schedule	Dose (ppm)		
	N	P	K
Vegetative stage (September-October)	80	50	60
Flowering and harvesting flush (November-March)	100	60	80
Flowering and harvesting normal (April-August)	80	50	80

*Irrigation***:** Drip irrigation system (4-5 l/m^2/day) is used for irrigating plants. The ideal pH for irrigation water should be 5.0 - 5.5.

Pruning: Once a year during 2nd or 3 rd week of October. Periodical pruning of diseased, old and unproductive shoots is also practiced.

Desuckering: Removal of rootstock emerging from the base of plants is essential to keep the main plant vigorous.

Insect pests: Aphids-apply0.05% Monocrotophos or 0.03% Dimethoate at 15 days interval; *Spider mite* – spray 0.05% Dicofol or 0.03% Wettable sulfur or 0.5% Vertimac; *Red scale*-Give0.05% Monocrotophos; *Thrips*-0.05% Monocrotophos or 0.05% Methomyl; *Bud Borer* -0.01% Fenvalrate

Diseases: Die Back -Aapply Bordeaux mixture, avoid digger wasp damage; *Powdery mildew* -Dusting with Sulfur dust at 10 days interval or spray 0.05% Bayleton or 0.05% Bavistin; *Downy Mildew* -Spray Copper Oxy Chloride and Mancozeb @ 0.25%; *Rust* -Zineb @ 0.02% at 15 days interval.

Harvesting: When bud starts showing the colour and sepals are fully reflexed the buds are harvested and the cut ends are placed in water to ensure the continuity of the conducting vessels.

Yield: 100-200 flowers/m^2 to get 10,00,000-20,00,000 flowers per ha comprising of A,B,C grade flowers in a ratio of 50:40:10.

b) Chrysanthemum

Growing environment: Deep sandy loam having pH 6.2 -6.7 and 1 M wide beds which are 10-25 cm elevated above the ground are suitable for cultivation. A temperature of day 18-21°C and night 10-16°C, light intensity of 1.2-1.6 MJ/m^2/day, light quality of 600-800 nm, photo period of less than 9.5 hours, 500-1000 ppm CO_2 and 50-60% RH is required for plant growth in protected conditions. Support net ladders of 12.5 × 12.5 cm mesh are used to support plants in protected conditions. Pinching should be done 7-8 days after planting to produce the lateral stems.

Varieties:Standard: Bright Golden Anne, Thai Chin Queen, Tata Century, Poornima, Snow Ball, Sonar Bangla, Snow Don, Mountaineer, Pusa Centenary; *Spray*: Ajay, Flirt, Ratna, Discovery, Nanako, Kundan, Shyamal. Nilima, Ravi Kiran, Pusa Anmol; *Pot mums*: Sadbhavana, Liliput

Propagation: Terminal soft wood cuttings of 10-15 cm are used for propagation during May June.

Planting: Rooted cuttings are planted during June end at 12.5 × 12.5 cm spacing

Plant build up: The plants are pinched one month after planting to encourage branching. Repeated pinching is done so as to attain the required bush size. Disbudding is done to remove the unwanted flower buds and to encourage only few buds to attain bigger size.

Thinning: Standard: Single or sometime 2-3 stems are retained; *Spray*: 3-4 stems/plant are retained after 10-14 days of pinching.

Growth control: Alar 64% at the strength of 3 g/l in a volume of 50 liters is sprayed ten and twenty days after the beginning of the SD period to inhibit the growth.

Photoperiod: Yellow Regan: Long day – 13/11 h light/dark- vegetative growth; short day – 10/14 h of light/darkness- flowering

Staking: With the help of bamboo and nylon nets the plants are staked to prevent lodging of the branches and plants.

Disbudding: Standard Cultivars: Remove all the axillary buds and retain the terminal bud; Spray Cultivars: Remove the terminal/crown bud and encourage the growth of lateral buds

Desuckering: Remove the suckers developing from the base of plants to encourage the growth of the main plant.

Fertigation:

Vegetative stage (September-October)	80	50	60
Flowering and harvesting flush (November-April)	90	60	80
Maintenance dose (May-August)	50	30	50

Irrigation: Ideally irrigated through drip irrigation. Short impulses of irrigation are given twice during day time.

Insect pests: Aphids-Sray 0.05% Monocrotophos or 0.1% Metasystox; *Thrips* -Spray Monocrotophos 0.05% ; *Caterpillar*-Spray 0.05% Quinolphos ; *Leaf miner*-Spray 0.01% Nuvacron; *Nematodes*-Apply Furadon 3G@ 33 kg/ha

Diseases: Septoria leaf spot -Spraying Bavistin 0.1% ; *Rust and powdery mildew*- Spray Wettable sulfur 0.2%; *Stem rot-S*pray Benomyl 0.2%

Harvesting: Standard: When outer florets are fully elongate; Spray: When most of the florets are already opened

Yield: 80-200 stems/m^2

c) Gerbera

Growing environment: Light alkaline, sandy loam with high organic content and having pH 6.5 -7.5 and 1.4 EC are suitable for cultivation. A temperature of day 22-25°C and night 12-16°C are ideal for growth and productivity. These are highly sensitive to low temperature i.e. frost, strong sun, pest and diseases.

Varieties: Thallasa, Tara, Sunsett, Ornello, Diablo and Twiggy are grown near Pune and Bangalore.

Propagation: Gerbera are propagated through suckers and tissue culture. The plants raised through tissue culture are uniform and are well accepted by the farmers.

Planting: Planting is done on raised bed to 20 cm at the spacing of 30× 30 cm. If planting is done in November – December, then it gets sufficient time to develop to enter and pass winter. They produce good flowers in February and onward. They produce 10-12 plants/m^2 depending on the variety.

Irrigation: The water requirement per day is around 4.5-5.0 lts/m^2 which is split into three parts during the day time.

Fertigation:

Vegetative stage (September-October)	70	50	60
Flowering and harvesting flush (November-April)	80	60	80
Maintenance dose (May-August)	40	24	40

Insect pests: *White fly* -Spray Cypermethrin 0.1% or Dichlorvas 0.1%; *Leaf miner*-Spray Dimethoate 0.03%; *Aphids-S*pray 0.05% Monocrotophos or 0.1% Metasystox

Diseases: Foot end rot (Drenching soil with 0.2% Benomyl); Powdery mildew (spray 0.2% Wettable sulfur); Anthracnose (spray 0.1% Bavistin); Crown rot (spray Ridomil or Benomyl 0.3%)

Harvesting: When outer 2-3 rows of disc florets are perpendicular to stalk.

Yield: The gerbera has potential to yield 175-200 flowers/m^2 to produce as many as 17,50,000-20,00,000 flowers per hectare in a year comprising of A,B,C grade flowers in proportion of 60:30:10.

d) Anthurium

*Varieties: Red***:** Hawaiian Red, Ozaki, Cancan, Tropical, Fla Red, Avo Netta, Scarlet, Mauritius Red, Tanaka, Cherry Red, Honduras; *Orange*: Nitta, Sunset Orange, Sun Burst, Gino Orange, Avo Gino, Mauritius Orange; *White*: Acropolis, Manoa Mist, Trinidad, Lima White, Haga White; *Pink***:** Agnihotri, Passion, Candy Queen, Candy Stripe, Pink Hawaii, Abe Pink, Sonata; *Obaque*: Red Dragon, Fantasia, Madonna, Lambada, Senator; *Green*: Modori; *Miniature***:** Lady June

Growing environment: Commercial scale Anthurium cultivation can be taken up in low cost polyhouses, shade houses or climate controlled greenhouses. For a luxuriant growth, the cultivated Anthurium required 18.3ºC during night whereas a higher night temperature of 21.2 to 23.9ºC is essential for initiation of flowering. Night temperature should not fall below 18ºC. It cannot tolerate freezing temperature. Anthurium does not prefer temperature above 35ºC. It is basically a shade loving plant. During summer where the light intensity is more, plants are provided with 80 per cent shade. The optimum light intensity that suits is 20000 to 25000 lux. The optimum relative humidity levels range from 50 to 85 per cent. The relative humidity levels can be maintained by overhead sprinkling/misting/fogging or ground level sprinkling.

Growing media: It should be well aerated with good water retention, low salt concentration, provide good anchorage, optimum pH (5.0) and EC (0.6 m mhos/cm^2). Coco peat is the most popular medium for Anthurium cultivation.

Propagation: Propagation using stem cutting is the most common method.

Planting: Avoid planting during season with high temperature and rainfall. Plant is done in rows in cross wise pattern at optimum depth (15 cm). The optimum spacing for commercial cultivation is 45 × 45 cm, which accommodates 5 plants/ m^2 and 29640 plants/ha.

Irrigation: Anthurium requires generous watering and should be irrigated at least twice a day in summer months. Irrigation can be done by installing micro sprinklers at the plant level.

Nutrition: Anthuriums prefer smaller doses of fertilizers at frequent interval rather than larger doses in linger intervals. Anthuriums can also efficiently take up nutrients through foliage, Foliar application of 0.1 per cent urea at monthly intervals is beneficial. Adequate levels of calcium and magnesium are also necessary for optimum yield. Deficiency of calcium often results in colour break and application of 5 g of $CaCO_3$ at monthly interval stabilizes the spathe colour.

Insect pests: Mites –Spray Docofol (18.5 EC) 2.5 ml/l; *Thrip*s -Spray Oxydemeton methyl (25 EC) 2ml/l) or Dimethoate (30EC) 2ml/l; *White fly* -Spray Dichlorvos 1ml/l or Malathion (50EC) at 1ml/l check adult flies.

Diseases: Wilt: Use of bacterium free planting stock and strict phytosanitation; *Bacterial blight*: Use of disease free tissue cultured plants and strict phytosanitation. Spray thoroughly with streptomycin sulphate (200mg/l) on a weekly schedule for about 6 weeks and then discontinue the spraying; *Anthracnose*: Spray Mancozeb (0.25%) or Captan (0.25%) or Cerbendazim (0.1%)

Harvesting: Anthurium flowers are harvested when the spathe completely unfurls and the spadix is well developed. Development of true flowers on the spadix is also used as a criterion for harvesting the blooms.

e) Carnation

It is one of the most demanded cut flower in the world because of the availability of wide range of colours and excellent keeping quality

*Types and exotic varieties: Standard carnations***:** It produces large size bloom and has a longer stalk length e.g Corleone, Lipstick, design, Empire, Romana, Dark Tempo, White Tundra; *Spray carnations***:** It produces flowers in bunches which are relatively smaller in size e.g. Rony, Rhodos, Light Pink, Barbara, Bagatel, Silvery Pink, Natila etc.

Growing environment: Carnations prefers plenty of sunshine and a temperature regime of 20-25°C during the day ad 10-15°C at night. At the initial stages of flower development long days play an important role whereas the later stages of bud development are influenced by light intensities. The critical photoperiod for most sprays are standard a carnation is about 13 hours. The relative humidity of 50-60 per cent favours its growth and flower production.

Propagation: Carnations are propagated vegetatively through soft terminal stem cuttings. Terminal cuttings measuring 10-15 cm with four leaves are taken. For better rooting, the cuttings should be treated with IBA (500 mg/l). The basic rooting medium i.e. sand has been found satisfactory for rooting carnation.

Planting: Carnation needs optimum spacing of 20 × 15 cm which accommodates 30 plants/m^2 for better growth and flowering. Deep planting of cuttings should be avoided so as to reduce the incidence of stem rot or foot rot disease. After making a hole in the bed, the cuttings are planted as shallow as possible. The soil temperature should be in the range of 15°C for the first few weeks.

Irrigation: Rooted cuttings should be watered immediately after planting. Spraying of water through misting is more effective than the surface watering for ready establishment of the cuttings. After 3 weeks of planting, drip irrigation has to be adopted. The crop requires 4-5 l of water/m^2/day. Stagnation of water should be avoided to minimize the incidence of diseases.

Providing support nets: Before planting, 7.5 × 7.5 cm single layer of metallic or nylon netting is laid out at 12.0 cm above the soil. The plantings are done with the netting with required spacing. As the crop grows, add the layers of netting. Total 4-5 layers of nettings are necessary whose squares should be 12.5 × 12.5 cm or 15 × 15 cm over the first net. These nets are placed 15 cm apart. For every 2.5 to 3.0 m, the wires should be supported with poles.

Pinching: Pinching refers to breaking out tip of budding to encourage growth of side shoots which is very much essential for the standard or Sim carnations. Depending upon need of the crop spread, single pinch, one and half and double pinch are given.

Disbudding: In standard carnation, the lateral flower buds are removed at the appropriate time leaving only the main flower bud. But in spray carnation, the terminal or main flower buds are removed to encourage the lateral flower buds to develop. The best time for disbudding is when the apical flower bud is about 15 mm in diameter.

Deshooting: Removal of unwanted shoots in axils of leaves or flowering shoots when they are 2-3 cm long has to practiced to get higher production.

Fertigation:

Vegetative stage (September-October)	50	30	40
Flowering and harvesting flush (November-March)	60	40	60
Maintenance dose (April-August)	40	20	40

*Insect pests:*Thrips (spraying of Rogor 0.01%); Caterpillar/bud borer (spraying of Ripcord 0.1% or Quinalphos 05% at 15 days interval);Spider mite (spraying of 0.05% Dicofol or 0.03% Wettable sulfur or 0.05% Vertimac)
Diseases: Fusarium wilt: Drench soil with 0.15% Bavistin or spraying of spraying of Vertimac at 15 days interval; *Alternaria leaf spot*: Spraying of Captan @ 0.2% at 15 days interval; *Grey mould*: Reduce the humidity in the green house
Harvesting: The standard flowers should be harvested at a large bud (tight bud) stage or at cross bud (petals visible) stage. In spray carnations, harvesting should be done when atleast two flowers have opened and other buds are showing colour.

Yield: Average production is 10 flowers per plant i.e 250 flowers /m^2/year

f) Lilium

Climate: Grows best at 20-25 ºC during day and 7-10 ºC during night.
Media: Soil is the best growing medium. However it can also be grown in soilless media like cocopeat, rockwool, volcanic ash.

*Varieties:Asiatic hybrids***:** Connecticut King, Enchantment, Grand Paradiso, Jollanda, Pollyana, Salmon Beauty, Monte Rosa, Snow Star, Roma, Alaska, Prato; *Oriental hybrids***:** Casa Blanca, Everest, Mona Lisa, Marco Polo, Stargazer

Propagation: The liliums are propagated through bulbs. The bulblets take one year to attain flowering size bulbs. It is also propagated through tissue culture.

Planting: Plant pre-cooled bulbs in moist soil on 15 cm raised beds at spacing of 10 cm × 10 cm

Fertigation:

Vegetative stage (September-October)	60	36	60
Flowering and harvesting flush (November-March)	80	50	80
Maintenance dose (April-August)	50	30	50

Staking: The plants are succulent and require staking. Support the plants with wire net or nylon net from planting to harvest.

Insect pests: Thrips-Spraying Monocrotopnos 0.05%; *Aphids*-Spraying 0.05% Monocrotophos or 0.1% Metasystox; *Bulb mite*-Spray Wettable sulphur 1.0g/l

Diseases: *Grey mould*-Spray Calixin or Zineb 0.2%; *Foot rot* -Spray Copper oxy chloride 0.3%
Harvesting: The flowers are harvested when the bud shows colour

Yield: 250-300 flower/m^2

Production technologies of coffee for kodagu and measures to reduce post harvest losses

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1. Introduction

Kodagu district is the leading district for coffee production in India. As on 2012-13, coffee is cultivated in a total area of 104780 ha comprising 28053 ha of Arabica and 76727ha of robusta. The average annual production is about 1.19 lakh tones, comprising 21705 tonnes of Arabica and 97575 tonnes of robusta. The productivity of coffee is highest in the district with an average peoductivity of over 1500 kg/ha in case of robusta and about 1000 kg/ha in case of Arabica. Traditionally, kodagu is divided into North Kodagu and South Kodagu separated by the river Cauvery, which takes birth in the district. Robusta is predominantly cultivated in South Kodagu while Arabica in Notrth Kodagu.

Coffee cultivation is an integral part of the lives of the people of kodagu district and forms the backbone of the economy of the district. The average productivity of coffee in the district is highest among all the coffee regions in the country. This is mainly because of the highly favourable soils and agro-climatic conditions and the entrepreneurship of the growers in general. However, the productivity in majority of the smallholding is mush lower compared to that of medium and large holdings, which could be improved upon by adopting improved production technologies. Even in case of medium and large growers, there is a scope to increase the productivity levels by judicious management of resources and taking the advantage of favourable climatic conditions. Improving the productivity levels and following the measures for preventing the post harvest losses would be advantageous for bringing down the cost of production. Considering these facts production technologies and measures to reduce post harvest losses for both Arabica and robusta coffee are suggested in this paper.

2. Soil and climatic requirements

Soils

The coffee soils in Coorg belong to the red lateritic soil groups. They differ in texture from sandy loam to clayey loam with colour varying from light grey to deep red. The soils are usually rich in organic matter and acidic to neutral in reaction (pH). The total soluble salts are well below the sensitivity limits. They are well supplied with potassium but are generally low in available phosphorus. They are also poor in calcium and magnesium. They respond well to liming, manuring and other soil management practices.

For good growth of coffee, the soil should be deep (atleast 75cm), well drained, slightly acidic in reaction and rich in organic matter content. Red ferruginous clayey loams having good aggregating ability with good drainage are ideal. Most hilly and forest soils in South India will fulfill these requirements. However, other soils under favourable climatic conditions can also support economically viable crops under skillful management.

Climate

Geographic parameters like elevation, aspect and environmental factors like rainfall, temperature and atmospheric humidity can influence economic production of coffee much more than soil factors.
Soil and climatic requirements for Arabica and Robusta coffee under South Indian conditions are as follows:

Factor	Arabica	Robusta
1. Elevation	1000-1500m	500-1000m
2. Aspect	North, East and N-E aspects ideal	Same as for arabica
3. Soils	Deep, friable, rich in Organic matter, well drained and lightly acidic in reaction (6.0 to 6.5 pH)	Same as for Arabica
4. Slopes	Gentle to moderate slope is ideal	Gentle slopes to fairly level fields to be preferred
5. Temperature	15^0 to 25^0 C ideal-cool, equal	20^0 to 30^0 C ideal-hot, humid
6. Relative humidity	70-80%	80-90% (ideal)
7. Annual rainfall	1600-2500mm	1000-2000mm
8. Blossom showers (Timing & quantity)	March-April (25-40mm)	February-March (25-40mm)
9. Backing showers	April to May (50-75mm well distributed)	March-April (50- 75mm well distributed)
10. Shade	Medium (50%) shade depending on elevation and aspect	Uniform thin shade (30%)

The major climatic factors that adversely affect production of arabica and robusta coffee are:

Factor	Arabica	Robusta
1. Blossom showers	Absence of rain in March-April	Absence of rain in March
2. Backing showers	Delayed beyond one month after blossom rain-poor crop set	Delayed beyond 20-25 days after blossom rain-poor crop
3. Hail stones	Injury to the floral and vegetative parts	Same as for arabica
4. Rain on the day of blossom	Partial failure	Partial to complete failure
5. Severe western exposure (with poor soil moisture)	Partial to complete	Complete
6. Excessive wetness and water logging	Partial to complete	Partial to complete
7. Wind exposure	Sensitive	Sensitive

3. Nursery management

The success of new planting in perennial crops like coffee depends primarily on planting vigorous, disease frees seedlings in the field. So atmost attention is required for raising the desirable planting material in nursery.

Site for nursery

- A gentle sloping land without big shade trees having a water source nearby is preferred for nursery site.
- The soil should be light to medium loamy and free from soil borne pathogens like nematodes.
- The nursery site should be fenced off from cattle and other grazing animals and provided with overhead pendal for shade.

Germination beds

- For sowing the seeds, germination beds on one meter width and six meter length raised to a height of 15 cm from ground level are prepared, by incorporating 4 baskets (2 forlits) of well rotted cattle manure or compost, 2 Kg of finely sieved agricultural lime and 400 g of rock phosphate in each bed.
- The beds are spaced at 30-45 cm. apart and provided with gentle sloping between two beds for preventing water stagnation.
- If the nursery soils are heavy loams, it may be necessary to add coarse sand for facilitating drainage and aeration.

Sowing

- Seeds are sown during December or January with their flat side facing the soil, at a distance of 2.5-3.0 cm in regular rows.
- They are covered with a thin layer of finely sieved soil. After sowing, the beds are mulched with a layer of paddy straw which ensures optimum temperatures for seed germination and protects the seed form desiccation.
- The beds are watered daily in the morning hours with a rose can.
- Under optimum conditions seeds would germinate in about 45 days and attain button or topee stage. Remove paddy straw cover once germination is noticed.
- The seedlings at button or topee stage are then transplanted into either polybag nursery (basket) or secondary nursery beds.

Polybag (basket) nursery

- Preparations for the polybag (basket) nursery should be commenced will in advance to the transplanting time.
- Top fertile soil preferably from virgin forest lands is collected and dried thoroughly. Later the dry soil is sieved.
- A nursery mixture of six parts of sieved jungle soil, two parts of well rotted and sieved cattle manure or compost and one part of fine river sand is prepared for filling up nursery bags.
- Polybags of 22.5 x 15 cm size and 150 gauge thickness with adequate number of 3 mm holes (10-12/bag) at the bottom half are preferred.
- The prepared nursery mixture is moistened with water and firmly filled into nursery bags.
- These bags are arranged in rows of convenient width (10-12 bags/row) within rectangular frames of bamboo reapers. These frames are held in position with bamboo or wooden props driven firmly into the ground at suitable distance.

Transplanting

- Coffee seedlings at “button” stage are transplanted into nursery baskets. Seedlings are gently lifted by using a bamboo stick from the germinating beds with minimum injury to roots.
- Prior to transplanting, the nursery baskets are watered and a vertical hole about 5 cm deep is made in soil at the centre of the basket.
- Seedlings are planted in the hole after nipping off the tip of tap root by taking care that shoot system is placed at the same height above the soil as it was in the germination beds.
- Transplanting is done preferably in the cool hours of early morning or late afternoon.
- Seedlings uprooted from the primary bed should not be stored for a long time but transplanted immediately.

- It is preferred to dip the roots of seedlings in cow dung slurry or water to prevent desiccation.
- The basket plants are usually planted in main field during late monsoon (Aug-Sept.) and can withstand long distance transport.

Secondary nursery beds

- In some areas, seedlings at button stage are directly transplanted into raised secondary nursery beds.
- These beds are made of the same soil composition as that of germination beds.
- Seedlings are planted at 30 cm apart after slightly nipping off the tap root.
- The beds are mulched and watered regularly.
- Secondary nursery beds are preferred when ball plants are required for field planting in the next planting season.
- If the ball plants are to be transported over long distances, soil around the roots should be removed and the seedlings may be planted into polythene bags with a mixture of moss, humus and FYM.

Aftercare of seedlings

- The seedlings are to be watered daily in the early morning hours depending upon weather conditions.
- Provide overhead pendal shade till the commencement of regular monsoon.
- Seedlings are manured once in two months with urea dissolved in water or supernatant solution of fermented cow dung slurry.
- For every square meter area 20 g urea dissolved in 4.5 l of water would be sufficient.

Boosting of seedling growth

- In case of delayed sowing and transplanting, the seedlings may not attain desired growth by field planting time.
- Under such conditions the growth of seedlings can be boosted by spraying any one of the following growth regulators in combination with urea at least one month before field planting, or when the seedlings are at 4-5 pairs leaf stage. Planofix 50ml + Urea 1 Kg, Or Agronaa 50ml + Urea 1 Kg Or Cytozyme crop plus 60ml + Urea 1 Kg in 200 l of water

Prevention of nursery pest and diseases

Parasitic nematodes (*Pratylenchus coffeae*)

The nursery soil should be checked for parasitic nematodes. If nematodes are present the soil should be thoroughly dried under sun.

Cockchafers and earthworms

Sieving the dry soil before use in nursery eliminates these pests which affect the root system and anchorage.

Cutworms and grasshoppers

Weeds harbour cutworms and grasshoppers which feed on young seedlings. It is important to keep the nursery surroundings free from all weeds.

Damping off

Damping off of young seedlings occurs mostly in primary seed beds if seedlings are retained for longer periods than necessary. Providing proper drainage and timely transplanting help in overcoming the disease.

Cercospora

This disease infects tender leaves and can be prevented if the seedlings are protected against afternoon sun.

Tips for raising a healthy nursery

1. Collect seed only from authorized source – Research Department of Coffee Board.
2. Sow the seeds immediately after receipt, as any delay would lead to poor germination.
3. Provide overhead pendal shade before sowing the seed. Avoid deep sowing and excess watering.
4. Use thoroughly dried and sieved jungle soil to prevent nematodes, cockchafers, earthworms etc.
5. Transplant seedlings at button stage. Do not transplant deep.
6. Nursery bags should be punched sufficiently for proper drainage.
7. Avoid use of Bordeaux sprays and Lindane on nursery seedlings.
8. Do not apply urea directly on nursery seedlings. This might cause scorching.
9. Keep nursery clean and free from weeds, fallen leaves etc.
10. Follow timely protection measures against nursery pests and diseases.

4. Planting and aftercare

Choice of land

- In choosing the site for plantation, due consideration should be given to altitude, aspect, rainfall, exposure to wind and transport facilities.
- A potential source of water supply is and essential requirement. Soils rich in humus and with gentle slopes providing good drainage are to be preferred.

Altitude and Aspect

- Coffee comes up well at an altitude of 1000-1485m but the lower and upper limits of elevation for its cultivation could be 500m and 1600m respectively.
- Location with northern aspect or eastern aspect is preferred. Southern and western aspect generally suffer from longer exposure to the sun, especially at elevations below 900m.
- To protect against the afternoon sun, thicker shade should be given to these areas.

Exposure to wind

- Eastern winds in December-February cause injury to plants. To prevent this, wind belts consisting of tall trees like silver oak, orange or tree coffee should be raised.

Preparation of Land

- Clean felling is not advocated when the forest land is cleared for planting coffee.
- Selective retention of desired species of wild shade trees, without too much over-crowding gives best results.

- The land should be divided into blocks of convenient size with foot paths and roads laid out in between.

Soil conservation measures

- For satisfactory performance of coffee, it is essential to conserve the top fertile soil. The loss of top soil is negligible on estates under proper shade. The problem of soil erosion attains serious dimension on steep slopes without good overhead shade. Such fields should be protected with a lower canopy of Ficus sp. (Attis, Basris), Albizzia sp. and other quality shade trees.
- In areas which are steep, terracing and contour on 'Soil management" may also be adopted.

Line marking

- Within each designated block, the points for planting coffee seedlings are located by marking the distance between the rows and plants.
- Generally square system of planting was found to be ideal in flat to gently slope areas. In steep slopes itt is advisable to adopt contour planting.
- The distance between the rows and spacing of plants would depend upon the type of planting material.
- The following are the optimum spacing for different coffee species/varieties.
  Arabica – Tall-1.8 x 1.8m; 2.1 x 1.8 m; 2.1 x 2.1 m
  Dwarf-1.5 x 1.5m
  Robusta S.274; Old Robusta-3 x 3 m; 3.6 x 3.6 m
  C x R - 2.4 x 2.4m

Pits for planting

- Pits are usually opened after the first few summer showers during March/April.
- The size of pits is usually determined by the texture and depth of soil. Usually pits of size 45 x 45 x 45 cm LBH are preferred.
- After opening, the pits are to be exposed for weathering for 15-20 days.
- Later they are closed by filling with the surrounding top soil. Addition of compost or FYM @ 1-2Kg/pit along with 20-30g of Rock phosphate is recommended at the time of closing pits.

Planting in the field

- Disease free and vigorous seedlings are selected for planting in the field. Seedling with stunted and twisted roots are to be discarded.
- Generally, seedlings raised in secondary beds (age about 16-18 months) are planted at the commencement of monsoon (June) and polybag nursery seedlings (6-8 months old) are planted during August- September.
- At the time of planting, a hole is made in the centre of pit after leveling the soil and seedlings are planted in the hole in case of all plants, the polythene bag is cut at the bottom and tip of tap root plants (secondary nursery seedlings) the tap root and lateral roots are o be spread out in proper position before packing with soil.
- Care should be taken the soil around the seedling is packed slightly above the ground level (2.5cm) to prevent stagnation of water around collar region.
- Avoid planting deep. The seedlings are provided with cross- stakes to prevent wind damage and mulched with dry leaves.

Planting shade trees

- Dadap is commonly used as a lower canopy shade. One to two meter long stakes are planted for every two plants of coffee during June when rains of South-West monsoon commence.
- During dry season, stems of young dadap are either painted with dilute lime solution or wrapped in agave leaves to protect them from sun scorch.
- Silver oaks can be planted as shade belts in E-W direction to protect coffee from southern exposure at a spacing of 6m apart within a row and 12m between the two rows.
- The silver oak stand should be alternated with dadap rows. Silver oaks stands are best suited for training pepper vines also.
- Permanent shade trees are planted at wider spacing (9-12m), wherever the forest tree cover is inadequate.

Inter planting, replanting and under planting

- Robusta coffees are usually planted at wider spacing of 3-3.6m and the bushes take 6-7 years for maiden crop and 10-12 years for producing economic yields.
- Wider spacing within the row as well as between the rows could be profitably exploited by planting quick yielding varieties such as Cauvery, which comes to bearing by 3 years from planting. Because of its fast growth, Cauvery covers up the inter space thus minimizing the weed growth too.
- By inter planting Cauvery both within and between the robusta rows the plant population is substantially boosted. For eg. If Cauvery is planted at a spacing of 10 m in the robusta block planted at 3m spacing an additional population of 3230 Cauvery could be accommodated per hectare.
- Early yields from cauvery could be exploited with judicious nutrition and plant protection measures.
- Once the robusta bushes start covering up, the adjacent Cauvery plants can be systematically eliminated to pave way for spread of main crop i.e., robusta coffee.
- In areas identified for replanting, two approaches could be made.

  If the blocks are to be replanted with similar material, it is advisable to plant the young seedlings under the existing old blocks, in separate rows laid in between the old rows. The old bushes can be rejuvenated by collar pruning after one or two seasons of under planting, and can be exploited on, multiple stems for few more seasons, before the newly planted bushes, start covering up the allocated space.

  If the old blocks are to be replanted with different variety whose spacing requirements are different from that of the old material, it is advisable to totally uproot the old stands and take up replanting in newly laid out lines. When the entire block is uprooted for replanting, manipulations in shade pattern are possible depending upon the requirement of the new variety being planted.

Aftercare

1. The clearing should be well fenced to prevent damages by cattle to coffee and dadaps.
2. The plants should be protected from cockchafer attack during first few years.
3. Weeds especially the grasses should be controlled by cover digging in the initial years itself.
4. Soil around the newly planted seedlings should be mulched properly.
5. In open patches the seedlings are to be provided with artificial shade with branch lets of jungle trees (hutting) during dry months.
6. Adopt regular manuring schedule from March-April of the following year.
7. Irrigation through sub-soil injection @2 liters of water per plant at an interval of 15 days could be given to the plants for better and early establishment.

8. If irrigation facilities are inadequate foliar application of NPK+ Zinc spray @urea 500g + Superphosphate 500g +MOP 375g +Zinc sulphate 250g in 200 liters of water may be given during summer months at 45 days interval before the plants show incipient wilting.
9. Plant protection measures as indicated should be carefully followed.

5. Soil management practices in coffee

Soil management includes all the operations and practices that are followed for the purpose of modifying the characteristics of soil so as to create favourable conditions for plant growth. In coffee tracts, due to varied fluctuations in conditions of wet and dry periods, the soils cropped to coffee need such management measures so as to conserve soil and protect the plants from saturated and dry conditions. Different soil management practices can be broadly classified into i) soil conservation measures, ii) soil moisture conservation measures and iii) drainage measures.

i) Soil conservation measures

Coffee is grown on sloping hill ranges coming under high rainfall regions. Soil erosion is a serious problem in these areas especially in new clearings. For preventing the soil erosion contour planting and terracing are practiced.

Contour planting

Contour planting can be adopted in areas with a 10-20 % sloping i.e, 10-20 ft vertical drop for every 100ft length). In contour method of planting, coffee plants in a given row of slope are located at a same level. Contour planting is done in the following manner. A vertical line is drawn from top to bottom to divide the sloppy area into two equal parts. Along this line points are marked by pegs at appropriate distances depending upon the degree of slope. Using a `Ghat tracer' adjusted to dead level, point is located perpendicular to the vertical line starting from the top most peg. The points thus obtained are joined to form contour line (rows) along which planting is done. In contour planting though soil erosion is minimized, the efficiency of farm operations remains low.

Terracing

Permanent terracing must be maintained on a land with a slope of more than 20 %. Terraces are generally formed by manual labour. The distance between the terraces are marked using a 'Ghat tracer' as done in case of contour planting. Soil is loosened all along the marked lines (rows) and terraces are laid out by fortifying the sides of terraces with stones and boulders.
Care should be taken to prevent the sub-soil coming to top. Terracing requires lot of manual labour and huge initial investment but has an advantage of better work turn out during farm operations.

ii) Soil moisture conservation measures

For conservation of soil moisture different cultivation practices such as digging, scuffling, mulching, trenches/ pits are recommended in coffee plantations.

Digging

In new clearings the field is given a thorough digging to a depth of 15-18 inches towards the end of monsoon (Oct-Nov). All the weeds are completely turned under and buried in soil and stumps of forest bushes are removed. This operation is called 'cover digging' and is practiced only during the initial one or two years

after planting coffee. It helps in suppression of weed growth and conservation of soil moisture in new clearings. It is better to avoid digging in steep slopes as it may lead to severe erosion. Cover digging is labour intensive operation and would require 100 Mandays/Ha.

Scuffling

In established coffee fields, scuffling or soil stirring towards the end of monsoon (Oct-Nov) helps in control of weed growth and also conserves soil moisture. Around 20-25 labour would be needed per hectare for this operation.

Mulching

Covering the soil with dry leaves, weed slashings or any other organic wastes is called mulching. It is advisable to mulch the soil around the coffee plants after digging/ scuffling operations. Mulching young coffee clearings helps in maintenance of optimum soil temperature, conservation of soil moisture, suppression of weed growth and prevention of soil erosion.

Staggered trenches/pits

In sloped areas, trenches and cradle pits are opened during Aug-Oct. when the soil is fairly easy to work. These are dug in a staggered manner in between the rows of coffee all along the contour. Trenches are dug 12" wide, 12-18" deep and of any convenient length. The cradle pits are short trenches measuring about 3-5 feet long. Trenches and cradle pits act as mini compost pits for fallen leaves, weed bio-mass and dadap loppings besides preventing soil erosion and conservation of soil moisture. For taking new trenches/pits around 20 mandays would be required/ Ha., and for yearly maintenance 2-3 labour would be sufficient.

Drainage measures

In coffee fields, conservation of soil moisture rather than drainage are more frequently called for. However in low lying flat lands, soils become saturated due to water stagnation during monsoon period and will not be able to support the activities requiring oxygen. In prolonged water logging conditions, coffee roots suffer badly and develop wet foot symptoms. In such areas drainage channels of 20" wide, 12" deep are dug at suitable intervals between the rows. For digging fresh channels 10-15 mandays would be needed/Ha., and for regular maintenance 2-3 labour are required.

All these channels in a plot are connected to a main channel which is connected to a catch pit at the end of plot. Proper drainage is essential for better soil structure, root respiration and development.

6. Bush management in coffee

The plant management involving training and pruning is an essential maintenance operation for achieving potential yields in coffee. This is a complicated process which differs from place to place. For a systematic plant management in coffee, a basic understanding of the growth and morphology of coffee plant is very much essential.

(i) Training

Why Training of bushes?

- Training of bush is important to give a proper shape and also for restricting the plant growth at desirable height.

- It leads to a strong framework and promotes the production of bearing wood.

What are the types of training in coffee?

- Generally two types of training namely single stem and multiple stem are adopted for coffee throughout the world.
- Single stem system of training is found to be more suitable under Indian conditions where coffee is grown under shade.
- The multiple stem system is generally practiced for coffee grown under open conditions, as in some countries of Africa, Latin and South America, in which more than one stem is encouraged by 'agobiada' system (bending of main stem).

Single stem system

In this method the height of the bush is restricted at a convenient height by a process called topping/capping.

(ii) Topping

Why topping?

Topping helps in diversion of food material to thicken the main stem and primary branches and facilitates lateral spreading of plants.

Topping method

The vertically growing main stem is cut two inches above the node near the prescribed topping height. Usually tall arabicas take 9-12 months after planting to reach first topping height and robustas take 18-24 months to reach the desired topping height. After cutting the main stem at prescribed height, one of the top most primary branches is also cut beyond the basal node to prevent splitting of main stem due to crop load in the subsequent years. After topping operations, several suckers start sprouting at all nodes on the main stem. The suckers/ vertical shots arising on main stem compete with the cropping branches for water and nutrients and hence weaken the plants. Hence, these new suckers on main stem should be removed periodically, to maintain the vigour of the main stem. The topping heights prescribed for different coffee types are as follows:

Tall Arabica Varieties –S.795, Sln.5, Sln.6, Sln.9 (2 tier system)
First Tier topping at 0.75m (2.5ft.)
Second Tier topping at 1.5m (5ft.)

N.B: The second tier should be raised when the main stem is sufficiently thick and branches between plants start overlapping. Usually this stage is reached after taking 4-5 crops on the first tier.

Dwarf Arabica varieties- Cauvery:
(Single Tier) 0.9-1.5m (3-5ft.)

N.B: The topping height is to be decided based on prevailing conditions like type of soil, wind proneness etc. In areas with deep fertile soil and no wind damage, higher topping height could be adopted while in areas with shallow soils and wind damage, lower toping height is advocated.

Robusta
(Single Tier) 1.0-1.2m (3-4ft.)

Multiple stem system

In multiple stem system of training, the stems are usually left untopped. In this system two types of pruning are adopted. In the first method, the main stems are stumped once in 4-5 years (after exhaustion of cropping wood) in alternate rows and new multiple stems are encouraged. Alternatively, cyclic removal of one of the multiple stems is practiced every year which will be replaced by new stem.

Whether multiple stem system could be adopted in India?

Under Indian conditions, multiple stem system is not desirable in Arabica because of threat of white stem borer. It could be adopted in only in case robusta, while going for replanting of old blocks as well as when raising high density plantings. When the old robusta blocks are to be replanted with a new material, the older plants can be stumped and converted into multiple stems to exploit few crops until the new plants are established. In new high density plantings, quincunx method of planting (one plant in centre of 4 plants) could be adopted in which the centre plants can be raised on multiple stems temporarily for few years to exploit few crops till the regular plants start covering the designated spacing. The centre plants (temporarily raised on multiple stems) apart from yielding few crops also help in avoiding weed growth in vacant spaces between the regular plants.

(iii) Pruning

It is well established that in evergreen plants like coffee which produce crop on one season/ one year wood require more regular pruning than those which bear crop on older wood.

Why pruning?

Pruning is essentially a thinning process to maintain proper balance between vegetative wood and cropping wood and to direct the vigour of plants into the cropping wood.

What is the principle involved?

The principle involved in pruning is to remove old unproductive and undesirable wood for encouraging the growth of new branches which would become next year's cropping wood.

Benefits of Pruning

- reduces the biennial bearing by preventing overbearing and exhaustion in any particular year
- permits entry of sunlight and air to bushes there by minimizing the incidence of pest and diseases
- keeps the bushes in a manageable shape and
- improves the efficiency of field operations like spraying, swabbing, harvesting etc.

What type of pruning?

In coffee trained on single stem system, regular light pruning is desirable. This is applicable to both arabica and irrigated robusta. In case of un-irrigated robusta light pruning may be necessary only in alternate years.

When to prune?

The main pruning should preferably be commenced 2-3 weeks after harvest and continued till the onset of monsoon. The 2-3 weeks gap is essential to allow for recuperation of plants after relieving the crop load.

Precautions for pruning

- When dry conditions prevail, it is better to commence the pruning after a few summer showers.
- Bushes suffering from exhaustion/die-back are to be pruned only when there is sufficient moisture in soil.

What type of branches to be pruned?

Light pruning involves removal of only old, unproductive branches, criss-cross branches, lean, lanky and whippy wood, diseased and damaged branches as well as branches growing towards main stem and touching the ground etc. Gormandizers which grow in a semi erect manner on the primary branches tend to suppress the lower cropping branches if allowed to grow. Hence they should be preferably removed during main pruning. Even if they are allowed, they should be invariably removed during next pruning season. In any given field, all the plants may not require same degree of pruning. The bushes which had carried good crop and exhausted may require more intense pruning than those which had less crop and suffered least exhaustion.

Hard pruning

When the bushes lose their shape due to irregular pruning practices or damaged during shade lopping, they can be brought back to shape by hard pruning, provided the primary branches are intact. In hard pruning, all the secondary branches are removed to encourage new branches. In hard pruning it is important to allow a lung branch for maintaining physiological activities like translocation and photosynthesis. In the absence of lung branch, there are chances of death of entire plant itself especially if the adverse conditions follow after hard pruning.

7. Handling, Centering and Desuckering

Handling

Handling is essentially a thinning process to remove excess flush and to retain only desired number of secondary or tertiary branches at each node.

During handling operation, the new flush arising after the main pruning is thinned out a desire number of well-spaced branches. Generally one or two rounds of handling is necessary once during early monsoon (June-July) and later during August-September. In North East monsoon influence areas like Andhra Pradesh and Orissa, where there is excess vegetative growth of bushes is noticed, three rounds of handling may become necessary in a year.

Centering

Centering is a process of removing the new flushes on primary branches that sprout near the main stem after pruning. If these new spouts near to the main stem are not removed, they affect ventilation to the lower branches and create congenial conditions for certain diseases like black rot in endemic areas. Clearing the centre of the bushes enables proper ventilation to all the parts of the coffee bushes.

Centering should be done along with the handling operation. The removal of new shoots should be restricted to 6" surrounding the main stem. Generally at the estate level, centering is done too extensively which leaves a wide gap of more than one feet at the centre of the bush. Too much opening of centre exposes the main stem which is an ideal condition for white stem borer attack.

Desuckering

Removal of suckers also called desuckering should be undertaken by removing all suckers on the main stem from time to time. This operation is carried out along with handling and centering operations and subsequently during other operations like weeding, manuring etc.

Rejuvenation

The coffee bushes, which have lost all or majority of primary branches due to damage during shade regulation or gone out of shape by irregular pruning, can be rejuvenated by collar pruning/stumping. Collar pruning is done cutting the main stem at a height of 30cm from the ground level at a 45^0 sloping angle facing towards East or North-East directions. Collar pruning should be practiced only after the receipt of adequate summer showers during March-April when there is sufficient moisture in soil. The cut surface should be treated with Bordeaux paste (1 Kg $CuSO_4$ and 1 Kg lime dissolved in 5 litres of water) to prevent rotting of cut surface. Stumping encourages many new suckers on the main stem. These should be thinned out by allowing 1-2 vigorously growing suckers from below the cut surface, which are later trained to form a single stem canopy.

Do's and Don'ts in training and pruning of coffee

1. Follow prescribed topping heights.
2. In marginal and wind prone areas prefer lower topping heights.
3. During topping, cut one of the top most primary branches to avoid splitting of main stem.
4. Prune the bushes 2-3 weeks after harvest and preferably after shade regulation but when there is adequate soil moisture.
5. In dry hot conditions, delay pruning till the receipt of a few summer showers.
6. Bushes suffering from exhaustion and die-back are to be pruned only when there is sufficient moisture in soil.
7. Practice only light pruning involving removal of old, unproductive wood, criss-cross branches, branches touching ground, lean and lanky branches, dead and broken branches and pest and diseases affected branches.
8. Always practice proper handling and centering in pruned plants.
9. Do not allow suckers on main stem.
10. Do not encourage gormandizers as they tend to suppress lower cropping branches.

8. Weed management in coffee

Weeds compete with coffee plants for water, light and mineral nutrients. If weeds are allowed to grow during late post monsoon period, they use the soil moisture which coffee needs in the following dry weather. Free growth of weeds reduces the yield of coffee and plants assume a sickly appearance. In young clearings weeds are a serious problem particularly during first three years. The pruned fields where ground is exposed are also prone to weed problem.

(i) Methods of weed control

Manual weeding

Generally weeds are controlled manually. New clearings are hand-weeded three to four times and established coffee fields two to three times a year. During the monsoon season weeds are slashed back (slash weeding) with the help of a matchet. Clean weeding is generally done during post-monsoon period. It is a labour intensive and time consuming operation in coffee estates.

Cultural methods

In new clearings, the field is given a thorough digging (cover digging) to a depth of about 15-18 inches, towards the end of monsoon. All weeds and vegetative debris are completely turned over and buried into the soil.

In young clearings coffee at normal spacing covers only a small portion of soil surface and there is room for prolific weed growth. Interplanting of green manure crops, cover crops and annual such as grain legumes, cassava, beans, pigeon pea, yam, sweet potatoes, vegetables, pineapple etc., help in suppression of weed growth to a large extent. Intercropping has been successful in robusta coffee in Wayanad region of Kerala. In established plantations, scuffling and mulching at the end of monsoon can be effective in controlling weeds.

Chemical methods

Chemical weed control methods are employed where labour is scarce or expensive or when there is a demand for diverting labour to other important cultural operations like manuring, spraying etc. The chemicals used for killing the weeds are known as weedicides and these can be classified based on time of application (Pre-emergent and post-emergent), mode of action (contact and systemic) etc.

Pre-emergent weedicides are to be applied before the emergence of weeds to moist soil. These are taken up mainly through germinating roots of weed seeds and remain in surface layers long enough to kill the surrounding weed seeds. These weedicides have long residual effect and their continuous accumulation in soil may be become large enough to affect the growth of coffee and cause phytotoxicity. Pre-emergent weedicides are not usually advocated in coffee plantations. e.g.: Simazine, Atrazine etc.

Post-emergent weedicides are applied when the weed flora is actively growing. Unlike pre-emergent weedicides, the post-emergent weedicides become inactivated on coming into contact with soils and are thus unavailable to root system of plants at recommending dosage. Hence, they have no residual effect. eg: *Paraquat-di-chloride, glyphosate* etc. Most of the post-emergent weedicides have either contact or systemic action. Contact weedicides kill only those plant parts, which come into contact with them. They are quick acting and control a wide range of weeds. Care should be taken to target only the weed growth. eg: Paraquat-di-chloride (Gramoxone). Systemic weedicides are absorbed through roots or aerial parts and are then translocated within the plant tissue and kill the entire plant system. eg: *Glyphosate (Glycel or Round up).*The efficiency of weedicides can be increased by adding surfactants, additives/synergies etc. Surfactants (wetting agents) facilitate uniform spreading of spray solution leading to complete wetting and coverage of spray surface. These help in sticking of spray droplets to the plant parts and prevent bouncing off of droplets. Eg: Tween-20m, Vettoplant etc.

(NOTE: Some weedicides contain appropriate wetting agent incorporated in the formulation itself. At the recommended rates of application, there is no need to add wetting agent to the spray fluid. eg: Gramoxone.)

Additives like urea, ammonium sulphate etc., improve the efficacy of weedicides and there by offer a scope to bring down the dosage of weedicides without affecting their need killing efficiency.

(ii) Time of application

Weedicides should be applied on a bright sunny day when there is sufficient moisture in soil and the weeds are actively growing before their flowering and seed setting. First round of blanket application should be taken up by the end of April or beginning of May when the weeds are about 10-15 cm high. If weeds are taller than this they should be slashed back and sprayed a week or 10 days later. Scattered patches of weed growth should be controlled by spot spraying 15-20 days after the blanket spray. A second round of blanket application may be necessary towar5ds the end of monsoon i.e., September/October, Which has to be followed by one or two spot application. Generally, 450 liters of spray solution is needed per hectare for each blanket spray.

(iii) Weedicides recommended in coffee fields

1) Paraquat-di-chloride 24% EC @ 0.067% a.i. (Gramoxone @ 500 ml per barrel)
2) Glyphosate 41% EC @ 0.27 % a.i. (Round up of Glycel @ 1200 ml per a barrel)
3) The cost of chemical weeding could be brought down by nearly 50% by addition of urea @ 1% in spray solution. The dosage of Gramoxone could be brought down to 250 ml/barrel and that of Round up or Glycel to 600ml/barrel when urea is added to the spray solution @ 2 Kg/barrel without any reduction in their weed killing efficiency.

Experimental evidences indicate that continuous application of weedicides did not affect the soil characteristics like organic matter content, pH, available 'P', 'K' etc., but slightly lowered the population of soil microflora.

9. Nutrient management in coffee

In Coorg, coffee is grown in acidic soils under varying climatic conditions. Under these conditions, maintaining vigorous and healthy growth off coffee bushes with tolerance to pest and diseases and consistently good crops are possible only if sufficient and balanced nutrition is maintained. Fertilizers requirement of coffee plants should be based on the amount of nutrients removed by the crop, the nutrient needed for the production of the necessary cropping wood, foliage, bush frame work and fertilizer use efficiency (FUE) in the plantation soils

(i) Suggested fertilizer dosage based on yield

Yield of Clean Coffee (Kg)	Annual fertilizer Dose $N:P_2O_5:K_2O$
100	30:27:30
500	70:55:70
1000	120:90:120

(ii) Fertilizer Schedule

The suggested doses are same for robusta as well as arabica. But for robusta, plants producing one ton clean coffee, 10 to 15 kg potash should be supplied in addition to the suggested dose. For young Arabica, a dose of 20:10:20 $N:P_2O_5:K_2O$ grams per plant is suggested in 3 to 4 splits for the first two years and thereafter 25:15:25 g/year up to the bearing age. For robusta, the fertilizer requirement is slightly higher (starter dose) in the initial years. For the first three years 38:28:38 20 N: $P_2O_5:K_2O$ g per plant is suggested in two splits doses and 40:30:40 g up to bearing age per annum.

Nitrogen should be applied in 3 or 4 splits doses as availability of nitrogen in soil throught the year is very essential for the development of bearing branches and foliage. Plants requirement of Phosphorus and potassium is not high during monsoon period. So application of urea, about 125 kg per ha, during break in monsoon can take care of nitrogen requirement in these period. Phosphorus nutrition should never be ignored as it helps in the sturdy growth of roots and should not be skipped during the pre monsoon application. Balanced application of potash averts many plant diseases. In case of short supply of potash, berry development will be affected and heance, post monsoon application of potash should not be neglected.

(iii) Choice of fertilizers

- In highly acidic soils (below pH 5.0), use of ammonium sulphate should be avoided as it leads increased soil acidity.
- Urea can be used as Nitrogen source in all soil pH conditions.
- DAP, SSP, and MAP may be applied into soils with pH above 6.0, Nitro-phosphate (Suphala) may be used in soils with pH between 5.0 and 6.0, Rock phosphate also can be used as P source in acidic soils.
- Muriate of potash and potassium sulphate can be applied as potassium fertilizer for coffee while potassium nitrate is not recommended.
- Complex fertilizers are also effective as sources of major nutrients.

All the fertilizers should be tested for their composition and purity before use.

(iv) Time, method and frequency of nutrient supply

Nutrients should be applied in splits doses and on time. The uptake of N,P and K is highest during the moist conditions. During monsoon period, application of N and K nutrients is helpful. A month gap should be given between fertilizer application and liming. The fertilizer should be placed into the soil with an even distribution under canopy, leaving a circle of one foot diameter around the stem. In steep areas fertilizers can be applied in semi arch (Horse shoe) from on the upper side of the stem.

Application of calcium sulphate (Gypsum) or magnesium sulphate (Epsom) @ 125 kg /ha during post monsoon is beneficial as it improves soil physical properties and fertility status of soil. It also supplies sulphur, which is essential for improving coffee quality, aroma ad size of the beans.

Foliar feeding: Foliar sprays helps quickly in correcting the deficiency of nutrients in coffee plants. Foliar spray of 0.5 – 1% urea during break in the monsoon (July / August) is found to arrest fruit droop in coffee. Sprays of muriate of potash (0.25%) and DAP (1—2%) are useful. Phosphatic fertilizers should not be mixed with Bordeaux mixture for spray purpose. Micronutrients sprays are suggested espcialyy during high cropping seasons**.**

Phosphorus solubilizers: Application of phosphorus solubilizing bio fertilizers like biophos @10 kg /ha would release the fixed soil P and thereby saves one third phosphorus requirement.

Tips for efficient fertilizer use

- Test your soil once in three years.
- Correct soil acidity by liming.
- Apply balanced NPK to get sustainable yield from healthy plants.
- Apply NPK in 3-4 splits
- Use 10:7:10 kg NPK for every additional 100 kg claen coffee yield
- Recycle all the farm wastes.
- Apply organic manure / compost once in 2-3 years.
- Spray micronutrients only during high cropping seasons.

Soil acidity and liming

- Soil reaction (pH) is the indication of the acidity and is measured in pH units.
- The pH scale ranges from 0-14 with pH 7as the neutral point.
- From pH 7 to 0 the soil is increasingly more acidic & from 7 to 14 soil is increasingly more basic.

- The ideal soil pH for coffee cultivation ranges from 5.8 to 6.0

Liming materials

- The term 'liming' in agriculture refers to addition of Ca & Mg containing compounds that can neutralize the soil acidity.
- Commonly used liming materials in coffee plantations are Calcium carbonate (Ag.lime), Ca and Mg.carbonate(Dolomite), Calcium oxide (burnt lime) and Calcium hydroxide (slaked lime)

Neutralizing value of liming material

- Liming materials differ markedly in their ability to neutralize acids.
- Pure CaCO3 is the standard against which other liming materials are measured.

Material	Neutralizing value(%)
CaCO3	100
CaO	179
Ca(OH)2	136
CaMg(CO3)	109

Time of application:

- Nov-March
- Sufficient moisture should be there for the reaction to take place.
- There should be minimum of one month gap between lime and fertilizer application.

10. Irrigation management

Coffee is prominently cultivated as a rain fed crop worldwide. In equatorial regions such as South and Central America where there are no well defined alternations between wet and dry periods, coffee is generally not irrigated. But in the regions of single rainfall regime such as East and Central Africa and India, coffee usually encounters 4-6 months of dry period in a year. Under such conditions, growth and productivity could be boosted substantially by irrigation.

- Coffee, being an evergreen plant, requires maintenance of soil moisture during dry months.
- In coffee tracts of South India, the South-West monsoon zones predominately receive more than 60% of rain during June to September and the rest during North-East monsoon period up to Oct-Dec.
- The drought period usually consist of 4 months from December onwards. In some years the N-E monsoon tapers off by the end of October itself leading to extension of dry period by another month.
- The most important factor which limits the production of coffee even in well managed estates is long drought period. Besides this, if blossom rains are delayed beyond March then the production of coffee receives a major set back.
- In coffee, irrigation is mainly used as an insurance against failure of good blossom and backing showers and for overcoming long drought.

(i) Sprinkler Irrigation

Sprinkler irrigation is the most versatile method of irrigation to supplement the natural rain fall for the growth and blossoming of coffee. In sprinkler irrigation the water application resembles rainfall. Water is sprayed under pressure through small orifices or nozzles and is externally applied all over the plant and land surface.

- Systems are designed based on the factors like area to be irrigated, type of soil location water source topography of land wind velocity, infiltration rate etc.
- For successful establishment of young plantations, coffee should be irrigated during dry months to a depth well below the root zone and the intervals between irrigations should be long enough to allow the soil to dry out without causing serious wilting. This encourage deep rooting as a protection against drought and also improves the anchorage of trees.
- Robusta coffee being susceptible to drought, responds well to irrigation compared to arabica.
- First winter irrigation needs to be commenced 20-25 days after the cessation of monsoon. Irrigation is to be given @ 25mm once in 20-25 days till the end of December.
- Later blossom irrigation @ 25-38mm is to be given during the second fortnight of February followed by backing irrigation with a gap of 15-20 days after blossom.

Preparing coffee for overhead irrigation

- This is essential for getting proper response to irrigation. Over crowed and old coffee under thick shade should be avoided.
- Preference should be given to younger and more responsive coffee.
- Shade should be well regulated and coffee pruned every year after harvest.
- Short-hole borer affected, dead twigs and whippy wood are to be removed. Weed growth has to be checked.

Beneficial effects of sprinkler irrigation in coffee: By adopting sprinkler irrigation the following benefits are observed.

- Two fold increase in length of laterals due to increase in number of nodes and inter nodal length; increase in leaf area by 45%; retention of foliage as against loss of foliage in un irrigated plants; improved nutrient uptake; uniform ripening of berries.
- Irrigating only for blossom and backing improved yields by 48-57% and continuous irrigation throughout drought period gave an yield increase of 85-95% over un-irrigated plots in robusta coffee.

(ii) Drip Irrigation

The drip or trickle irrigation has assumed considerable importance in recent years in view of the greater need for economy in water.

- In drip method, water is distributed by a net work of tubing to each plant directly, near the root system in the form of droplets daily or on alternate days bases on the exact water requirement of crops.
- Thus the water losses during conveyance and due to seepage, evaporation etc., are totally avoided.
- Besides, the water is not applied to the unwanted areas like inter-spaces between the rows and plants.
- Thus drip irrigation system offers greater savings in water (up to 60%). The other advantages of drip irrigation system include, saving in labour, increased yields, better quality of produce, less weed growth, increased fertilizer efficiency, possibility of fertilizer application through irrigation water (fertilization) and reduced incidence of foliar pests.
- How ever, initial cost of drip equipment is considered to be its limitation for large scale adoption,. Cost of the unit per hectare depends mainly on the spacing of the crop.
- The main item of expenditure is the lateral pipe line which is run all along the rows. The wider the row spacing lesser will be the cost drip irrigation system.

Components of Drip Irrigation System

- The basic components of a drip irrigation system include a pump, fertilizer injector, filters, distribution lines, emitters/ drippers and other control and monitoring equipments.
- Distribution lines consist of a network of graduated pipe lines starting with a main line followed by smaller sub-main and lateral lines. The main and sub-main lines are made of PVC and are buried in soil.
- Lateral lines are usually made of polyethylene plastic and are laid above ground along the rows and are connecter to sub-main. Emitters/ drippers which discharge water in droplet from are fixed on lateral lines near the root system of the trees.
- The main control station for the drip irrigation system is organized to measure and filter the water and to regulate pressure and time of water application.
- The control station include the pump, back-flow prevention device, primary filter, pressure regulator, pressure gauge, water meter and usually chemical gauge, water meter and usually injection equipment.

Beneficial effects of drip irrigation in coffee

Results obtained with drip irrigation in coffee for the last few years have revealed that this method is most suited for sustenance irrigation of coffee plants during the dry period. Establishment of young coffee is much better with drip irrigation compared to sprinkler irrigation as there would be less weed growth under drip irrigation system.

- Application of 3-4 liters of water in day at weekly intervals was found to ideal for establishment plantations, application of 8 liters of water/plant on alternate days to Cauvery and every day to robusta during dry months from Nov-May could increase the crop yield by 28% and 48% respectively.
- Under drip irrigation the arabica (Cauvery) coffee could be allowed for natural blossom showers, while in robusta, blossom could be induced by applying around 200litres of water per plant during Feb/March through drippers or micro sprinklers.
- This blossom irrigation needs to be given at a stretch, after with holding daily drip irrigation for about 15 days prior to blossom irrigation.

11. Pest and disease management

*White stem borer: Shad**e*** management; tracing/uprooting; scrubbing; pheromone traps; chemical: Spraying 10 % lime (Spray lime at 20 kg in 200 litres of water along with 200 ml fevicol) on main stem and thick primaries before flight periods (April- May and October –December) after light scrubbing of the stem. Apply insecticide only in hot spot areas once during mid April and once during end of October or first week of November. One more spray given at first week of December with chlorpyriphos 20 EC at @600 ml in 200 litres of water along with 200 ml wetting agent.

Shot hole borer: Prune the affected twigs 5-7 cm before the shot hole and burn. This should be commence from September onwards and continued as a routine; Remove and destroy unwanted infested suckers during summer; Maintain shade and good drainage; Not economically viable for established plantation with chemical. But young plants up to 5-6 years old may be protected by spraying tilt 20 EC (Propiconazole) 0.02% (200 ml in 200 litres of water with 200 ml of wetting agent)

Mealy bug: Maintain optimum shade; Weed management; Dicourage nesting of red and cocktailed ants*;* Spray affected patches with 4 litres of kerosene in 200 litres of water along with 200 ml of agricultural wetting agent.; If root is affected drench the root zone with dimethoate 30EC (about 660 ml in 200 litres of water); Release parasitoid *Leptomastix dactylopii* against *planacoccus citri* and *cryptolaemus montrouzieri* irrespective of species.

Field release: release Leptomastix *dactylopii @5000-10,000 numbers in batches per hectare as an introductory release and repeat the release @5000-7500 numbers during every pest season starting from December- January.*

Green Scale: Maintain optimum shade; Dicourage nesting of red and cocktailed ants; weed control; Spray green scale affected patches with dimethoate (Rogor) @170 ml in 200 litres of water with 200 ml wetting agent.

Brown Scale: Control ants; Spray dimethoate (Rogor) @170 ml in 200 litres of water with 200 ml wetting agent.

Coffee Berry Borer: Collection of left over berries/ gleanings ; timely and thorough harvest; at time of harvest using mats to minimize gleanings ; infested fruits should be processed after dipping in boiling water for 1-2 minutes ; heavily infested berries may be destroyed by burning or burying in the soil to a depth of atleast 20 inches ; maintain thin shade and maintain plant structure so that harvest and plant protection operations are efficient; dry the coffee ib the following moisture specifications (arabica 10% and robusta 11%); use of brocatraps @30traps per acre; chemical control: Spray 35EC @340ml in 200 litres of water; chlorpyriphos 20 EC at the dosage of 600 ml per barrel along with 200 ml of wetting agent, it should be sprayed when most of the beetles are still at the tip of the navel region of the fruit before entering into beans. The thumb rule is to spray the berries between 120-150 days after blossom (August – September for arabica nd Sep-Oct for robusta); Biological control: Using *Beauveria bassiana.*

*Cockchafer and Hairy caterpillar***:** Incorporate 5 g thimet in to pits at time of planting; Collect and kill the grubs; install light traps after the first summer showere during March and June and kill the trapped adults

Hairy Caterpiller: Collect and kill the caterpillars and burn pupae from January to May; Install light traps in June-July to kill the moths; Spray Fenvalerate 20 EC @20 ml in 200 litres of water aling with 100 ml of wetting agents.

*Nematode***:** In Nursery; Dig up the soil and expose the soil to the sum during the summer; sieve and dry the jungle soil and FYM; In field: uproot & burn; dig up soil and expose the soil to the sun for one year; keep plots free of weeds; plant the area with the robusta; drench the soil around the plants with carbosulfan (Marshal) @480 ml in 200 liters of water. Depending on the size of the plant, 50-500 ml of the solution would be required per plant; three applications should be done, one during pre –monsoon, second- break in monsoon, third during post monsoon.

Leaf Rust: Spray freshly prepared Bordeaux mixture (0.5%) with proper coverage of the under surface of the leaves before onset of the SW monsoon (May-June); spot application of triadimefon (Bayleton @160g/200litres) to highly susceptible populations during break in monsoon (August) to prevent defoliation -and dieback; second round prophylactic spray of bordeux mixture (0.5%) during post monsoon (Sep- Oct) ; Varieties showing higher incidence should be sprayed with hexaconazole (Contaf @400 ml/200 liters of water) or Triadimefon (Bayleton @160g/200 liters) as Bordeaux mixture spray will not contain disease and defoliation at this stage.

Black rot or Koleroga: Thinning overhead shade in black rot endemic blocks before onset of SW monsoon Avoid monoshade; proper pruning; adequate coverage of Bordeaux mixture 1.0 % on both the surfaces of leaves and also to the developing berries just before the onset of monsoon; Remove and destroy the affected leaves and berries along with the thread of mycelia; Spary Carbendazim 0.03% (Bavistin @120g/200 litres) inblack rot endemic areas after 45 days of first spray of Bordeaux mixture under clear break of monsoon.

Root diseases: Remove the fallen logs and felled shade tree stumps from coffee plantations to prevent multiplication and of the pathogens; remove and destroy the affected shade trees and coffee plants along with the root system to reduce inoculums; Isolate the affected area and one row of apparently healthy adjoining plants all round with 60 cm deep and 15 cm wide trenches. Soil taken out from the trenches should be placed inside the isolated area. The trenches should be cleaned at least once in three months. Apply 203 kg of agricultural lime and turn the soil in thepits where affected plants and shade trees are uprooted. Apply agricultural lime to the affected areas inside the trench and take up cover digging during the dry period to expose the pathogen to sunlight;Supply planting in the affected arease to be done anly after exposing the pits to sunlight for 6-8 hrs.; Treat the plants with *Trichoderma viride* with FYM @125g +3kg respectively twice in a year when sufficient moisture exists. OR soil drenching with carbendazim solution (8g/liter) 2-3 liter /plant at collar region.

12. Measures to reduce post harvest losses

- Timely harvesting of ripe fruits and sorting greens
- Drying the fruits to the desired moisture levels at appropriate thickness.
- Storage in well ventilated moisture free condition to prevent fungal infection in stored beans.
- Storing coffee in fumigated rooms at appropriate

Tree spices – Problems and prospects

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1. Introduction

Among the various groups of spices, tree spices are unique owing to their nature. As the name indicates, tree spices are tall plants with more canopy compared to other spices like rhizomatous, seed and herbal spices. There are seventeen tree spices (Table 1) grown in different parts of India. They are the best components suitable for intercropping systems particularly those of coconut and arecanut. Among the tree spices clove, nutmeg, cinnamon and tamarind are relatively more important and they are grown on area of 78031 hectares with a production of 221536 tonnes (Tables 2-4). During 2010-11, India exported 2100 tonnes of nutmeg and mace to the tune of Rs.9777 Lakhs.

Table 1. Tree spices grown in India

Sr. No.	Botanical name	Family	Common name	Part used
1.	*Averrhoa bilimbi* L.	Averrhoaceae	bilimbi	Fruit
2.	*A. carambola* L.	Averrhoaceae	carambola	Fruit
3.	*Cinnamomum aromaticum* Nees	Lauraceae	Chinese cassia	Bark, leaf
4.	*C. tamala* Nees	Lauraceae	Tejpat, Indian cassia	Leaf, bark
5.	*C.verum* Bercht &Presl.	Lauraceae	Cinnamon	Bark, leaf
6.	*Garcina gummi-gutta* (L.) Robs.	Clusiaceae	Garcinia, Cambogia	Pericarp of fruit
7.	*G. indica (*Thouars) Choisy	Clusiaceae	Garcinia, kokum	Pericarp of fruit
8.	*Illicum verum* Hook	Illiciaceae	Star anise	Fruit
9.	*Juniperus communis* L.	Cupressaceae	Juniper	Fruit
10.	*Laurus nobillis* L.	Lauraceae	Bay leaf	Leaf
11.	*Mangifera indica* L.	Anacardiaceae	Mango	Rind of immature fruit
12.	*Murraya koenigii* (L.) Sprengel	Rutaceae	Curry leaf	Leaf
13.	*Myristica fragrans* Houtt.	Myristicaceae	Nutmeg	Kernel, Aril
14.	*Pimenta dioica* (L.) Merr.	Myrtaceae	Allspice, Jamaica papper	Immature fruit, leaf
15.	*Punica granatum* (L.)	Punicaceae	Pomegranate	Dried seed (with flesh)
16.	*Syzigium aromaticum* (L.)	Myrtaceae	clove	Flower bud
17.	*Tamarindus indica* L.	Fabaceae	Tamarind	Fruit

Table 2. Area, production and productivity of certain tree spices in India (2010-11)

Crop	Area (ha)	Production (MT)	Productivity (kg/ha)
Clove	2420	1160	480
Nutmeg	16130	11420	708
Cinnamon	510	40	73
Tejpat	2440	4980	2044

Table 3. Statewise area (in ha) of important tree spices in India (2010-11)

State	Clove	Nutmeg	Tamarind	Total
Andhra Pradesh	-	-	5930	**5930**
Karnataka	90	115	15163	**15368**
Kerala	1123	17545	11924	**30592**
Tamil Nadu	765	-	18028	**18793**
Andaman & Nicobar Islands	156	70	-	**226**
All India including other states	2195	17760	56531	**76486**

(Source: Spices Board, Govt. of India)

Table 4. Production (tons) of important tree spices in different states (2010-11)

States	Clove	Nutmeg	Tamarind	Total
Andhra Pradesh	-	-	28345	28345
Karnataka	113	77	82029	82219
Kerala	90	11911	31794	43795
Tamil Nadu	714	-	56655	57369
Andaman & Nicobar Islands	5	5	-	10
Total including other states	963	12088	203936	216987

(Source: Spices Board, Govt. of India)

b. Production of tree spices

Like other major spices *viz*., turmeric, ginger, chilli, black pepper etc. tree spices are seldom cultivated in organized form. Most of their plantations in India are found in either forest or back yard of home. They are also found as intercrops in existing coconut and arecanut plantations. Importantly, India import considerable amount of tree spices for domestic consumption and export.

Annually clove, nutmeg (both nutmeg & mace), cassia & cinnamon are imported to the tune of 22610 tonnes worth Rs. 31764.7 lakhs (D G C I & S, Kolkotha). This import of tree spices into India and drain of considerable economy needs to be terminated. When cultivated systematically tree spices provide tremendous potential for sustainable income to the farmer. Based on experimentation Dr. B.S.Konkan Krishi Vidyapeeth, Dapoli has conceptualized a "Lakhi Bag" concept which includes planting of coconut and tree spices in a systematic and scientific way. This provides opportunity to farmers to earn more than 1 lakh Rs. per ha. The layout of "Lakhi Bag" and probable expenditure and income is given separately (Fig. 1).

In India, at present the treespices research work is conducted through Indian Institute of spices Research, Kozhikode, AICRP on spices and various State Agriculture Universities. The significant achievements are as under:

i) In nutmeg, three varieties *viz*., Konkan Sugandha, Konkan Swad, Konkan Shrimanti are released by Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli (MS). IISR Vishwashree and Kerala Shree (proposed) are nutmeg varieties by the Indian Institute of Spices Research, Kozhikode.
ii) In cinnamon, two varieties *viz.*, IISR Navashree and IISR Nityashree by the India Institute of spices Research, Kozhikode; Konkan Tej and Konkan Tejpatta by Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli; YCD-1 and PPI (C-1) by TamilNadu Agriculture University; Sugandhini by Medicinal and Aromatic Plants Research Station, Odakkali (Kerala Agriculture University) and RRL (B) C-6 by the Regional Research Laboratory, Bhubaneshwar, Orissa are released.
iii) In clove, SA-3 has been released by the Horticultural Research Station, Pechiparai (TNAU, Tamil Nadu).
iv) In garcinia, Konkan Amruta and Konkan Hatis have been released by Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli (MS).

v) In tamarind, Prathisthan, Yogeshwari, PKM 1, Urigam, DTS 1, DTS 2 are released.
vi) For rapid vegetative propogation, air layering in cinnamon and epicotyls and soft wood grafting in nutmeg, soft wood grafting in tamarind have been developed.
vii) Drying techniques for nutmeg, mace & cinnamon are standardized. The germpalsm lines have been characterized for oil profile and oleoresin in nutmeg, clove & cinnamon.
viii) Major pests & pathogens are documented.

c. Problems in cultivation of tree spices

In spite of the remarkable potential, its cultivation in India is neglected because of certain constraints:

Lack of high yielding varieties

At present, few superior varieties are available in nutmeg, cinnamon, garcinia & tamarind.More varieties are needed in these crops as well as in other tree spices to augment productivity. Similarly, more varieties with specific reference to premium quality are required to be developed in all tree spices.

Limited availability of planting material

There are limited nurseries for supply of quality planting material of tree spices. More nurseries producing quality planting material of tree spices need to be encouraged.

Dioeciousness and tropism

Nutmeg and garcinia are major trees spices which are dioecious. Furthermore, both are influenced by tropism in grafting. The technique of epicotyl grafting and softwood grafting are developed in nutmeg and garcinia for their rapid multiplication. However, while grafting if orthotropic scion is used then only the resulting graft grow erect as of the mother plant. But very few orthotropic shoots are available for grafting. Whereas when plageotropic scion is used for grafting, the resulting graft grows like that of a bush. Ample number of plageotropic scion sticks are available for grafting. The plageotropic grafts are slow in growth. Both types of grafts have merits and demerits. Farmers are reluctant to grow slow growing plageotropic grafts.

Lake of standard package of practices

The appropriate and location specific management practices such as integrated nutrient, water, pest and disease management are lacking in tree spices.

d. Harvesting

Harvesting in cinnamon is a highly skillful operation. It involves high amount of human labour because of which farmers neglect cinnamon plantation. A backup of mechanization is necessary in cinnamon harvesting. In nutmeg, most of the fruits are harvested in rainy season. The harvesting continues for about 100 days. Drying is a major problem in rainy days. Most of the nutmeg growers are small. Appropriate small scale and economical driers are necessary for curing of nutmeg in rainy season. In clove, fully mature flower buds are harvested. It involves large number of human labours. Similarly, in garcinia traditionally, the fruits are harvested by climbing trees and shaking the branches which results in 30 to 40% loss because of dropping of immature fruits and spoilage of ripe fruits. Harvesting span is very short. Storage of fresh fruit is a major problem. Research and development are urgently needed in these pre and post harvest areas.

e. Post harvest handling and value addition

Standard protocol for post harvest handling is necessary in all tree spices which would contribute for improvement in quality required for domestic and export market. The tree spices are mostly traded as whole which gives lower remunerations to the farmers. It is necessary to focus on value addition for tree spices which respect to powder, oil, oleoresins etc. with a back up of suitable and economical small scale machinery.

f. Prospects for cultivation of tree spices in India

There exists good scope for increasing tree spices production in the country.

i) Mixed cropping in existing coconut and arecanut plantations

Traditionally, tree spices are cultivated in coconut and arecanut plantations as mixed crops. Similarly, few plants in scattered form are planted. However, plantations of tree spices in an organized form is lacking. A systematic planning and cluster approach will not only help to establish tree spices plantation in an organized form but also facilitates farmers for better management and marketing in a co-operative mode.

ii) Establishment of sole plantation of tree spices

Among various tree spices, cinnamon tolerates shade. Partial shade is essential for nutmeg and clove whereas garcinia and tamarind do not need shade. It is essential to promote sole plantation of garcinia and tamarind in cluster mode. It will provide sizable raw material for transport as well as processing industry. This will be mutually beneficial for farmer as well as self help groups, small entrepreneurs etc.

iii) High density orchard for nutmeg and cinnamon

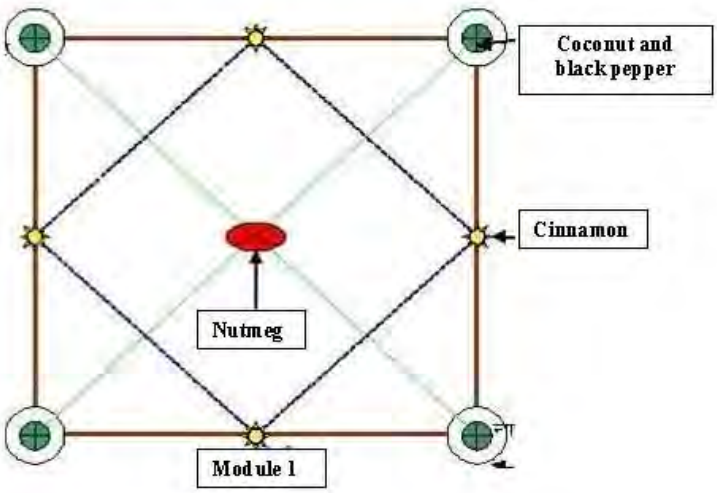
A plageotropic graft of nutmeg grows slowly and takes shape that of a bush if trained appropriately. Both cinnamon and nutmeg grafts can be planted at high density spacing under agroshade net. A cluster of such small unit poses potential for sizable production.

iv) Organic spice production

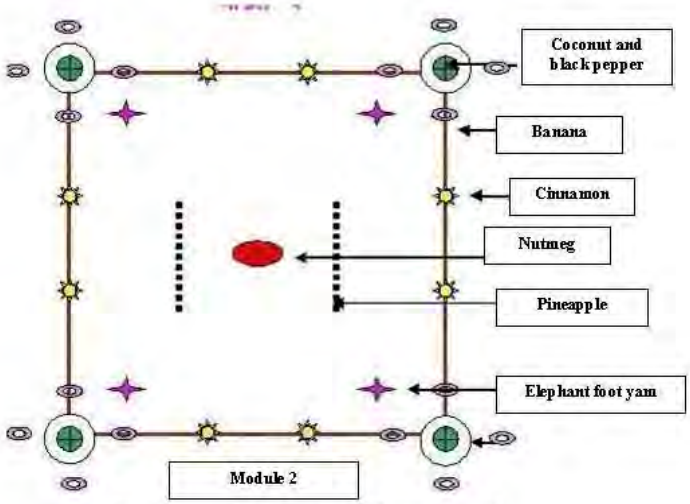
The demand for organic spice is increasing day by day. Presently, the packages of practices performed by the farmer for tree spices are mostly organic. Hence, there is greater scope for organic cultivation of tree spices in India. The Spice Board of India has already launched number of programmers to create awareness for organic spice production in the country. The spices board and state agriculture departments are also helping group of farmers in getting organic certification. The development of Indian GAP standard is in progress.

v) Protocols for value addition

There is great scope for developing protocols for novel value added products of tree spices. At present, various value added products of kokum *viz*., *Kokum syrup, Kokum amsol, Kokam aagal* are unique to the country.



Lakhi Baug module 1	
Expected expenditure per acre	Rs. 1,50,000/-
Expected Income per acre	Rs. 2,80,000/-



Lakhi Baug module 2	
Expected expenditure per acre	Rs. 2,30,000/-
Expected Income per acre	Rs. 3,75,000/-

Fig. 1. Lakhibag modules of tree spices

Genetic resources and crop improvement in tree spices

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1. Introduction

Tree spices, as the name indicates, are tall plants with more canopies compared to other spices like rhizomatous spices, seed spices, herbal spices. There are seventeen tree spices grown in different parts of India. They are best components suitable for agro-forestry systems particularly coconut based system. The tree spices like clove, nutmeg, tamarind, cinnamon, tejpat are relatively more important and they are grown in an area of about 81189 ha with a production of about 208445 t.

2. Cinnamon

The true cinnamon, *Cinnamomum verum* Bercht. & Presl., (Syn. *C. zeylanicum* Blume), (Lauraceae) commonly known as Sri Lankan cinnamon, is an evergreen tree reaching a height of 6-15 m, with bisexual flowers. Cinnamon of commerce is the dried inner bark of *C. verum*. Besides cinnamon, the bark oil, bark oleoresin and leaf oil are products sought after by the food, pharmaceutical and perfume industry for varied uses.

a. Species diversity

The genus *Cinnamomum* Schaeffer (Lauraceae) comprises about 250 species of trees and shrubs of tropics and subtropics. It is distributed in South-East Asia, China and Australia, growing mainly in tropical rain forests at varying altitudes. In India, it is represented by 26 species . Many of the species of *Cinnamomum* have medicinal and spice value and are of great demand commercially. *C. verum* Bercht. & Presl (true or Ceylon cinnamon), *C. cassia* Presl. (Chinese cinnamon, *Cassia lignea*), *C. burmannii* Blume (Indonesian cassia), *C. loureirii* Nees (Vietnamese cassia), *C. tamala* (Buch-Ham.) Nees & Eberm. (Indian cassia, Indian bay leaf or tejpat), *C. camphora* (camphor tree) etc. are a few of the economically important species of the genus. As most of the species occur only in the wild, semi-domesticated gene pools of *Cinnamomum* do not occur.

b. Cultivar diversity

High coefficient of variation for dry and fresh bark yield per plant, bark oleoresin, leaf oil, leaf size index and percentage recovery of bark was observed in cinnamon germplasm maintained at Indian Institute of Spices Research (IISR), Kozhikode.

c. Rare and endangered species

Owing to severe deforestation there is every possibility of some species becoming extinct in the near future. The wild population of *Cinnamomum* is in real threat due to indiscriminate bark extraction from them. *C. nicolsonianum* Manilal and Shylaja and *C. heynianum* are reported as endangered. *C. nicolsonianum* is a very rare and endangered species having large leaves and very small axillary panicles which occur in low elevations in Western Ghats. The tree is extremely rare and is possibly in the verge of extinction. *C. sulphuratum*, which was listed as red listed spices in found in abundance in Kemmangundi (Western Ghats).

d. Varieties

Seven cinnamon varieties have been released from various research stations in India (Table 1).

Table 1. Varieties of cinnamon released for cultivation in India

Varieties	Institute/ organization from where released	Year of release
IISR Navashree	Indian Institute of Spices Research, Kozhikode	1996
IISR Nithyashree	Indian Institute of Spices Research, Kozhikode	1996
YCD- 1	Horticultural Research Station, Tamil Nadu Agricultural University, Yercaud, Salem District	1996
PPI (C) 1	Horticultural Research Station, Tamil Nadu Agricultural University, Pechiparai, Kanyakumari District	2002
Konkan Tej	Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra	NA
RRL (B) C-6	Regional Research Laboratory, Bhubaneswar, Orissa	NA
Sugandhini (ODC-130)	Aromatic and Medicinal Plants Research Station, Kerala Agricultural University, Odakkali, Ernakulam District, Kerala	2000

e. Conservation

The conservatory of Cinnamon at IISR, Kozhikode includes *C. verum, C. cassia*, *C. camphora* (an economically important tree yielding camphor oil), *C. citriodorum*, lemon grass oil smelling *Cinnamomum* spp. collected from Munnar (Idukki District) *C. malabatrum, C. perrottetti, C. wightii, C. macrocarpum, C. sulphuratum, C. riparium* and *C. tamala.* The germplasm of cinnamon are also conserved at Konkan Krishi Vidyapeeth, Dapoli, Maharastra; Tamil Nadu Agricultural University (Horticultural Station. Yercadu), Regional Research Laboratory, Bhubaneswar and Kerala Agricultural University (Aromatic and Medicinal Plants Reserach Station, Odakkali).

f. Quality

Cinnamon trees of Indian and Sri Lankan origin were analyzed for their essential oil composition and oleoresin content. The Indian trees yielded bark essential oil in the range of traces to 4.28% and Sri Lankan trees in the range of trace to 3.85%. A study on seedling progenies of cinnamon revealed a clear variation in the performance of the progenies. Four different flush colours were noted among the cinnamon collections, *viz*., pure purple, purple dominated with green, green dominated with purple and pure green. The colour of young leaf flushes of cinnamon was found to be related to its quality. Plants with purple leaf flushes recorded about 29% more bark oil compared with green flushes, showing that flush colour may be taken as a criterion for selection of quality seedlings at the nursery stage.

3. Cassia

The conservatory of tree spices at the Indian Institute of Spices Research(IISR) consists of seedling progenies of 26 Chinese cassia lines collected from Sri Kundara Estate, Valparai, Tamil Nadu. Quality analysis of these accessions revealed a high co-efficient of variability for bark oil and leaf oil (28.1% and 30.1% respectively) but the pungency and flavour of the accessions were more or less uniform as indicated by the cinnamaldehyde content. Bark oil ranged from 1.2 to 4.9%, leaf oil 0.4 to 1.6% and bark oleoresin 6 to 10.5%. The leaf and bark oils possess cinnnmaldehyde as the major constituent and few accessions C1, D1 and D3 were identified as superior, based on their overall chemical and flavour profile and regeneration capacity.

Little crop improvement work has gone into the Chinese cassia in China or Vietnam where the production is located. The crop improvement programme in Chinese cassia aims mainly at selection of clones with high quality (high essential oil content having high cinnamaldehyde); high bark recovery; and high regeneration capacity and growth. With these objectives, cassia germplasm maintained at IISR were evaluated for morphological and quality parameters. Bark oil in various lines ranged from 1.2% to 4.9%, leaf oil 0.4% to 1.6% and bark oleoresin 6.0% to 10.5%. The cinnamaldehyde content of leaf oil ranged from 40 % to 86% and that of bark oil 61% to 91%. The coefficient of variation was high for bark and leaf oil (26.76% and 26.74% respectively). Based on quality and other characteristics, four promising lines were identified. Two lines (A_1 and C_1) have high bark oil (4.7% and 4.9%, respectively) and high cinnamaldehyde in bark oil (91.0% and 90.5%, respectively).

4. Garcinia

a. Species diversity

The genus *Garcinia* (Cluciaceae) includes more than 200 species of trees and shrubs, distributed in the tropics of the world chiefly in Asia and Africa. About 35 species are reported to exist in India including some exotic ones, many of which are economically important. Out of 35 species reported to exist in India, 7 are endemic to Western Ghats, 6 in Adaman and Nicobar Island and 4 in North East India. The genus *Garcinia* includes *Garcinia atroviridi, G. dulcis, G. echinocarpa, G. gummi-gutta, G. hombroniana, G. indica, G. lanceaefolia, G. livingstonei, G. mangostana, G. microstigma, G. morella, G. paniculata, G. pedunculata, etc*. These species can be useful as sources of gamboges, dyes, hydroxyl citric acid (HCA), as good rootstock or for breeding purpose. Among the commercially important species, *G.gummi-gutta* and *G. indica* are cultivated mainly for their spice, which is obtained from the dried rind. *G. mangostana* and *G. morella* are also cultivated to a certain extent for their fruit and gamboges respectively. However, little attention has been given to document and conserve the other economically important species of this genus in the era of Intellectual Property Rights and Biodiversity Conservation.

Garcinia indica Choisy *(Kokum)* is an evergreen graceful tree growing with conical canopy attaining about 10 meters in height. The main shoot is orthotropic whereas branches are plagiotropic exhibiting branch dimorphism. Three sex forms are seen in Kokum namely female, male and hermaphrodite types though it is generally reported to be dioecious. The dried rind of its fruit is the traditional 'kokum' or 'binda' of commerce used for garnishing curries. It is a popular tree spice having tremendous potential and also has many medicinal properties. In South India, it is used as substitute of tamarind in fish curries. The juice of the fruit is used as a mordant and the expressed oil of the seed is the kokam oil of the natives, extensively used to adulterate ghee. The seeds of the fruits yield valuable edible fat known in commerce as kokam butter. The recent understanding on the effect of hydroxyl citric acid (HCA) in preventing obesity in humans has boosted its economic value due to it's HCA content. It is also the richest source of red pigments in the plant kingdom. The tree grows extensively in the Konkan region of Maharashtra, Goa, coastal areas of Karnataka and Kerala, evergreen forests of Assam, Khasi, Jantia hills, West Bengal and Gujarat. Kokum' or *Garcinia indica* Choicy is a spice with great medicinal values occurring in the western coast in a semi wild state. It is a

native of Western Ghats of Kerala (India) and Malaysia. It is fairly common and abundant in the forests of western Sri Lanka from sea level to 600 m. It is widely distributed in the evergreen forests of Western Ghats from South Kanara and Mysore to South Kerala up to the low lying reclaimed lands bordering the backwaters. In Kerala the tree is quite rare except as few trees in state agriculture farms.

b. Conservation

Garcinia gummigutta grows in the evergreen forests of the Western Ghats in South India and its habitat extents from Konkan southward to Travancore and into the Shola forest of Nilgiris where it can reach an altitude of up to 2000 m above mean sea level. In Kerala, it is very popular in the Central Travancore areas and Kerala seems to be one of the centers of origin of cambodge where maximum diversity is seen.

Currently collection of biodiversity of kokum (*G.indica*) is actively being persued by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra in the Konkan region. Several clones are already under evaluation. However, the variability in South Canara types is yet to be collected. The variability in Goa is being collected by ICAR Research complex for Goa at Old Goa. Some collections also have been made by UAS, Dharwar. The Indian Institute of Spices Research, Kozhikode; National Bureau of Plant Genetic Resources (NBPGR) Regional Station at Trichur and the Regional Agricultural Research Station ,Kerala Agri.University at Kumarakom are engaged in collection of biodiversity of all Garcinia especially Kokum and Cambogia. More surveys need to be concentrated in the South Canara district for collection of biodiversity of kokum. The variability of other species in the Andaman and Nicobar Islands and in the North Eastern States of India need to be collected for conservation. The correct identities of many species also need to be confirmed. NBPGR; Indian Institute of Spices Research (IISR) and Botanical Survey of India can mobilize necessary resources in the collection and conservation of the existing variability of kokum and other *Garcinias* in the country. A free exchange of germplasm by the forest departments of various states is also necessary to achieve the objective of kokum improvement.

c. Rare and endangered species

Garcinia mestonii Bailey found in Australia has been identified as a rare species (Hammer and Khoshbakht 2005) and *G. indica* which was listed in the red list in Charmandi (Western Ghats) is at present found in abundance there.

5. Nutmeg

Nutmeg (*Myristica fragrans* Houtt.) is an important tree spice, yielding two spices, namely, the nutmeg (dried seed) and the mace (dried aril surrounding the seed). It is an evergreen, conical tree reaching a height of 10 metres, belonging to the family Myristicaceae.

a. Species diversity

The primitive family Myristicaceae, has about 18 genera and 300 species. The members of the family are pantropical, being associated with the rainforests of Asia, Africa, Madagascar, South America and Polynesia. India has four genera namely *Horsfieldia, Gymnacranthera, Knema* and *Myristica* and altogether 15 species. The members occur in the evergreen forests of Andaman and Nicobar Islands, Meghalaya and the Western Ghats. *Myristica* with 120 species is the largest of the genus and New Guinea has the largest number of species.

Nutmeg is indigenous to the Moluccas islands in Indonesia. Semi-domesticated gene pools of *Myristica* species do not exist as most of these species occur in the wild.

b. Ecosystem diversity

The *Myristica* swamps are dominated by members of Myristicaceae. *Myristica* swamp is a special type of habitat. These swamps were found in the valleys of Shendurney, Kulathupuzha and Anchal forest ranges in the southern Western Ghats. *Myristica* swamps are also reported in Uttara Kannada District of central Western Ghats in Karnataka. These swamps are isolated and situated in localities from near sea level to about 450 m altitude. The northernmost swamp known is associated with a sacred grove in the Satari taluk of Goa. *Myristica* swamps are also reported from New Guinea.

The Western Ghats have three genera and five species of Myristicaceae; all of them are trees associated with evergreen to semi-evergreen forests. Of these *Gymnacranthera canarica* and *Myristica fatua* var. *magnifica* are exclusive to the swamps. *M. malabarica* is occasional in the swamps and more frequent in the evergreen forests. *M. malabarica*, often produce stilt roots and flying buttresses, even though it is seldom associated with swamps, indicating its possible origin in the swamps. Myristicaceae was the most dominant family of the swamps forming 32% of the total number of trees. Within the Myristicaceae, *G. canarica* accounted for 78%, followed by *M. fatua* var. *magnifica* (19%), *K. attenuata* (2%) and *M. malabarica* (1%). Since two species namely, M. *fatua* and *G. canarica* seem to be the most characteristic of *Myristica* swamps, the distribution of these species can be considered as an indicator of the distribution of *Myristica* swamps.

c. Cultivar/varietal diversity

M. fragrans is typically dioecious, with male and female flowers on different trees. Occasionally, male trees carrying a few female flowers are observed. Hermaphrodite trees having bisexual flowers are rarely noticed.

Nutmeg is cultivated in Ernakulam, Trichur, Kottayam and Trivandrum districts of Kerala and also in few areas in Tamil Nadu, Karnataka, Maharashtra, Goa, Andhra Pradesh, North East India and Andaman and Nicobar islands. The oldest nutmeg populations in Kerala are in Kalady (Ernakulam Dt) and Pala(Kottayam dt) and are reported to be more than 150 years old. Nutmeg is usually grown in river banks as it grows luxuriously in silts deposited by rivers. It is reported to be wind pollinated, Inflorescence is branched raceme in male and simple cyme in female. The male inflorescence has more number of flowers (up to 10) while female is less (up to 3).

In a study to identify the sex segregation in nutmeg, it was observed that out of 90 progenies, 40 were males, 45 females and 5 bisexuals. A preliminary analysis of genetic variability in 28 trees (14 years old) indicated some variability only for fruit number per tree. In a more systematic study on genetic variability of nutmeg, progenies from 16 mother trees of different localities (five progenies for each mother tree), lack of adequate genetic variability was evident for many of the important attributes. This particular study revealed that even though morphological variation exists for leaf shape, canopy shape etc. in nutmeg populations, exploitable genetic variation of crop improvement in nutmeg is lacking.

Variability of growth, flowering, and fruit set of 39 seedling progenies of nutmeg was studied at Ratnagiri, Maharashtra and they ,however ,reported considerable amount of variation among the genotypes with respect to growth parameters. High magnitudes of phenotypic coefficient of variation and genotypic coefficient of variation indicated good amount of variation among the genotypes for these characters. High estimates of heritability and genetic advance for fruit set suggested that it is under the control of additive gene action.

Sixty-five nutmeg germpalsm accessions conserved at Indian Institute of Spices Research were evaluated for chemical composition of nutmeg and mace and high variability was observed among the accessions. The essential oil content ranged from 3.9% to 16.5% in nutmeg and 6% to 26.1% in mace. Myristicin content ranged from 1.1% to 45.6% in nutmeg oil and 0.21% to 36.6% in mace oil; the elemicin content. ranged from 1.0% to 29.7% in nutmeg oil and 1.0% to 30.2% in mace oil. Safrole content ranged from 0.1% to 22.1% in essential oil and 0.2% to 21.8% in mace oil.

Accessions with high oil yield in nut and mace, high butter content, high oleoresin in nut and mace, high myristicin and elemicin, low myristin and elimicin etc. have been identified from the germpalsm available at Indian Institute of Spices Research,Kozhiokde.

Crop improvement programme in nutmeg aims at selecting and breeding high yielding trees. Since nutmeg and mace are of economic importance, while breeding/ selecting, emphasis is laid on both the products. High yielding elite trees have been identified from various nutmeg growing areas and their progenies are being evaluated for yield. Recently few varieties have been released for commercial cultivation. The details of these varieties are as under.

A) Name of the variety	**:**	**Konkan Sugandha**
Breeding method	:	Single plant selection.
Originating source/institution	:	Regional Fruit Research Station. Vengurle. Dist. Sindhudurg.
Year of release	:	1998
Potential yield	:	600 fruits / tree / year
Average yield	:	526 fruits / tree / year
Recommended regions / areas of adaptation	:	Konkan region of Maharashtra
Characteristics	:	Tree bears, bisexual flowers, High yielding.
Special attribute	:	Higher fruit set, nut weght 5 g.
B) Name of the variety	**:**	**Konkan Swad**
Breeding method	:	Single plant selection.
Originating source / Institution	:	Regional Coconut Research Station. Bhatye, Dist. Ratnagiri
Year of release	:	2003
Potential yield	:	500-1040 fruits / tree / year
Average yield	:	761 fruits / tree / year
Recommended regions / areas of adaptation	:	Konkan region of Maharashtra
Characteristics	:	Tree bears female flowers, high yielding.
	:	High yielding, higher fruit set, nut weight 5.8 g.
C) Name of the variety	**:**	**Konkan Shrimanti**
Breeding method	:	Single plant selection.
Originating source / Institution	:	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.
Year of release	:	2005
Potential yield	:	9.370 kg dried nut / tree / year and 1.916 kg dried mace / tree/ year.
Recommended regions / areas of adaptation	:	Konkan region of Maharashtra
Characteristics	:	Bold nut, thick mace and high yield.
D) Name of the variety	**:**	**IISR Viswashree**
Breeding method	:	Clonal selection from elite trees.
Originating source / Institution	:	Indian Institute of Spices Research, Kozhikode, Kerala
Year of release	:	2001

Potential yield	:	4800 kg mace / ha at 25th year 31220 kg dry nuts / ha
Average yield	:	480 kg mace / ha 8th year 3122 Kg dry nuts / ha
Recommended regions / areas of adaptation	:	All nutmeg growing areas in Kerala
Characteristics	:	Dark red colour Mace and shining black bold seed and high yield.

In addition to these released varieties few promising nutmeg accessions (A9-4, A9-20, A9-22, A9-25, A9-69, A9-79, A9-86, A4-12, A4-22, A4-52, A11-29, A11-70) are identified at IISR, Kozhikodeand Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, (N-72, N-29, N-70, N-49 and N-74).

d. Conservation of germplasm

The germplasm collections of nutmeg at IISR include 484 accessions. The important species conserved include *M. fragrans*, *M. fatua* var. *magnifica*, *M. malabarica*, *M. beddomeii*, *M. andamanica*, *M. attenuata*, *M. prainii*, *M. amygdalina*, *Gymnacranthera canarica* and *Knema andamanica* .The unique types are a tree bearing 1-4 seeds per fruit, an endangered species, M. *fatua* var *magnifica* and few elite lines. Another bold accession A9-69 and a 'bald type' are of importance. The germpalsm is conserved in the field repository at Indian Institute of Spices Reseach ,Kozhikode. Germpalsm of nutmeg is also conserved at NBPGR Regional Station, Trissur; Kerala Agricultural University,Trissur; Tamil Nadu Agricultural University,Coimbatore; Konkan Krishi Vigyan peeth, Dapoli,etc.

e. Rare/threatened species

Myristica swamps are considered as an endangered habitat. The species *M. magnifica* var *fatua, M. malabarica* are reported to be rare/threatened and need to be conserved. *M. malabarica* has been reported as endangered. *M. dactyloides* included as red listed species from Charmadi and Kammangundi (Western Ghats) is now found widely distributed in those areas.

6. Clove

The clove of commerce is the dried, aromatic, fully grown but unopened flower buds of *Syzygium aromaticum* (L.) Merr. & Perry (Syn. *Eugenia caryophyllus* (Sprengel) Bullock & Harrison) (Myrtaceae). Clove is indigenous to Moluccas where it occurs as a second storey forest tree on the lower mountain slopes. The Dutch Government had restricted the cultivation of clove exclusively to Moluccas but by 19th century beginning, it was smuggled to Mauritius and later on established in the islands of Zanzibar and Pemba. These islands, now part of Tanzania, have become the world's largest producer of clove followed by Indonesia. Under natural conditions, both aromatic and non-aromatic trees occur and the selective culture of aromatic trees led to the present clove population in the world all over. In India, clove cultivation is limited to parts of Kerala and Kanyakumari, Tirunelveli and the Nilgiris of Tamil Nadu. The clove plantation within our country is reported to have originated from a few seedlings introduced from Mauritius.
Clove belongs to the genus *Syzygium* Gaertn. (Myrtaceae) with about 500 species. Genus *Syzygium* Gaertn. has spread to many tropical countries. Many species of *Syzygium* occur in the Indian subcontinent, but they are all very distant species resembling clove only on taxonomic grounds. Hence, a detailed listing of these species is not attempted here. The important species of *Syzygium* occurring in the Western Ghat forests are *S. aromaticum, S. cuminii, S. fruticosum, S. jambos, S. zeylanicum, S. travancoricum* and *S. jambolana.*

Flowers of clove are hermaphrodite, borne at the terminals in trichotomonous panicles, with 3-20 flowers/panicle. Floral biology of cloves favours self pollination. Self pollination is reported to be more

probable mechanism for pollination in clove, as maximum pollen viability and stigma receptivity are attained simultaneously. However, flowers are frequently visited by ants, thrips and bees, suggesting possibility of transferring the pollen from the anther to stigma of same flower or cross pollination.

Genetic base of clove in India is narrow because the original number of introductions was few. Clove tree appears to be uniform type and no distinct varieties/cultivars have been recognized. It is also known that the tree population in Zanzibar and Madagascar are also rather uniform, but in Indonesia, 3 types are distinguished. These types differ in tree habit, leaf size, clove size and colour. In India, differences have been observed in the tree shape, bearing habits, cropping season, yield, colour of the petiole, shape and size of clove.

Seed and seedling characters of progenies of 14 elite clove trees revealed no appreciable variation for 100 fruit weight, 100 seed weight, fruit breadth, fruit length, seed breadth, seed length, germination percentage, root and shoot length and number of leaves of seedlings at 40 days after sowing, one and two years old plant height among the progenies of elite lines at the seedling stage Morphological variability in seedling characters of the progenies of indigenous accessions was found to be very narrow.

At present, the crop improvement programme in clove is limited to the selection of mother trees based on their regular and heavy bearing nature by surveying clove growing tract, besides selection in germplasm. Recently with the introduction of dwarf gene source in the conservatory, it is proposed to develop a dwarf, bushy and early bearing tree with bold cloves. This would favour easy harvest and other cultural operations. High oil yielding accessions would be beneficial for the distillation of oil. Breeding trees with high leaf oil and bud oil would also be advantageous, but is not easy to achieve these aims due to the lack of wide variability in the population. The only way is to introduce further variability from Zanzibar and Indonesia and then initiate a cross breeding programme. Clonal propagation of selected mother trees, avoiding a juvenile phase may result in a breakthrough in productivity.

a. Variety

Horticultural Research Station, Pechiparai (Tamil Nadu), has released a clove variety PPI (CL-1), suitable for Kanyakumari, district. It has high yield (5.2 kg dry/tree), high oil (6%) and high oleoresin (7.13%) contents.

b. Conservation

Surveys were conducted in the major clove growing areas of Tamil Nadu and Kerala and a total of 408 accessions are conserved in the germplasm repository of clove atthe Indian Institute of Spices Research, Kozhikode. Special efforts were made to identify and collect diverse types form Ashamboo hills, the southern most hills of India, where clove was first introduced. The distinctly diverse collection of clove includes three morphological variations *viz*., dwarf and bushy types, accession with exceptionally bold and thick clove buds (king clove) and narrow leaved variants, whereas a reddish purple petioled Zanzibar type from Zanzibar island and one from Sri Lanka are the only introductions at present. Very rarely clove tree with very small buds called *lilliput* clove is also observed in clove. The dwarf gene source in clove has important breeding value in developing dwarf genotypes with compact canopy size. Some of the impotant species of *Syzygium* conserved at IISR are *S. aromaticum*, *S. heynianum, S. jambos, S*. *jambolana, S*. *fruiticosum, S*. *cuminii, S*. *caryophyllatum, S. lanceolatum* and *S. zeylanicum* (Table 2).

7. Allspice

Allspice, *Pimenta dioica* (L.) Merr. (syn: *P. officinalis* Lindl., *Myrtus pimenta* L., *M. dioica* L. and *Eugenia pimenta* DC is a polygamodioecious evergreen tree, the dried unripe fruits of which provide the culinary spice, pimento, of commerce. Leaves are aromatic and are used in the distillation. The berries are used for the preparation of essential oil and oleoresin. It belongs to the family *Myrtaceae* and is known in English as allspice or pimento. The family *Myrtaceae* consists of about 3000 woody species, most of which is grown in the tropics. The genus *Pimenta* Lindl. consists of about 18 species of aromatic shrubs and trees native to

tropical America. The genus is closely related to *Myrtus* L. and *Eugenia* L. The commercially important *Pimenta* spp. are *Pimenta dioica* (L.) Merr. providing the spice pimento (allspice) and *P. racemosa* (Mill) Moore, bay or bay rum tree providing oil of bay.

Allspice was introduced into West Indian Islands (Grenada, Barbados, Trinidad and Puerto Rico) from its place of origin. Attempts to introduce it into countries in tropical regions namely, India, Sri Lanka, Fiji, Malaysia, Singapore and Indonesia (Java, Sumatra) have not succeeded fully due to various reasons. In India, a few trees are available in Maharashtra, Tamil Nadu, Karnataka and Kerala. In India, the plant is reported to be grown in some gardens, especially in Bengal, Bihar and Orissa. There are a few allspice trees available in Nagarcoil, Kallar, Burliar and Horticultrual Research Station, Ambalavayal.

IISR, Kozhikode has a germplasm collection of 180 trees. Variants are rarely reported in allspice. Two seedling variant types with dwarf/semi-dwarf habit and short internodes and bushy nature possessing a large number of branches are being conserved in the field germplasm repository of Indian Institute of Spices Research, Kozhikode, Kerala, India. The leaves were smaller (about 1/3 the size) when compared to that of normal leaves. The variants were multiplied clonally through approach grafting and all the clones exhibited the parental character at IISR, Kozhikode. This dwarf/semi-dwarf plant type in allspice with large number of branches offers great potential in utilizing them in crop improvement programmes.

Post-harvest and processing status report -Kokum (*Garcinia indica* Choisy)

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1. Introduction

Garcinia species are distributed widely throughout the tropical Asian and African countries and have tremendous potential both as spice and medicinal plants. Some of the species in this family possess medicinal properties whereas most of the plants are known for their oil glands or secretary canals and cavities The genus *Garcinia* includes 200 species of which about 30 are reported to be grown in Andaman Islands, North east Hill Region, West Bengal, Orissa, Bihar, Western Ghats covering Maharashtra, Goa, Karnataka, Kerala and Nilgiri Hills in India. *Garcinia indica* (Kokum), *G. gummigutta* (Kodampuli), are widely spread and *G. mangostana* (Mangosteen) and *G. spicata* sparcely distributed in Western Ghats.

Four species are economically very important to India however, only three species are cultivated. *Garcinia indica* Choisy is the source of Kokum/ Murugalu/ Punarpuli grown in Konkan coast for its extensive use of rind, pulp and seed in culinary and medicinal purposes in Kerala, *G. gummigutta* (L.) Rob locally known as Kodampuli or Kodapuli is traditionally grown in homesteads for the fruit rind. *G. magostana* L. is cultivated for its delicious fruit in the Nilgiris, Courtallam and other parts of South India. *G. morella* is still in the wild and is the principal source of gamboges used in medicine.

The precise statistics regarding area under production and productivity is not available for all the varieties of Garcinia since all of them are not planted in an organized manner. As per a base line survey in 2010, Kokum is grown on about 1000 hectare area in the Konkan region with production of about 4500 MT fruits. According to the survey conducted earlier by Chief Conservator of Forest, out of the total 46600 kokum trees in the state of Maharashtra; 43000 trees existed in Ratnagiri and Sindhudurg Districts. It was also reported that in South Konkan1674MT of Kokum fruits were used for production of dried Kokum rind, 757MT for preparation of Kokum syrup and 40MT for manufacture of Kokum butter. Research on production technology for Kokum is being conducted at Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, ICAR Research Complex for Goa, University for Agricultural Sciences, Dharwad and at Indian Institute of Spice Research, Kozhikode, Kerala.

Kokum/ Kodampuli fruits contain compounds that have antioxidant, anti-bacterial and anti-fungal properties. Scientific research indicates activity against ceveral cancer cell lines. In addition it also exhibits antihistamine and anti-inflammatory properties. Therefore, traditionally the fruits have been used for many years as medicinal treatment for diarrhea, skin infection and wounds throughout South Asia.

2. Harvesting and pre-post harvest

- Much of the produce from scattered forest/hilly region trees
- No systematic plantations/orchards
- Even present promotion limited as farm border tree or
- Mixed crop in Cashew garden.
  All these make the adaptation of modern harvesting techniques somewhat cumbersome, if not irrelevant. Besides the fruits being highly acidic and therefore not consumed as fresh fruit but needing further processing, makes it vulnerable to lot of abuse in the form of:
- Harvesting not at proper stage of maturity

- Picking by simply shaking the trees, dropped fruits being severely bruised
- Non Padded-abrassive picking containers
- No Field Packing to reduce handling
- No set time limit for its further processing etc.

However, thanks to the initiative taken by the Western Ghats Kokum Foundation and several other institutions including the Krishi Vidyapeeths and ICAR etc. a move is now set to standardize the harvesting and post harvest procedures to national/international standards of acceptance ,a step in the right direction for extractions of Hydroxy Citric Acid, Garcinol, Colour Pigments and value added products like squash, powders, concentrates, carbonated R.T.S., in tetrapak R.T.S, cosmetics, creams, confectionaries.

3. Post harvest technologies

India is the second largest producer of fruits and vegetables in the world, utilizing 11.6 mio hectare of land with a produce of 94 mio. tonnes. Out of this only 2% of the crop is processed in value added products. 30-35% crop perishes during storage, grading, transport, packing and distribution. Ever more reason that more produce should be processed without delays instead of transporting it over a long distance from the field in the perishable fruit form.

Versatile medicinal fruit like Kokum opens us to a variety of value added products ranging from simple culinary supplements to highly sophisticated anti obesity, anti-allergic, dermatological products. The range also offers opportunities for cottage industry to small and medium scale industrial outfits

Fruit portion and corresponding preparations

Fruit Rind	***Seed***
Dried Rind	Kokum Butter
Squash	Facial Creams
Syrup	Lipsticks
Rind powder	Skin Ointment
Wine	Chocolates
Hydroxy Citric Acid Formulations	
Garcinol Formulations	
Anthocyanins as Natural Colourants	

Need for standardisation of processing methods

Presently Kokum Syrup, Kokum Agal, Kokum Amsul are being prepared traditionally, in the entire Konkan belt, the problems associated with are:

- Lacking in uniformity in product quality due to variation in non standardized starting materials
- Being a cottage industry operations, hygiene norms are difficult to maintain
- Not packed in appropriate packaging material so that it could be kept safe storage for longer duration
- Extraction of Kokum Seeds is done inefficiently so that the yield as well the quality is adversely affected.
- Nutritional composition of the products needs to be studied and mentioned
- Shelf life of the products has to be determined and accordingly labeled.
- HACCP principals as modified by WHO ,specially for small scale industry in India need to be implemented

(i) Traditional (standardized) products from kokum

Kokum Syrup (Amrut Kokum)

The fruits are washed with clean water and each is cut in two halves and the seed and pulp of fruit is removed. Rind is cleaned internally and sugar is poured into a the opened fruit halves forming one layer. Alternate layers of Kokum rind halves and sugar are put in cleaned food grade plastic drums for 7 days. Kokum rind gets extracted by osmosis while quantity of sugar gets dissolved in it the syrup is then strained through 1mm sieve or muslin.

Kokum Amsul (Dehydrated Salted Rind)

Fresh Kokum fruit is washed thoroughly and cut into two halves to separate the seed and pulp from the rind. The seed and the pulp is mixed with around 10 percent salt. The salt solution leaching out from this mixture is used for dipping of the separated rind. This coated rind is for drying in the sun or preferably is tray dried in the oven. The next day the dried sample is again dipped in the salt solution, which has leached on the second day from salt seed mixture. The rind is again exposed to sun/tray drying.The process of dipping and drying is further repeated for 2 to 3 times to get the
deesired coloured quality Amsul.

Kokum Agal (Brined Kokum Juice)

Agal is a simple salted juice of Kokum fruit. The salt is added upto the concentration of 20 percent. Stirred and kept aside. The mixture is stirred daily for subsequent seven days. At the end, the whole mixture is strained through stainless steel sieve of 1 mm the filtered brined juice is filled in pre-sterilised bottles.

Kokum drink ready to serve (R.T.S.)

The T.S.S. and acidity of the juice is evaluated and then required quantity of citric acid and sugar is added to raise the Brix and acidity levels to 200 Brix and 0.3 percent acidity respectively.In general, following parameters are adopted.Juice 20%, T.S.S. 20%, Acidity 0.3% and Water q.s. Preservative, sodium benzoate at 140 mg/kg of final product. After addition of required quantity of sugar, citric acid and water, the mixture is boiled till all the ingredients are dissolved. Sodium benzoate is added at the end and subsequently the product is filtered and filled into presterilized bottles with crown caps and sealed. The filled bottles are pasteurized for 30 minutes in boiling water, removed, cooled.

Kokum Squash

Kokum Squash is prepared as per the following parameters with addition of sugar to bring Brix level to 450 Brix.Juice 25%, T.S.S. 45%, Acidity 1.2% and water q.s. After adding necessary quantity of sugar, the product is boiled to dissolve the ingredients. Preservative sodium benzoate at 610mg / kg of final product is added to it and the contents are filled in clean bottles with crown caps. Bottles are pasteurized for 30 minutes in boiling water, removed and cooled.

Kokum Butter

The oil is traditionally extracted by boiling the kernels in water and oil which separates out at the top is skimmed off. Currently preferred way is by solvent extraction. The yield of oil (fat) is about 25%. The fat is greasy to feel and is of whitish yellow to off white in colour. The final product has to conform to the following specifications:

Colour: Off white to yellowish
Melting Point: 39–43 deg centigrade
Sap Value: 189
Iodine Value: 34.7 to 36.7
Unsap. Value: 1.4%

(ii) Recently introduced value added products of kokum

Kokum rind powder

Dried Kokum fruits are cleaned to remove seeds and extraneous matter. It is cut into bits, loaded in percolator and extracted with hot water to obtain Kokum concentrate. The concentrate is mixed with a suitable carrier and dried under controlled conditions to obtain Kokum powder. The product may also be obtained through spray drying in the form of flakes or powder.

Kokum sarbat mixture

It is instant mix product (ready to use). Kokum powder, sugar and spices as desired are added in requisite concentrations and the mixture is dried in controlled atmosphere dryer.

Kokum solkadhi mixture

It is an instant mix product (ready to use). Kokum powder, coconut milk powder, milk powder, salt, sugar and spices are added in requisite quantity and the mixture is dried in controlled atmosphere dryer.

Kokum honey

Efforts are on to establish apiculture unit of Kokum, where systematic plantation of Kokum trees exists e.g. Cuncolim, Goa. If successful, we may expect to derive honey of some additional medicinal value.

Kokum wine

Kokum juice has approximately 4 percent sugar and can be fermented to produce wine. For homemade wine making, Goa has always been in the fore front.

Hydroxy Citric Acid (HCA)

One of the phyto-chemical in Kokum is HCA, which is an anti-obesity agent, marketed in the form of its salt.

The Kokum rind is extracted with water and the combined extract containing approx 30TDS is hydrolised to PH 8 at 800 deg. centigrade, the resultant mixture is precipitated to desired salt of Calcium/ Potassium/ Magnesium or double salt of Ca-K or Ca-Na. The salt is filtered, dried, milled, sieved and autoclaved.

Anthocyanins (Colourants)

Kokum offers as one of the best candidate for extraction of anthocyanins (upto 2.4% of dried rind) which can be used as colouring material of natural origin, for food and pharmaceutical products. The pigments have a potential to absorb UV light as a result they could be components of sunscreen lotions and pastes in cosmetic industry.

Garcinol

Kokum is rich in polyisoprenylated benzophene derivatives such as Garcinol. Traditionally Garcinol was used in tropical region for centuries but its biological properties are beginning to be elucidatedonly recently. Besides its potential antioxidant properties, emerging evidence confirms that Garcinol could be useful as an anti cancer agent and being a pleotropic agent is capable of modulating key regulatory cell signaling pathways. Though Garcinol isolation /production has yet not gone beyond laboratory/pilot scale levels, at current process it can be easily crystallized out in the form of yellow needles (1.5%) from the hexane extract of the rind.

4. Machinery manufacturing and processing technologies

Entire range of machinery, right from harvesting to pre processing, cleaning, cutting, separations to finally syrup making etc. is available locally in Konkan region itself and the units so manufactured and supplied are operating in small and medium scale units for the traditional products. Similarly technology for modern products in powder/ spray dried form is available with Hardikar Technologies, Pune, Hydroxy Citric Acid with Prakruti Products Pvt. Ltd, Karwar, Microencapsulation of Anthocyanins with CFTRI, Mysore, Tetrapak presentation of Liquid Products with Aparant Agro Foods Pvt. Ltd., Dapoli and Wine making with Dr. John Carmo Rodrigues, Goa.

5. Conclusions

Multi facet therapeutic fruit tree of the Konkan region,Kokum, has remained virtually unnoticed to the medicinal and scientific community elites despite its track record of being in every household of South India in daily cuisine and medicine cupboard. Part reason being, none of its traditional - products were ever 'standard', nor its cultivation took to mass scale to catch the eye. Thus with the authorities it always remained as a "minor fruit" of the region and was relegated to background with no promotion efforts. Thanks to the joint initiative by Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli and three successive national seminars by Western Ghats Kokum Foundation, Goa, superior varieties Konkan Amrita and Konkan Hatish are released for planting in the hands of farmers and the standardization of traditional products such as Dried Kokum Rind, Kokum Agal, Amrit Kokum, etc. have already begun and soon the institutions will come up with guidelines-Good Production Procedures- for the processors of the region.

It would be equally important to see that instead of each farmer household indulging in a processing venture, a cluster approach will have to be adopted such as formation of Self Help Groups (SHG) of the community that will then initiate this processing venture. This will have two distinct advantages; one that it brings in larger volumes for the project and second that the final standard product can be marketed under a brand name even locally. The more modern and sophisticated products dealing in Hydroxy Citric Acid, Garcinol, Anthocyanins and even Wines will require further research and development efforts to bring them to level of desired status of international standards before they contribute handsome returns to kokum family. Keeping the focus on ultimate benefit to the farmer, efforts should be to convince the entrepreneurs to work out their manufacturing flow charts in a way that the preliminary steps as much as feasible are passed on to the farmers concerned. The Western Ghats Kokum Foundation will thrive for this and in fact is in preliminary discussions with producers of HCA and large beverage manufacturers.

Development schemes of Spices Board

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1. Introduction

India is a leader in global spice market having a volume share of 48% and value wise share of 43% in the world spice trade. India is famous world over as "The Home of Spices" widely acknowledged for its unique taste and aroma, making it a top favourite in world market.

India is considered as the largest producer and consumer of spices in the world. The unique climate of India varying from sub-tropical to temperate is ideal for growing almost all the spices. There will not be a single state in India, which does not produce at least a single spice. Out of the 109 spices listed by ISO, India produces more than 60 spices in different varieties. The total spice production in the country accounts for more than 45% of the world production. The Indian spices like Guntur Sannam chillies, Byadagi chillies, Naga chillies, Alleppey finger turmeric, Erode turmeric, Lakadong turmeric, Cochin ginger, Malabar pepper, Alleppey green cardamom, Coorg green cardamom etc. are much sought in the International market.

The global spice industry is experiencing a paradigm shift. Due to the change in lifestyle, there is an increased preference for convenience foods and hence the focus of demand has changed from whole spices to value added spices. Other than the food industry, spices are now well known for oil, oleoresins, health foods, cosmetics, nutraceuticals and medicinal properties. The stringent quality parameters imposed by the importing countries has shifted the focus to food safety, traceability, sustainability and fair trade. This has created an increased demand for organic spices.

With the entry of more countries in spice production and trade, the position of India in the world market is becoming more competitive. Therefore, it becomes imperative to raise the productivity level of spices to make available the commodities at competitive prices and also to improve the quality of the produce adopting the latest technology.

2. Area and production of spices in India

The average production of spices in India is over 63.24 lakh tons and area under cultivation of spices is approximately 35.41 lakh hectare (Table 1). Only 10% of spices produced in India is exported. The remaining 90% is consumed in India itself. Pepper and cardamom (small) are mainly produced in the states of Kerala, Karnataka and Tamil Nadu, cardamom (large) in Sikkim & West Bengal, seed spices in the states of Rajasthan, Gujarat, Uttar Pradesh, Haryana; Mint in Uttar Pradesh, Tree spices in the southern states, Konkan belt and Andaman & Nicobar islands , Saffron in Jammu & Kashmir, herbal spices in the Tamil Nadu. The common spices like chilli, ginger, turmeric and garlic are produced in almost all the states (Fig. 1).

Table 1. Spice wise area and production (2011-12)

Spices	Area in ha.	Prodn. in tonnes
Pepper	201381	48000
Cumin	842560	461160
Chilli	840610	1426520
Coriander	540700	511760
Garlic	262780	1302070
Turmeric	237720	1246220
Ginger	161850	773060

Fennel	100610	142960
Fenugreek	93170	117320
Cardamom (Small)	71285	10380
Tamarind	60680	205180
Ajwan	45700	28050
Cardamom (Large)	26460	3860
Dill Seed	21900	23632
Nutmeg	18440	12210
Celery	4070	5510
Saffron	2989	9
Clove	2100	1110
Grand Total including others	**3541804**	**6319011**

Source: State Agri./ Horti. Depts. /Spices Board

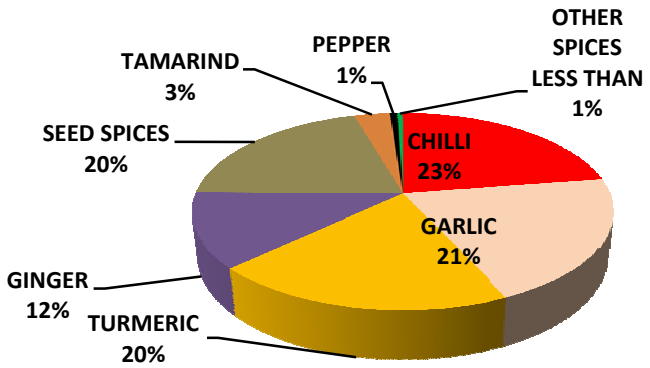

Fig. 1. Production share of major spices (2011-12)

3. Export of spices

Indian spices exports have been able to record strident gains in both volume and value in rupee terms. Spices exports have registered substantial growth during the last five years, registering an annual average growth rate of 21% in value and 10% in volume and India commands a formidable position in the World Spice Trade

During the 2012-13, a total of 6,99,170 tons of spices and spice products valued Rs.11171.16 crore (US$2040.18 Million) has been exported from the country as against 5,75,270 tons valued Rs.9783.42 crore (US$ 2037.76 Million) in 2011-12, registering an increase of 22% in volume and 14% in rupee terms of value (Fig. 2 & Table 2). It is first time in the history of spices export, the growth in volume registered an all time growth of 22%. Major contributors of the export basket are listed in Table 3.

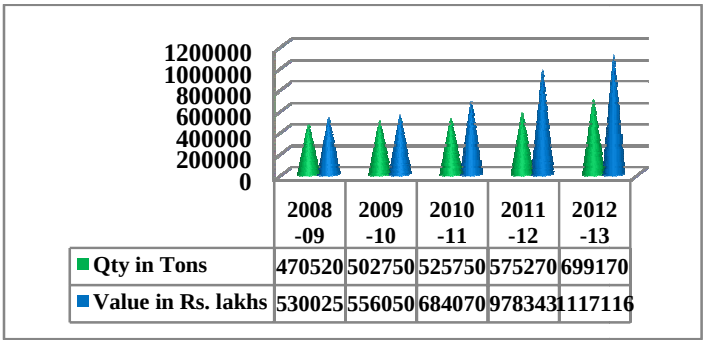

Fig. 2. Total spices export from India over last five years

Table 2. Export of spices from India during 2011-12 and 2012-13

Spices	2011-2012 (E)		2012-2013 (E)	
	Qty. in Tons	Value in Rs. Lakhs	Qty. in Tons	Value in Rs. Lakhs
Pepper	26700	87813.45	16000	67256.57
Cardamom (S)	4650	36322.28	2250	18505.92
Cardamom (L)	935	6830	1100	7366.19
Chilli	241000	214408	281000	226144
Ginger	21550	20420.02	19850	16863.1
Turmeric	79500	73434.4	80050	53985.4
Coriander	28100	16401.85	37100	21076.9
Cumin	45500	64442.05	79900	109317.6
Celery	3650	2340.05	4800	3055.15
Fennel	8100	7209.2	14575	11402.04
Fenugreek	21800	7275.2	31100	10835.74
Other Seeds (1)	13050	5881.25	18600	11612.1
Garlic	2200	1415.7	24000	7449.21
Tamarind	21395	12364	18200	10756.2
Nutmeg & Mace	3620	24097.51	3645	26095.06
Vanilla	31	286.14	55	682.72
Other Spices (2)	14474	19382.86	19295	21411.03
Curry Powder/ Paste	17000	25208.25	19000	29835.93
Mint Products(3)	14750	222372	19980	332179.3
Spice Oils & Oleoresins	7265	130438.3	8670	131286.3
Total	**575270**	**978342.5**	**699170**	**1117116**
Value In Million US $	**2037.76**		**2040.18**	

(1) Include Mustard, Aniseed, Bishops weed (Ajwainseed), Dill seed, poppy seed etc.
(2) Include Asafoetida, Cinnamon, Cassia, Cambodge, Saffron, Spices etc.
(3) Include Mint oils, Menthol & Menthol crystals
Source : DGCI&S., Calcutta/ shipping Bills/ Exporter's Returns

Table 3. Major contributors to export in 2012-13

Major spices	Value		Volume	
	(Rs. lakhs)	(%)	(MT)	(%)
Mint products	332179	29.7	19980	2.9
Chilli	226144	20.2	281000	40.2
Spice Oils & Oleoresins	131286	11.8	8670	1.2
Cumin	109318	9.8	79900	11.4
Pepper	67257	6.0	16000	2.3

Turmeric	53985	4.8	80050	11.4
Curry Powder/paste	29836	2.7	19000	2.7
Nutmeg & mace	26095	2.3	3645	0.5
Coriander	21077	1.9	37100	5.3
Cardamom (S)	18506	1.7	2250	0.3
Ginger	16863	1.5	19850	2.8
Fennel	11402	1.0	14575	2.1
Fenugreek	10836	1.0	31100	4.4
Tamarind	10756	1.0	18200	2.6
Garlic	7449	0.7	24000	3.4
Cardamom (L)	7366	0.7	1100	0.2

In 2011-12, Indian spices reached more than 137 countries and 20 countries cover 80% of export value (Fig. 3 & Table 4).

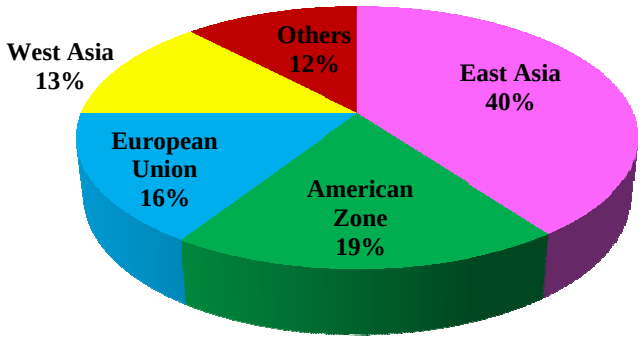

Fig. 3. Zone wise exports from India

Table 4. Major markets for Indian spices

Country	Major items
U.S.A	Mint items, Spices Oils & Oleoresins, Pepper, Chilii and Turmeric
China	Mint products, Chilli, Spices Oils & Oleoresins
Malaysia	Chilli, Turmeric, Coriander, Cumin, Fennel
U.A.E	Turmeric, Chilli, Nutmeg, Curry powder, Cumin
U.K.	Spices Oils & Oleoresins, mint products, Chilli
Bangladesh	Chilli, Turmeric, Garlic, Ginger, Cumin
Germany	Spices Oils & Oleoresins, mint products, Turmeric
Pakistan	Chilli, Large cardamom, Cumin, Coriander
Japan	Spices Oils & Oleoresins, mint products, Turmeric
Sri Lanka	Chilli, Turmeric, Coriander, Cumin, fennel
Saudi Arabia	Small Cardamom, curry powder, Turmeric, Ginger
Singapore	Spices Oils & Oleoresins, mint products, Chilli
South Africa	Spices Oils & Oleoresins, Turmeric, Chilli, Coriander
Netherlands	Spices Oils & Oleoresins, mint products, turmeric, Pepper, Chilli
Mexico	Spices Oils & Oleoresins, mint products, Cumin, Chilli
Brazil	Spices Oils & Oleoresins, mint products, Cumin, Chilli

4. Import of spices 2012-13

The import of spices during 2012-13 was 1,31,722 tons valued at 2102.31 crores (US$ 387.90 million) (Table 6).

Table 6. Item-wise import of spices into India

Item	2012-2013 (E)	
	Qyt. in tonnes	Value in Rs. lakhs
Ginger Fresh / Dry	57090	10409.89
Pepper (1)	15600	56944.18
Cassia	12180	8225.59
Poppy Seed	11630	23221.5
Clove	10105	45188.27
Other Spices (2)	4960	7848.88
Star Anise	4695	7482.4
Coriander	4470	3526.04
Cardamom (Large)	3895	14558.8
Turmeric	2495	2173.89
Oils & Oleoresins (3)	1325	19303.95
Chilli/ Paprika	1225	940.22
Nutmeg	720	3575.04
Mace	567	4937.27
Cardamom (Small)	495	1612.44
Cumin Black/ White	120	165.36
Garlic	95	105.3
Mustard Seed	55	12.84
Total	131722	210231.86
Value in million US $		387.9

(1) Include White Pepper, Light Pepper and Black Pepper
(2) Include Aniseed, Asafoetida, Cinnamon, Pepper Long, Cambodge, Herbal Spices And Spices Nes.
(3) Include Spices Oils & Oleoresins And Mint Products.

Source: From Customs/ D G C I & S., Calcutta

The import of spices is mainly for value addition and re-exports. However, spices such as ginger fresh and cardamom (large) are from neighbouring countries under Free Trade Agreement and tree spices are to meet domestic demand.

5. Development schemes of Spices Board

Spices Board, India, under the Ministry of Commerce and Industry, is the apex organization for promoting Indian spices and spice products worldwide. The Board was constituted on 26th February, 1987 as per the Spices Board Act, 1986 by merging the erstwhile Cardamom Board and Spices Export Promotion Council.

The mandate of the Board is mainly export development and promotion of 52 scheduled spices and their processed form. The Board extends support for production, processing, domestic marketing and export of cardamom (small & large). As an export enhancing measure, it also supports post harvest and quality improvement of spices and development of organic spices in North East region. Besides development, the Board carries out research on cardamom and post harvest improvement in spices, quality evaluation services, sampling and testing of select spices for adulteration/ contamination and regulatory function of granting certificate for export of spices & licensing of dealers and auctioneers of cardamom.

All the development programmes of Spices Board are implemented under a single scheme – Export Oriented Production. The priority is for overall development of cardamom, both small and large. All the programmes are for the benefit of small and marginal framers. The programmes are grouped under the below listed heads.

1) Cardamom (small)
2) Cardamom (large)
3) Development of spices in other North Eastern States
4) Post harvest improvement of spices
5) Extension advisory Programme
6) Quality improvement programmes
7) Pepper Development Programme

(i) Programmes for cardamom (small)

Small cardamom is grown mainly in the Western Ghats of Kerala, Karnataka and Tamil Nadu. The majority of the cardamom holdings are small and marginal. The total area under cardamom during 2012-13 was 69870 ha with an estimated production of 14000 tons.

a) *Production of quality planting materials:* In Karnataka, the planting materials are produced through bed nurseries, poly bag nurseries and sucker nurseries and Rs.1.25 per planting material is given as subsidy whereas in Kerala Rs.1.75 per sucker is given assistance for sucker multiplication nurseries.

b) *Replanting:* This programme is intended to encourage small and marginal growers to take up replantation of old, senile and uneconomic plantations. A per hectare subsidy of Rs.39,171/- and Rs.29,675/- is offered to small and marginal growers respectively having cardamom area up to 4 ha. and above 4–8 hectares respectively in the States of Kerala and Tamil Nadu. In Karnataka, the per hectare subsidy offered is Rs.29,919/- for holdings up to 4 hectares and Rs.22,666/- for holdings above 4-8 hectares The subsidy provided for planting material production is deducted from replanting subsidy.

c) *Irrigation and land development:* The programme aims at providing water resources in cardamom plantations by constructing water storage devices like farm ponds and wells. Installation of irrigation equipments, soil & water conservation works are also supported. The programme provides financial support to farmers by way of subsidy ranging from 25 to 50% of the unit cost.

d) *Rainwater harvesting:* Irrigation during summer months is very much essential in cardamom plantations for getting a higher yield. A cheap method of harvesting rain water for irrigation purpose in the cardamom plantations is adopted using excavated storage tanks lined with UV resistant polythene tarpaulin also called Silpauline sheets. It is estimated that a storage tank of 200 cubic metre capacity (eg. 16 m × 5 m × 2.5 m lined with Silpauline) can store about two lakh litres of rain water, which is sufficient to provide 10 – 12 rounds of irrigation in a cardamom plantation of 0.8 hectare. The cost of such a device is estimated to be around Rs. 24,000/- (Rs.16,000/- for excavation work and Rs. 8,000/- for silpauline sheets). Subsidy @ 33.33% of the actual cost, limited to Rs. 8000/- is given for the construction of one 200 cubic metre capacity tank to registered small and marginal growers of cardamom.

e) *Improved curing devices for small cardamom:* Cardamom is dried in traditional curing houses using firewood as fuel. Sun drying is not popular due to the loss of green colour during the process. Few innovative growers have started installing cardamom curing systems using alternate fuels, *viz*., Diesel, LP gas which gives their produce better colour and cost effective drying. These driers are eco-friendly, labour saving and easy to operate. The drying time is reduced from 28–36 hours to about 20 hours in

these driers. Under this programme, assistance of 33.3% of the actual cost of drier subject to a maximum of Rs.60,000/- per device is provided.

(ii) Programmes for cardamom (large)

Cardamom (large) is mainly grown in the Sub Himalayan tracts of Sikkim and Darjeeling district of West Bengal. The total area under large cardamom during 2012-13 was 26060 ha with an estimated production of 4145 tons. Non availability of quality planting materials, presence of senile, old and uneconomic plants, incidence of blight disease, are the major factors affecting large cardamom production.

a) *Replanting:* The programme is intended to encourage the growers to take up replantation of old, senile and uneconomic gardens. A per ha. subsidy of Rs.12,500/- is offered to small growers and Rs. 9,500/- to marginal growers, which being 33% and 25% respectively of the cost of replanting and maintenance during gestation period (subsidy offered for planting material production will be deducted from the subsidy for replantation).

b) *Production of planting materials through certified nurseries:* For making available quality planting materials to the growers, Board gives assistance @ Rs.1.15 per sucker for raising of sucker nurseries in farmers' field.

c) *Rainwater harvesting:* Harvesting of rainwater in plantations is encouraged using devices made of earth excavated pits lined with silpauline sheets. Subsidy @ 33.33% of the actual cost, limited to Rs. 8000/- is given for the construction of one 200 cubic metre capacity tank to registered small and marginal growers.

d) *Curing houses (Modified bhatti):* The large cardamom growers traditionally cure their cardamom in the locally fabricated bhatties. This does not ensure proper drying and ideal colour in the cured cardamom. Board had introduced and evaluated a number of curing methods using different fuels and has selected a system which gives best quality. In order to popularize this method, Board is providing subsidy @ Rs.5,000/- for 200 kg capacity and Rs.9,000/- for 400 kg capacity drier respectively.

(iii) Other North Eastern States

The agro – climatic conditions prevailing in NE states are suitable for the cultivation of pepper, large cardamom, ginger, chilli, turmeric etc. and these crops can be profitably grown in these regions for making available more spices for export. The greatest advantage of the spices produced in these regions is that they are organically produced and thus organic cultivation of these spices are promoted.

The major constraints noticed in the development of spices in NE region are lack of an organized marketing system and lack of knowhow on cultivation and post harvest practices. Spices Board therefore, is implementing an integrated scheme for the development of spices in North East.

a) *Cardamom (large) development -New planting:* Large cardamom cultivation is presently concentrated in Sikkim and North West Bengal. The agro-climatic conditions prevailing in other NE States are suitable for cultivation of large Cardamom.

b) The scheme envisages to extent large cardamom cultivation in these north eastern states by providing Rs.17,500/- per ha as subsidy towards cost of planting material and maintenance during gestation period. This programme was mainly taken up in the states of Arunachal Pradesh, Mizoram and Nagaland.

c) *Rainwater harvesting:* Harvesting of rainwater in plantations is encouraged using devices made of earth excavated pits lined with silpauline sheets. Subsidy @ 33.33% of the actual cost, limited to Rs. 8000/- is given for the construction of one 200 cubic metre capacity tank to registered small and marginal growers.

d) *Curing houses (Modified bhatti):* The large cardamom growers traditionally cure their cardamom in the locally fabricated bhatties. This does not ensure proper drying and ideal colour in the cured cardamom. Board had introduced and evaluated a number of curing methods using different fuels and has selected a system which gives best quality. In order to popularize this method, Board is providing subsidy @ Rs. 5,000/- for 200 kg capacity and Rs.9,000/- for 400 kg capacity drier respectively.

e) *Organic cultivation of Lakadong turmeric:* Lakadong turmeric is having high curcumin content (5.5%) and hence suitable for extraction of colour. This variety is highly location specific and is very much preferred by the exporters for extraction of the colour. Availability of quality planting materials is a major limiting factor in its production and so an assistance of Rs.12,500/- per ha towards 50% of the cost of planting material is provided under this programme.

f) *Organic cultivation of ginger:* Ginger varieties like Nadia and China are having higher oil content and hence are suitable for exports. To promote production of these varieties organically in NE states, Rs.12,500/- per ha is provided as assistance towards 50% of the cost of the planting materials.

g) *Training of officers and farmers of NE states:* Board arranges training programmes for the officers of the State Agri/ Horti. Departments and growers of North Eastern States on the recent advances in the areas of cultivation, harvest and post harvest techniques of spices. The training is arranged in alternate years for officers and every year for farmers.

(iv) Post-harvest improvement in other spices

The Board supports post harvest improvement programmes for those spices having good demand in the international market. With the stringent quality parameters being imposed by the importing countries, it is necessary that the post harvest processing of spices should be done under hygienic conditions, which will result in production of clean spices for export.

a) *Seed spice threshers:* The harvesting and post harvest practices followed by some farmers of seed spices are unhygienic which results in contamination of the products with foreign matters like stalks, dirt, sand, stem bits etc. The seeds are separated by beating the harvested and dried plants with bamboo sticks or rubbing the plants manually by hand or trampling under the feet of the cattle. In order to separate the seeds from the dried plants and to produce clean spices, Board popularizes the use of threshers which are operated manually or with power. The cost of such a power and manual thresher are estimated as Rs.1.00 lakh and Rs.30,000/- respectively. The assistance provided is 50% of the cost subject to a maximum of Rs.50,000/- for a power thresher and Rs.15,000/- for a manually operated thresher.

b) *Supply of pepper threshers:* The objective of this programme is to assist the pepper growers to acquire threshers to separate pepper berries from spikes under hygienic condition. Pepper growers having a minimum of 500 vines are eligible to avail the programme. The subsidy offered is Rs.7,000/- per thresher irrespective of the capacity of the equipment.

c) *Supply of turmeric steam boilers:* The programme is intended to assist the turmeric growers to adopt improved scientific methods of cooking using boilers and perforated trough made of GI or MS sheet extended with parallel handle. This ensures optimum cooking of turmeric, which provides better colour

and quality to the final produce. Hence the use of large scale turmeric boilers is popularized among growers for production of quality turmeric suitable for exports. The subsidy provided under this programme to turmeric growers groups/ NGOs is 50% of the cost of the boiler or Rs.1.20 lakhs per boiler whichever is less.

d) *Promotion of Integrated Pest Management in chilli (IPM):* In order to reduce the pesticide residues in chilli and make available quality produce for export, the programme of integrated pest management in chillies is taken up. The Board has implements this programme selected districts od Andhra Pradesh and Karnataka by supplying IPM kits containing pheromone traps, bio agents like Trichoderma, Trichogramma, neem based pesticides, BT, HNPV lures, SNPV lures etc at an estimated cost of Rs.2,000/- per ha. This comprises 50% of the cost of the IPM package.

e) *Supply of HDPE/ Silpauline sheets for drying spices:* In order to dry spices *viz*., pepper, chillies and seed spices under hygienic conditions, the Board subsidizes the supply of HDPE/ Silpauline sheets to the small and marginal growers. The Board arranges centralized supply of sheets at subsidized cost of 33%, 50% and 90% for farmers under general category, scheduled caste and scheduled tribes respectively. The non-subsidy portion is met by the growers.

f) *Distribution of bamboo mats for pepper:* The programme is intended to encourage the small and marginal pepper growers to dry pepper on hygienic bamboo mats coated with paper-fenugreek paste.

g) *Training programme for quality improvement of spices:* The Board is regularly conducting quality improvement training programmes for farmers, officials of State Agri./ Horti. Department, traders, members of NGOs for educating them on scientific methods of pre/post harvest & storage operations and updated quality requirements for major spices all over India.

(v) Promotion of organic farming

The major bottlenecks in promoting organic farming are non-availability of organic farm inputs and high cost of organic certification of farms and processing units. In order to promote organic production of spices, programmes like organic farm certification assistance, support for setting up vermi-compost units, promoting organic cultivation of spices are given assistance.

a) *Organic farm certification assistance:* The programme aims to help growers/processors of spices in acquiring organic certification which is a pre-requisite for marketing organic spices. Under this programme, Board provides assistance to group of farmers, NGOs and Farmers Co-operative Societies/Associations in acquiring certification for their farms/processing units by meeting 50% cost of the certification, subject to a maximum of Rs.75,000/-. Individual farmers and processors are eligible for 50% of the cost of certification subject to a maximum of Rs.25,000/- per certification.

b) *Support for vermicompost units:* There is need to produce organic inputs in the farm itself to maintain soil fertility and to us organic production. In order to enable the growers to produce organic farm inputs, particularly vermicompost, Rs.2,000/- is offered as grant-in-aid to growers to set up a unit with one ton output of vermicompost.

c) *Organic cultivation of spices*: Since the market for organic products is gradually registering an upward trend, there is large scope for promoting organic cultivation of spices in suitable locations. The Board is assisting growers for taking up organic cultivation of spices by giving a subsidy of 12.5% cost of production subject to a maximum of Rs.5,000/- per ha. The programme will be implemented with the participation of selected NGOs by paying them retention fee @ Rs.500/- per ha and Rs.250/- per ha is

given for meeting the cost of organic certification. These expenses will be deducted from the total amount of subsidy and balance only will be paid to the beneficiaries.

(vi) Extension Advisory Service

Transfer of technical know-how to growers on production of spices is an important factor in increasing productivity. Under this programme, technical/extension support is given to growers on the scientific aspects of cultivation through personal contact, field visits, group meetings and distribution of literature in vernacular languages. All the programmes under the scheme "Export Oriented Production" are implemented through the extension net work.

(vii) Black pepper development

As an Agency concerned about the plight of Indian pepper industry and in response to the invitation from various quarters of the industry and directions from the Ministry of Commerce, Spices Board had taken up production development of pepper in Idukki District of Kerala in line with NHM guidelines with financial assistance from NHM. The Ministry of Commerce, Govt. of India had approved a scheme for development of pepper in Wayanad and North Eastern States in 2009 for a period of five years. The main programmes are –

a) Production of planting material: Planting materials required for replanting/rejuvenation are produced through small scale certified nurseries opened in growers' field. Assistance of Rs.1.50 per rooted cutting is given and maximum of 5000 cuttings can be produced by a grower. In North East, assistance of Rs.3.00 is given per cutting.

b) *Replanting/ rejuvenation of senile plantations:* Under this component, senile, disease affected and poor yielding vines in the existing plantations are replanted/rejuvenated with healthy, disease free planting materials of high yielding local cultivars and identified traditional/improved varieties which are adaptable to the habitat. The scale of assistance @ Rs.15,000/- per hectare was given under this programme.

c) *Promoting production of organic inputs:* It is necessary to produce organic inputs in the farm itself to maintain soil fertility and to support organic production. Vermicompost is considered as a potential soil enrichment input as well as a soil re-conditioner. Under this component assistance of @ Rs.3,000/- per unit is given.

d) *Promotion of integrated disease management:* Proper cultivation practices and biological control of diseases can revive the health of the soil and sustainability of the crop. Through this programme, farmers are given bio-inputs such as Trichoderma and Pseudomonas as well as copper sulphate at subsidized rates for

All the payments under the different programmes are directly credited to the account of the beneficiaries through e-payment.

(viii) Other programmes of the Board

The different programmes are infrastructure improvement, trade promotion, product development and research, market study abroad, promotion of Indian spice brands, spice parks for common processing facilities, participation in International fairs/meetings/seminars/trainings, promoting organic/ medicinal value of spices and GI registration.

The quality evaluation laboratory of the Board carries out the mandatory pre-shipment quality checking of export consignments of chilli, chilli products, turmeric powder and nutmeg, provides training to technical persons on physical, chemical and microbiological analysis and renders quality evaluation services for the spice industry. Tthe research wing of Spices Board also conducts mobile agri clinic services and residential training on GAP to unemployed youths.

6. Constraints in spices development

1) Vagaries of climate
2) Large number of small and marginal holdings.
3) Lack of availability of quality planting materials.
4) Inadequate nutrition management.
5) Pest and disease problems.
6) Low productivity.
7) Pesticide residue and label claim issues in spices
8) Lack of mechanization in pre and post harvest operations.
9) Market Intermediaries
10) Weak supply chain management.

7. Proposals for XII Plan

In the XII plan, in addition to the ongoing programmes, Spices Board is mainly focussing on a sustainable production, increasing productivity, addressing issues of pesticide residues and labour shortage and improving quality, which in would ensures a stable income to the farmers. The expanded programmes are-

Spice Producers Societies: The Board proposes to set up spice producer's society in major spice growing tracts. These societies will function as nodal centers for dissemination of information to farmers and act as bridge linking the Board and the farmers. These societies' would be given preference for availing the Board's programmes. It is proposed to promote processing and value addition at primary level through these societies. Production of quality spices adhering to GAP and GMP will help them to a premium price for their produce. Backward linkage, direct procurement by exporters can be linked to the SPS by eliminating the role of intermediaries for a better price realization. These groups can function as nodal groups for promoting traceability in spices.

Mechanization programmes: In order to assist farmers to take up timely cultural operations, the Board proposes to popularize mechanization of major spices through subsidized supply of plant protection equipments, weed cutters, pit makers, harvesters, threshers and post harvest equipments for washing, cleaning, drying, polishing, grading etc. Propsals have been made for primary processing and vale addition facilities at the farmer's level.

Organic Farming: We need to expand infrastructure, training facilities manifold besides putting in place attractive financial incentives to farmers for taking up organic farming. Programmes for seed bank, area expansion, organic certification, bio inpts and processing units have been strengthened in the proposals made for XII plan.

8. Vision of the spice industry

To become the international processing hub and premier supplier of clean and value added spices and herbs to the industrial, retail and food service segments of the global spices market by meeting the quality requirements.

Development of spices in India

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1. Introduction

Spices play an important role in the Indian economy as it account for 6% of the agriculture GDP of the country and bring in a substantial foreign exchange earnings. Almost all the States produces one or other spices. Spices production and trade besides earning foreign exchange provide employment for millions of farmers and agriculture labourers and traders. India's share in world Spice trade is about 52% making it a major player in spice trade. India produces around 6 miillion tones of spices annually from an estimated area of 3.5 million ha. Chilli is the major spice crop occupying about 29 percent of area under cultivation and contributing about 23 percent of total spices production in the country. Turmeric accounts for 20% of production and 7% of area, seed spices 20% of production and 37% of area, pepper, 1% of production and 9 % of area of the total spices in the country.Among thedifferent states, Rajasthan occupies the major area under spices owing to seed spices cultivation in the country followed by Andhra Pradesh, Kerala, Karnataka, Madhya Pradesh and Gujarat. Andhra Pradesh, which is the foremost state producing chilli and turmeric in the country, ranks first in terms of production followed by Rajasthan, Madhya Pradesh, Tamil Nadu, Orissa, Karnataka, Kerala.

2. History of development programmes in spices

The organized cultivation and development of spices in India, dates back to 1951 by setting up of a high level *Spices Enquiry Committee* by the Planning Commission in view of the significant role spices play among agricultural commodities produced in the country. The committee in their report submitted in October 1953, stressed the need for better planning, research and coordinated efforts in the proper development of these crops. The Government of India accepted above recommendations and provided necessary funds to ICAR for implementing various schemes on Research, Development and Marketing in all the regions of the country. An ad-hoc '*Central Spices and Cashewnut Committee*', a semi autonomous body consisting of government officials and representatives of growers and traders was set up in 1961, for devoting special attention in solving problems confronting the crop development and financed research schemes to be implemented by the State Governments.

Based on the report of the Agricultural Research Review Team, appointed by Government of India, the Central Spices and Cashewnut committee was abolished in September 1965 and the responsibility for spices research was transferred to the ICAR. The Government of India took over development and marketing functions handled by the Committee by setting up of a Regional Office of the Ministry and subsequently created the present Directorate of Arecanut and Spices Development as a subordinate office under Ministry of Agriculture with effect from 1st April, 1966 at Kozhikode in Kerala, for paying adequate attention in different aspects of crop development. The Directorate looks after the development of Spices at national level through a well defined mandate.

No sizeable programme for development of spices was undertaken in the first four Five Year Plans. A well organized effort for spices development was mooted in the Fifth Five Year Plan (1974-79) with a plan provision of Rs 175 lakhs with stress for the development of major spices alone that too confined to traditional centers of cultivation.

In the Sixth Five Year Plan (1979-84) the development programmes on spices were assigned to State Governments on the recommendations of the National Development Council. However, Central Sector Scheme was continued in the Union Territories and autonomous organizations like State Agricultural Universities and ICAR Institutes with the limited financial resources. These arrangements were continued till 1986-87.

As this mode of implementation of the scheme was found inadequate in view of the growing demand of spices for domestic consumption and export, it was felt necessary to pay more attention towards spices development with adequate central assistance. Thus Centrally Sponsored Scheme for Spices Development was revived with the launching of an '*Integrated Programme for Development of Spices*' with an outlay of Rs 435 lakh with a central share of Rs 240 lakh for providing 50% of the financial requirement in respect of the schemes to be implemented by the state governments and 100% requirements for the schemes implemented in Union Territory administrations and autonomous organizations.

In the Annual Plans 1990–91 and 1991–92, centrally sponsored schemes for the development of spices were intensified by increasing the financial outlay to the tune of Rs 244 lakh and Rs 574 lakh, respectively by providing cent per cent financial requirements. The Integrated Programme for Development of Spices was further intensified in the VIII Plan (1992–97) with a financial outlay of Rs 125 crore comprising programmes for the overall development of 27 commercially important spice crops grown in India and the developmental activities were extended throughout the country particularly to the non-traditional areas.

The developmental efforts put into in the VIII Plan were intensified in the IX Plan with increased outlay and wider area of operation, so that due attention was given to every nook and corner of the country which have potential for development of any of the spices crops. Considering the growing demand of spices all over the world, planting material production programme was intensified during Ninth Plan period. The strategy adopted during the plan period was production of nucleus planting materials of all the improved varieties of spices at research stations, their large scale multiplication at the State Agriculture Department farms. These programmes were helpful in creating an indirect impact on production in the long run as well, considering growing requirement for domestic consumption as well as export.

During the Tenth Plan, the development programmes on spices were implemented through the State Horticulture/ Agriculture Departments utilizing the funds earmarked to them under Macro-management in Agriculture. In order to foster this programme, the basic components particularly production of nucleus planting material of high yielding/ export oriented varieties, transfer of technologies etc. were taken up by the Directorate of Arecanut and Spices Development in association with State Agricultural Universities, ICAR Institutes, State Agriculture/ Horticulture Departments etc.

3. Development of spices under National Horticulture Mission

During 2005–06 (end of Tenth Plan period), Government of India had launched National Horticulture Mission (NHM) to give further impetus to encourage growth in production of horticultural crops including spices. The NHM specially focus on increasing both production and productivity through adoption of improved technologies for ensuring quality, including genetic upgradation of all horticultural crops. Special emphasis being given on adoption of area based cluster approach for developing regionally differentiated crops, which are most suitable for the state/region. The following are the major programmes on spices under NHM being implemented through State Horticulture Missions (SHM) in various spice producing States, except North-East and Himalayan states, for which a separate mission, HMNEH, is going on.

- Production and productivity improvement
- Production & distribution of planting material
  - Model nurseries
  - Small nurseries
- Tissue culture units
- Seed infrastructure

- Rejuvenation / Replacement of senile plantations
- Promotion of integrated nutrient management/Integrated pest management
  - Disease forecasting units
  - Plant health clinics
  - Biocontrol labs
  - Leaf/tissue analysis labs
- Organic farming
  - Adoption of organic farming
  - Vermicompost units
- Technology dissemination through Frontline Demonstration

Planting material, its type and quality are of paramount importance in spice cultivation. In other words, it is the single most important factor around which the entire gamut of other spice trade related activities revolves. It is of special significance, especially in perennial spice crops which have a long juvenile/gestation phase and any mistake committed by the grower in the initial stage will result in enormous loss in the later stages. Hence, genuineness, quality and health of planting material are the major requirements of multiplication, sale and adoption of any planting material. In the present scenario, with the increased demand in planting materials, it is estimated that only 30 to 40 percent of the demand for planting material in different horticultural corps is being met by the existing infrastructure in public domain. Much of the dependence is on private source of which majority of the units are not regulated or monitored in most of States. Hence, the farmers have no access to the genuine disease free, certified planting materials in different spice crops and as a result, suffer with respect to production, productivity and quality of the produce. In these circumstances, availability of good quality planting material receives focused attention under NHM and efforts are being made to create necessary infrastructure in the form of nurseries and upgrade existing tissue culture units.

In order to meet the requirement of various planting materials, nucleus planting material production programme with all the available released high yielding varieties is being taken up directly by the Directorate of Arecanut and Spices Development including building up the required facilities in the Research Farms attached to the State Agricultural Universities, ICAR Institutes etc. The Directorate assesses the requirement of nucleus planting materials well in advance, for the large scale multiplication programme for various State Horticulture Mission Programmes and ensures their timely supply and monitor the overall production process as contemplated in the NHM. This is being supplemented with establishment of seed storage and processing infrastructure.

The Directorate also implements certain programmes on promotion of IPM/ INM, establishment of frontline demonstration for technology dissemination, conducts National Level Seminars/ Workshops and Training Programmes to disseminate the latest & improved technologies developed in the Research Stations for improving productivity of spices. The Directorate utilized an amount of Rs. 4329.20 lakhs for implementing various spices development programmes under National Horticulture Mission during the period from 2005-06 to 2012-13.

4. Development of spices under HMNEH

The development of horticulture in North-Eastern States has gained momentum after the launch of Technology Mission for Integrated Development of Horticulture in North-Eastern States (TMNE) by the Ministry of Agriculture, Government of India. The Mission has now been renamed as Horticulture Mission for North East and Himalayan States (HMNEH). Though the development of horticulture as a whole is being taken care of by HMNEH in the North-Eastern and Himalayan States, Spices Sector needs much more attention, especially in the area of quality planting material production. North-East and Himalayan States offer immense potential for large-scale cultivation of spices such as ginger, turmeric, chillies, black pepper, tree spices like clove and cinnamon and aromatic crops.

4. Impact of development programmes on Indian spice scenario

The efforts made by the implementation of National Horticulture Mission (NHM) programmes and HMNEH programmes have reflected in the production statistics of spices. Area and production of spices in the country has increased to the tune of 4.4% and 6.5% per annum respectively during the period from 2005–06 to 2012–13. Productivity of spices has also increased substantially during the period from 1634 kg/ha to 1872 kg/ha.

The export of spices has also shown tremendous increase during the same period. Spices export from India has crossed 2 billion US$ in the year 2011–12. Spices export, which was 350.36 tonnes of spices valued at Rs 2628 crores during 2005-06 has increased to 699,170 tonnes valued at Rs 11,171 crores (2.04 billion US $). India dominates the world spice trade because of the intrinsic qualities of Indian spices such as the bold black pepper with high piperine, turmeric with high curcumin, chillies with varying capsaicin and good colour, superior quality cardamom and ginger and seed spices with high volatile oil etc.

5. Conclusion

We are facing stiff price competition from other newly emerged spices producing countries like Vietnam, Guatemala, China etc. in the export of different spices. In the case of black pepper, being the largest producer and having higher productivity, Vietnam is in a position to offer their produce at a lower price as compared to the Indian produce. Similarly for cardamom, being the largest producer with lower production costs and having negligible domestic consumption, Guatemala is selling their produce at a lower price. China also now offers chilli at a competitive price than the Indian produce. We need to make concerted efforts to produce clean spices at competitive prices.

To be able to compete in the world market, the cost of production need to be brought down by increasing the productivity. Though India has the edge over the other competing countries with regard to the available research network and technologies in production of spices, this has not translated into improved productivity in the field. This coupled with rising wages of labours and other agriculture inputs has resulted in high cost of production. Formulation of Good Agricultural Practices (GAP) for each spices on a regional basis, ensuring availability of good planting materials of high yielding varieties and mechanization would go a long way in improving productivity of the spices and reducing cost of production.

Export scenario of spices –challenges and opportunities

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1. Introduction

The industry has set for itself the vision of achieving 10 billion USD by 2017, going by the opportunities in the spice industry, and that more people across the world are waking up to the health preserving properties of spices. Growing the Indian spice industry to 10 billion USD from the current 2 billion USD, would require that we bring about major changes to the way we do business. It is clear that a mere increase in the quantities we sell will not help achieve this. (Quantities have more or less stagnated over the last few years). Facilitating value addition should be a key area of focus. Also, product quality requirements are becoming stringent by the day. Initiatives to ensure food safety would be the second area to focus on. Backward integration and intensive research in agriculture and processing technology has become inevitable. The government should collaborate with Industry associations like the World Spice Organization to achieve these results. Export-import trade agreements with emerging markets (Iran, Africa, Egypt, Libya, etc) is an area that requires governmental involvement

Industry challenges that threaten to hamper the growth targeted:

- Reduced productivity in traditional spice growing areas;
- Rising quality issues – low active ingredient content, occurrence of contaminants in spices – pesticides like Ethion, Illegal Dyes, Aflatoxins
- Competition from other countries.

The industry has identified the following critical areas that needed to be focused on, that will negate the challenges, and help attain the industry vision:

- Non-traditional areas of cultivation
- Creating a pool of technical experts
- Infrastructural/Technological advancements
- Research and Development
- Building brand image/Dialogue at the right forums

Given below is an elaboration of the different actions that we as a country should take:

2. On farm

1. Bring more area under spice cultivation, to ensure sustainable supply of good quality exportable surplus. This will also include :
    a. The developments of non-traditional areas for spice cultivation and ensuring land availability. Make spice cultivation attractive to farmers.
2. Invest in agricultural research to develop new cultivars (disease resistant, high yielding) and replicating the results to benefit the farmer.
3. Support for contract farming/backward integration.

4. Review of pattern of paying of wages, under NREGA: the timing of wage payment coincides with the harvest season of major spice crops, worsening the labor shortage situation.
5. Extensive educational and awareness programs for the farmer to promote good agricultural practices, low chemical use and sustainability.
6. Improvements in post harvest infrastructure : drying areas, cold storage, etc
7. Incentivize organic farming or, those farmers who use fewer chemicals.
8. Maintain India's leadership in mint – India is currently the largest producer of mint. To maintain this position unchallenged – we have to work towards stabilizing prices. Due to the uncertainty on prices, synthetic menthol is coming up as a strong alternative. The reason for uncertain pricing is the lack of a farmer friendly stable pricing mechanism and storage facility. If we provide a concept similar to what is operating in cardamom to mint farmers, we will have stable prices instead of farmers being abused by the traders who hoard the material. The concept of Spice Parks where farmers can be provided the option of storing their produce (for a cash advance of upto 50% value of the oil) or converting to menthol which gives them higher value addition is a process that has to be implemented in the current plan etc. This should cost about Rs 100-125 Crores over 5 years and yield Rs 750 – 1000 crores in that period.

3. Post harvest

1. Invest in developing localized indigenous post harvest technology for small farmers (e.g. solar technology, driers, grading machines, etc): Spices Board working with the World Spice Organisation has developed a nutmeg drier. This work should continue into other spices and should be widely disseminated. Investment required: Rs.100 Crore/-
2. Warehousing and Cold storage support in major spice producing centers to facilitate clean and safe spices for export and domestic markets, moving up quality standards across the country.

4. Commercial initiatives

1. Critical: Re-introduction of VKGUY scheme for all spice and spice products at 5%.
2. Financial support/training/grants to innovate and develop new products – technology initiatives/labs, clinical. Subsidies that cover 50% of the project cost recommended. Spices are now finding successful, non-conventional applications. To ride this trend, the industry has to invest heavily in R&D. Strict criteria to avail such packages to be put in place, to ensure that all genuine firms operating with a stated agenda and deliverables can avail this from the beginning. India lags behind all developed nations in R&D as the costs are prohibitive. India has the human resources to be the best in the world, if only infrastructure support can be provided. Any firm that can submit a viable project report and is currently exporting Rs 10 Crores or more should be able to avail of this benefit.
3. Critical: Extend the time limit of 120 days currently permitted, for re-export to 1 year, for the import of spices under advance license, SEZ, EUO Scheme This will ensure and keep investments in India. E.g. The following companies have set up bases outside India due to the number of days restriction – Bafna, Indian Products/Jayanti, Synthite, Geshmack. The total value of investments amounts to Rs. 500 Crore, and the value of business lost to India amounts to over Rs.1000 crore.
4. Critical**:**Interest subvention at par with other agriculture based industries
5. Exemption from payment of APMC cess, by exporters.
6. Duty free import of lab testing consumables and equipment.
7. Exports to be exempted from service tax as per *constitution section 14* which reads as – *"No law of center or state can tax goods for sale in course of exports. Same way no service tax should be taxed on services for goods in course of export."* Currently, service tax is imposed also on export certification/testing charges.

8. Sustainable government policies, Consistency and adherence to declared policies & promised benefits: Government policies should be formulated keeping long term sustainability in mind. Subsidies and developmental policies should not be withdrawn/changed in short intervals.

5. Processing/Technology

1. Creating a team of technical experts, in each of the 10 focus spices, across all areas starting from soil health, seeds program, disease resistant crops, new cultivation practices, new generation low residual pesticides and bio fertilizers. This can be outsourced to the autonomous not-for-profit spice body – the World Spice Organisation so that there is a pool of resources to be used anywhere in India. Also to outsource if need be to other spice producers there by gaining prominence as not just the leading spice exporter of the world, but also a leading technology provider and general upgrade of food safety and quality globally. These experts employed/monitored by WSO, would be a source of technical direction and expertise to the entire industry. Funding requirement: 15-20 Crore
2. Encouragement and support to use higher technology and quality systems – GMP, HACCP, Steam Sterilization, new technologies of extraction using HFCs, Carbon Dioxide. Lab up-gradation to meet ISO 17025 global standards. With increasing quality standards, India ought to meet these. The technology and systems are expensive and providing support to firms that can implement these can only encourage world class state of the art facilities in India. It is time for us to support the industry in meeting and sustaining these standards. And initial outlay of Rs 500 Crores to promote newer investments as above should be executed.

6. Regulatory/Quality control

1. Work with EU & other countries to accept certificates of analysis issued in India, by Spices Board.The importing country governments have resisted India's requests to do this – this could be due to their alliance with the private labs in the importing country, which actually carry out the analysis.
2. Facilitate the ban on Ethion and other potentially harmful Organophosphate and Organochloride pesticides immediately and in a systematic manner. *(*If *US customers alone, decide to look outside of India for "Chilli", because of the presence of Ethion in Indian Spices and Spice Extracts, it would lead to a loss of more than 230 Crores for the Industry in terms of future business: similar impact can be expected from other origins as well).*
3. Stricter control over pesticide registration, manufacture, distribution and sale in India *with SB having a say in approval of these chemicals for use in Spices and creating the PoP.*
4. Lobbying with international trade and government bodies to remove trade barriers – in the form of unfair regulations (e.g. the MRLs for Aflatoxin in spices are 6000 times more stringent compared to malt used in beer production, spices being consumed in far lesser quantities compared to beer.
5. Exports to be made hassle-free – simplification of policies and procedures, exemption from payment instead of refunds, single window clearance for export shipments, Electronic linkages between Customs, DGFT, Revenue – for less paper work.
6. Develop/Demand better command over food regulations in importing countries. Regulations have to be developed keeping in mind the agricultural scenario in India. Initiate joint working plans with the regulatory bodies, to achieve the same.

7. Brand building and promotion

(a) Create culinary expos popularizing Indian cuisine and the spices that make up Indian cuisine. This can be done in association with the tourism department and international hotel chains. These can take place either as stand-alone expos or as a part of other food ingredient shows. These can culminate in a major Indian food show at the World Spice Congress 2014.

(b) Build awareness to comply with FSSAI standards, meeting importing country regulations, etc. Invite US, EU, Japan and Australian regulatory bodies for a joint session.
(c) Marketing/branding/promotion support to Indian companies – trainings, grants, etc
(d) Couple the above along with the Codex initiative, India should be able to drive the harmonization agenda facilitating breakdown of trade barriers.
(e) Cost: Rs 4 Crores over the next 4 years to host the Spice Committee for Codex in 2 years time in India. Returns will be over Rs.500 Crores in way of reduction of rejections, better quality correlations, longer time frame for banning of pesticides, etc
(f) Employ the services of an international PR agency. This will get us the required presence and mileage in international media, technical papers, and draw eminent persons into support of the industry, lobbying for regulatory support in developed countries to accommodate gradual changes instead of sudden ones. Also to create awareness on Indian genotype that will stand the country in good stead when the patent regime in other nations tries to take advantage of the benefits of indigenous spices.
    a. To manage bad press on spice that comes up occasionally on the international media.
    b. To build positive perceptions about the goodness of spices and the Indian Quality, thereby improving the demand for spices.
    c. Convey India's advancements in agriculture, manufacturing and research.
    d. The Target audience: consumers, importers, regulators, international media.
    e. Cost: Rs. 2.5 Crore p.a. over 3 years

(g) Promotional Road Shows and Conferences – to hard sell the Indian Spice industry, professionally, across the globe. Conduct spice evenings in major trade shows that will incorporate an Indian spice theme along with paper presentations to create awareness among the who-is-who of the industry to the progress and pro active steps India does to support global trade. To sensitize industry challenges, create opportunities for dialogue.

8. Moving up the value chain

1. The global seasonings business (USD 50 billion) is dominated by foreign MNCs when India supplies the raw material. To move into the value added seasonings/nutraceutical business space, the Spices Board portfolio should be expanded to include the value added segments as these call for R&D, clinical trials, branding, etc. Cost : Rs.250 Crore, which should yield a return of over Rs. 1500 Crore in the next 2-5 years

Intellectual property management strategies and technology commercialization at Indian Institute of Spices Research, Kozhikode, Kerala

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1. Introduction

The establishment of Indian Institute of Spices Research (IISR) was a major initiative towards sustained and intensive research on spices. It was established by upgrading the National Research Centre for spices (NRCS) in 1986 by merging with the Cardamom Research Centre of CPCRI at Appangala, Karnataka. The NRCS was further elevated to the status of Indian Institute of Spices Research in 1995. The Institute is located at a beautiful campus at Chelavoor with its Germplasm Conservatory at Peruvannamuzhi and cardamom research station at Appangala. Modern facilities for both applied and basic research and specialized facilities for molecular biology, biotechnology, biocontrol and post harvest technologies are available at the Institute. It also functions as the headquarters of All India Coordinated Research Project on Spices and Outreach research Project on PHYTOFURA with 19 centres all over the country and the Indian society of Spices. It functions as a major centre for postgraduate studies for various reputed universities in the country. Besides, IISR has excellent facilities like library, Distribution Information Subcentre (DISC) and internet facilities and foster collaborative research in Bioinformatics and above all research personnel with expertise in improvement and management of Spices. The vision of the institute is to enhance productivity of spices for meeting growing demands and to be the global leader in spices export. In the renewed context of Intellectual Property Rights, commercialization and benefit sharing, IISR has remodeled its strategies towards attaining self sustainability through protection and commercialization of its technologies through the Institute Technology Management Unit (ITMU). IISR is also aiming at widening its umbrella through business support initiatives via the newly established Business Planning and Development (BPD) Unit.

2. Technologies at IISR

IISR in the past has developed several technologies for the sake of farmers and other stake holders. These technologies were transferred from time to time to end users. These technologies are widely accepted by spice growers all over the country. IISR has developed a number of varieties of black pepper such as Sreekara, Subhakara, Pournami, Panchami, IISR Girimunda, IISR Malabar Excel, IISR Thevam and IISR Shakthi. In ginger three varieties with high yield and quality have been released *viz*., IISR Varada, IISR Rejatha and IISR Mahima. Seven high curcumin and high yielding turmeric varieties have also been released *viz*., IISR Prabha, IISR Prathibha, IISR Alleppey Supreme and IISR Kedaram and three cardamom varieties have been released by IISR *viz*., Appangala I, IISR Avinash and IISR Vijetha. Two high quality cinnamon varieties released are *viz*., IISR Navashree and IISR Nithyashree. A high yielding elite nutmeg variety, IISR Viswashree was also released and is in high demand among nutmeg growing farmers. Another nutmeg variety IISR Keralashree was approved for release at the recent AICRP workshop on Spices. This is the first variety developed through a Farmer Participatory approach. Four high yielding high quality cassia accessions have been identified for release. Eight hybrid lines of cardamom for high yield and disease resistance were identified and promoted to future coordinated varietal trials.

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. An efficient method of propagation of black pepper cuttings called serpentine method was developed.

Technologies have been developed for management of diseases like *Phytophthora* foot rot in black pepper, rhizome rot of turmeric etc. Along with conventional technologies for disease management, soil application of a Plant Growth Promoting Rhizobacteria (PGPR) consortium is found to be very effective under organic and integrated management systems. *Trichoderma harzianum* formulation was found to effectively control diseases of black pepper and turmeric. Methodology for the large scale multiplication has been standardized for distribution to farmers. Cultures of biocontrol agents are also being provided to entrepreneurs for multiplication. An agreement for the commercial production and sale of *Trichoderma harzianum* has been signed with Pest Control India Pvt. Limited. A PGPR formulation for ginger has been developed. It is a talc formulation of PGPR strain GRB 35 for managing soft rot, enhanced sprouting, growth and nutrient mobilization in ginger. In case of black pepper, a microbial consortium of PGPR (BRB-3, -13, -23) was developed that enhanced growth, soil nutrient mobilization and control of *Phytophthora*. Technologies are also available for management of pollu beetle and for integrated management of anthracnose/spike shedding in black pepper and shoot borer in turmeric. Diagnostic kits have been developed for detecting viruses infecting cardamom and black pepper. IISR has also developed production packages for black pepper, ginger and turmeric and crop specific micronutrient formulations. As far as value addition in spices is concerned, techniques have been standardized for preparing white pepper from green pepper by microbial fermentation.

In order to strengthen and protect the technologies and to enhance the bargaining power, IISR has since the past few years initiated efforts to protect its assets through implementation of the IP regime for technology management. Potential technologies are first identified based on their commercial value, success, utility and market preference and further processed for protection. Regarding plant varieties, popular released varieties only were chosen for Plant Variety Protection (PVP) rights. Similarly patents have been filed for only those technologies with a good market potential. Securing and maintenance of IP demands lot of money and as per the directives from ICAR, efforts are made to identify those technologies that need a protection under the IP regime, others are either placed in public domain or commercialized without protection through legal deeds.

3. Different forms of IPR

Presently seven types of IPRs are recognized *viz.,* copyright, trademarks, geographical indications, industrial designs, patents, integrated circuits and trade secrets. These can be classified into two broad categories. 1. Copyright and related rights and 2. Industrial property rights, which include IPRs like patents, trademarks, geographical indications, and industrial designs. IPRs that do not fit into this division are termed as *sui generic*, meaning "one of its kind" that covers the plant breeder's rights.

(i) Copyright

Copyright is the exclusive right to do or authorize others to do certain acts in relation to (i) literary, dramatic, musical and artistic works (ii) cinematograph film and (iii) sound recordings. The nature of acts varies according to the subject matter. Basically, it is the right to copy or reproduce the work in which copyright subsists. The term of copyright is life of the author of work plus 60 years with certain exceptions. The Berne convention and universal copyrights convention, for protection of copyrights are the results of joint efforts of many countries and most of the countries are signatory to either one of these conventions. India being a member of both can protect her copyright in any country in the world.

IISR has developed a number of databases and softwares and the information regarding a few has been forwarded to copyright office for their protection. The details are provided below:

Title	Purpose
JUZBOX	The work comprises of computer software tool to search for prosite patterns and biomedical words in amino acid sequences
PASSCOM	A database on predicted activity spectrum of spices compound
Phytoweb	The online portal of *Phytophthora*
PLASBID	A database for identification of plant associated bacteria
Spiceprop	A database on propagation protocols of major spices
SpiceEST	A database of spices EST
Spice Genes	A database on spice germplasm
Plant Virus Database	Provides a central source of information about all the plant viruses of India
Phytophthora Genome Database	Sequence information of hybrid assemblies of the *Phytophthora* infecting black pepper was incorporated to existing database
SpiceStat	Database of time series data on area, production and export of spices
PiperBase	Database on Piper species of India
Spice Bibliography	Database of published literature on spices
Spice Prop	Database on propagation protocols of major spices
Pepper anthology	An e-book on black pepper cultivation, production etc

(ii) Patents

A patent is the legal right granted by the Government to the patentee with respect to the invention of goods, giving exclusive right to prevent others from performing, without authorisation, the act of making, using, offering for sale, selling or importing that product for the above purpose, subject to his full disclosure of the invention. Where a patent covers a process, the patentee has the exclusive right to exclude others from performing, without his authorisation, the act of using that process, using and offering for sale, selling or importing for those purposes, the product obtained directly by that process in India. It is one of the most popular and strongest forms of IPR, which protects an "invention", which is defined as any new and useful art, process, method or manner of manufacture, machine, apparatus or other article, and any substance produced by manufacture. An invention also includes any new and useful improvement in any of them.

The process of globalization and liberalization has led to traditional mode of production system and innovation-exchange being altered with rapid expansion of science and technology and this has led to the establishment of a formal process of invention and consequent commercialization. Inventions or innovations being the result of considerable investment of time, money and above all intellectual activity, require innovators to be rewarded adequately to inspire the creativity. In this era of globalization and liberalization "free riding" is an issue of great concern in the knowledge based economy, hence granting a time limited protection for the invention will give the inventor control over his/her invention.

All forms of IPR that are applicable to agriculture are relevant to spices as well. Since spices are largely used in pharmaceutical, perfumery, cosmetic and food industries, patenting has special relevance in spices compared to other agricultural crops. But varieties of spices developed using modern plant breeding techniques cannot be patented as such as per the Indian patent law. But the process of developing such varieties can be protected through patents. Similarly, processes of extraction of active ingredients, product developments by using spices and their usages for new purposes are patentable as per the national law provided they meet the standards of novelty, inventive steps and industrial applicability.

An exhaustive list of approved patents in major spices was compiled and published. IISR has taken steps to improve its patent portfolio through patenting of technologies. Only technologies with a potential for commercialization were processed for patent filing considering the huge expenditure incurred for filing a patent. Some of the technologies were assigned to National Research Development Corporation (NRDC), which facilitated the patent filing through approved attorneys. In all seven technologies were processed for patent filing through NRDC, while two technologies were filed through ICAR approved attorney.

(iii) Trademarks

Trademarks are also applicable to agricultural products including spices for marketing of post harvest products and agricultural devices. It helps clear distinction of the goods and services of one from the other, thereby helping the consumer from being deceived. Once in use, trademarks confer a perpetual right, unlike plant breeder's rights or patents, and this is another major advantage of using one. In essence, this means that once plant breeder's rights have expired, the trademarked brand can continue in perpetuity. Renewal is usually every 10 years. Though it is a popular way of protection, the major drawback is that the registration may have to be renewed from time to time.

Trademarks act as key indicators which specify quality standards of a particular firm. Since a lot of firms are operating in spice industry dealing with the trade of various spices and their value added products, trademark registration is essential. In the absence of a registered trademark, the goodwill earned by a company may be encashed by some fraudulent enterprises. Infringement of any form can be effectively counteracted only when the brand is legally registered. The issue is of significance in spices, since unfair practices especially adulterants have been a major threat to reputed brands of spice products. A lot of trademarks are already being registered by different firms and assessing the trade mark registration status of spices in India has some intricacies. Trademarks are registered for different spices products. Registration is sought either for spices of all kinds or for a number of products including spices. Details of securing trade mark registration in spices are provided in our compilation (Sheeja *et al.* 2011).

Indian Institute of Spices Research is a premier institute of India involved in all spheres of spices research and the products and services needs to be marketed and protected from confusion due to spurious products that may be available in the market. Further, it is expected to promote the visibility of the quality assurance based on associated products and services from the Institute. The application for registration of "IISR" Logo as a multiclass (class 3-Essential oils, class 30- Fungicides, Herbicides, class 31- Agricultural and horticultural products, seeds natural plants and flowers, class 41- Education, providing of training, class 42- Scientific and Industrial research, services that can't be classified in other classes) was filed on 30/09/2009 with the Trademarks office. Subsequently it was advertised in the Trade Marks Journal No.1461 dated 06/12/2010 (Fig.1) and was granted certificate of registration on 21/04/2011 (Fig. 2). This will enable the Institute in protecting the Institutes Intellectual property with regard to its products and allied services. IISR is presently using its Trademark on all the products of the Institute. IISR is also providing this Trademark along with ICAR collective mark while an agreement is signed for technology commercialization. During non-exclusive licensing of its plant varieties, along with the denomination of the plant variety, IISR also provides the trademark or logo and insist that the licensee use it on seed packets/bags for sale. The trademark shall be shared in all the license agreements we are to make in the future for our technologies and shall provide not only protection but also authentication of our technologies.

The trademark registration certificate of "IISR"

4. Protection of plant varieties

Among the technological assets of Indian Council of Agricultural Research (ICAR), there are a number of high yielding and resilient crop varieties and natural resource management technologies that are related to genetic resources. Protecting or patenting the plant varieties was not customary in India and other developing countries prior to World Trade Organization (WTO) in 1995. Earlier scarcely any technologies were patented or commercialized in the ICAR. The prevailing ethos was to place the technologies in public domain for public use. Basically ICAR is an apex organization with "Farmer First" as its motto and selling varieties or any other technology to farmers was out of our thoughts. However, once the Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement was signed and once India became a signatory to this, ICAR recognized that Intellectual Property (IP) management of our varieties is important. Development of new varieties either by traditional methods or by modern molecular modifications requires a lot of time and effort. Once protected these technologies can be licensed and could be transferred to end users through private, co operative, non-governmental and public channels. Licensing can be done for commercial use or for research or for both. The marketing rights secured by the breeder shall help to recover the cost of research and development. Application of incentives and benefit sharing with scientists/ innovators and human resource development in ICAR would improve overall research environment and provide impetus for greater creativity and knowledge generation.

The Institute Technology Management Units (ITMUs) are institutional bodies assigned the duties of facilitating IP rights as well as commercialization of plant varieties. The ITMU will convene the regular Institute Technology Management Committee (ITMC), chaired by Director and having approved members for management of PVP rights. ICAR can file PVP applications for sole ownership over its plant varieties for all varieties developed in ICAR institutions, the hybrids developed in ICAR where the parent hybrid belong solely to ICAR and transgenic where the transgenic events are carried out in ICAR institutions and the initial variety and the gene sequence belong solely to ICAR. ICAR can also file joint applications with others such as State Agricultural Universities (SAUs) or other concerned organizations/ institutions/ research establishments in public or private sector on mutually agreed terms for varieties jointly developed. ICAR can also be a co-applicant with a collaborator in case the variety is developed through a joint effort. In this case it is necessary to sign a Memorandum of Understanding (MOU) as per mutual agreement. ICAR will be the institutional breeder and the applicant in the PVP application for each of the plant varieties developed in its set up, and is entitled to discharge any liability in terms of benefit sharing, compensation for under performance, or any other liability fixed by PPV and FRA or the PVP Appellate Tribunal or any court of law under the PPV and FR Act.

The transfer or commercialization is mediated through either non-exclusive or exclusive licensing to any interested party including Govt. agencies, public and private seed producers and others including foreign clients of seed industry. In case of exclusive licenses, the protected variety having a potential abroad is assigned to ATMC before licensing. Advance breeding material or parental lines shall not be transferred on exclusive basis. The agreement shall also involve a clause that provides a part of the benefit to ICAR. The breeder seed is provided by ICAR, but shall not be held responsible for any legal consequence due to any subsequent loss of quality. The licensee is bound by the agreement to maintain genetic purity and quality. The licensed material shall be done so only under the registered denomination, which will be printed on the label, which shall not be changed by the licensee or sub-licensee. Along with the registered denomination, it is required to use the ICAR's collective mark on all packets of licensed seed. But licensee may also use his trade mark simultaneously. Trademarks have helped to improve the value of agricultural products. Many multinationals have gained through registration of transgenic varieties like Roundup. Trademarks may be used to emphasize distinctive and attractive features of plant varieties for promotion of the variety. Trademark protection can serve as a proxy for plant variety rights in countries where PVP do not exist and provide long lasting and significant protection for plant varieties. Licensing of trademark can be done either alone or combined with Plant Variety Rights. In case enough quantity of the licensed material is not available, ICAR has the right to issue compulsory licensing and the seed material shall be provided by ICAR.

The license fee and royalty is fixed by the institutions, with expert opinion and guidance, keeping in mind the cost of attaining and maintaining PVP rights, cost of production and handling and institutional costs. The varieties are however exempted from fees for research use by ICAR institutions, SAU, AICRP and partners of ICAR with a standing MOU. A royalty is charged on seed sale of a protected variety developed by another agency or breeder using ICAR's genetic material, which is recurrently used for commercial production of the protected variety. The benefit sharing is as per the specifications of ICAR and Scientists/innovators, team members, other institute staff and ICAR is given their due share.

At IISR, we have so far submitted applications for 11 of our registered varieties with PPV and FRA. One of the cardamom varieties Appangala I is notified by PPV&FRA. IISR has issued nine non-exclusive license agreements since 2010 for our released varieties of turmeric *viz*., IISR Pratibha and IISR Alleppey Supreme, in ginger variety IISR Varada and nutmeg variety IISR Viswashree. IISR Prathibha and IISR Varada have already completed 15 years from their notification, and hence cannot be registered under PPV and FR Act. IISR Varada, IISR Prathibha, IISR Alleppey Supreme and IISR Prabha are elite high yielding and high quality varieties, which has earned wide acceptance by farmers all over the country. Hence, IISR has made successful efforts to commercialize these varieties through a non-exclusive licensing mode for popularization and also for meeting their growing market demand. The popular nutmeg variety, IISR Vishwashree is a plagiotropic graft that is high yielding. In 2011 this variety was licensed for mass production and commercialization. Appangala 1, is the cardamom variety that has been notified by PPV and FRA. Our Licensees include farmers, private and Govt. organizations like National Horticultural Research & Development Foundation in states of Maharashtra, Kerala and Karnataka. An amount of Rs. 25000 +service tax is charged per license and a royalty of 1% on the sales proceed is fixed. At present 100 Kg of breeder seed material is provide to Licensee and the cost of the seed material is borne by the Licensee. The benefit sharing is done as per the rules and regulations of ICAR. More licenses shall be issued in other crops like black pepper and cardamom in the coming years. IISR is also taking steps for commercialization of its first variety developed through a farmer participatory approach providing the farmer with maximum rights and benefits.

The Institute shall register only varieties having a commercial potential with PPV and FRA, since the maintenance of PVP title is a costly affair. As per the guidelines of ICAR, PVP title of aa registered variety will be subsequently maintained only if it has been commercialized or is being used in development of new varieties. In case of crops that are not notified by PPV &FR Authority, a special license agreement is drafted as found suitable, in consultation with an approved PVP attorney to aid in commercialization.

Table 1. Plant varieties of IISR with a potential for commercialization

Title of technology	Benefits/ Utility
Black pepper	
IISR Thevam	Stable performance over years as compared to Panniyur-1/rainfed condition, recommended in Kerala & other high altitude areas
IISR Girimunda	Stable performance over years as compared to Panniyur-1/rainfed condition, recommended for Kerala & other high altitude areas of south India
IISR Malabar Excel	Stable performance over years with high oleoresin content/rainfed condition, recommended in Kerala & other high altitude areas
IISR Shakthi	Resistant to *Phytophthora* foot rot disease/ berries are bold & dry recovery is more, farmers and Industry.
Ginger	
IISR Rejatha	Plumpy & bold rhizome with low fiber content/relatively free from diseases and less prone to storage pests/rainfed conditions in Kerala

IISR Mahima	High yield, resistance to nematodes & low fiber/rainfed conditions in Kerala
IISR Varada	Good quality, high yielding variety with plumpy rhizomes with flattened fingers & medium size reddish brown scales. tolerant to diseases and low fibre content
Turmeric	
IISR Alleppey Supreme	Stable performance over years, consistency in curcumin content in different locations & tolerant to leaf blotch disease. Cultivated in rainfed conditions in Kerala and irrigated condition in Maharashtra, Karnataka and N. Bengal
IISR Kedaram	Stable performance over years, consistency in curcumin content in different locations & tolerant to leaf blotch disease. Cultivated in rainfed conditions in Kerala and irrigated condition in Maharashtra, Karnataka and N. Bengal
IISR Prathibha	A high yielding and good quality variety with reddish yellow coloured rhizome. A high quality and value added variety/ cultivated all over India under rainfed and irrigated conditions
IISR Prabha	A high yielding and good quality variety with reddish yellow coloured rhizome. Free from disease incidence in farmers field. A value added variety
Cardamom	
IISR Avinash	High yielder, suitable for planting in valleys, has extended flowering period.
IISR Vijetha	Virus resistant selection with 77% bold capsules & good appearance
IISR Appangala 1	Highly adaptive & produces 89% bold capsules, responds well for nutritional inputs
Nutmeg	
IISR Viswashree	Highly adaptive & input responsive variety, produces 89% bold capsules (>7.2 mm & above), golden yellow coloured capsules. Bushy & compact canopy, low incidence of fruit rot. Nut recovery- 70.0%,
IISR Keralashree	First nutmeg variety developed by farmers' participatory breeding. Very bold nut with thick and entire mace, semi erect canopy, wide adaptability.

5. Ready to market technologies for commercialization

ICAR may decide to keep a technology solely in public domain or else it may be licensed for commercial use depending on the direct impact of the technology on social security, income and food and nutritional security. All technologies are transferred after necessary IP protection through exclusive or non-exclusive license agreements to any interested party including Govt. agencies, public and private agencies and others including foreign clients. In case of exclusive licensing the technology is assigned to ATMC before licensing. The resource generated through licensing is an important means for gap filling requirements for research and development. Besides it also provides an encouragement to researchers and innovators. IISR has developed several technologies in the ready to market form for commercialization. Some of these technologies are patent protected (Table 2) and efforts are on for licensing them to potential entrepreneurs.

Table 2. Details of technologies for which patents have been filed

S. No.	Application No. & Date of filing	Title	Innovator(s)	Status of Application
1	3433/CHE/2011 4.10.12	Production of Off-odour free white pepper from matured green pepper by bacterial fermentation	Dr. Aundy Kumar Dr. T. John Zachariah Dr. V. Vinod	Patent Filed
2	3594/CHE/2013 13.08.13	A novel method of storing and delivering PGPR/ microbes through biocapsules	Dr. M. Anandaraj Dr. Y.K. Bini Dr. R. Dinesh	Patent Filed
3	3794/CHE/2013 27.08.13	A micronutrient composition for ginger and a process for its preparation	Dr. V. Srinivasan Dr. R. Dinesh Dr. S. Hamza	Patent Filed
4	4754/CHE/2013 22.10.2013	A micronutrient composition for turmeric and a process for its preparation(for soils with pH below seven)	Dr. V. Srinivasan Dr. R. Dinesh Dr. S. Hamza	Patent Filed
5	4745/CHE/2013 21.10.2013	A micronutrient composition for black pepper and a process for its preparation	Dr. V. Srinivasan Dr. R. Dinesh Dr. S. Hamza	Patent Filed
6	4465/CHE/2013 01.08.13	A seed coating composition and a process its preparation	Dr. M. Anandaraj Dr. Y.K. Bini Dr. A.K. Johny	Patent Filed

- *Production of off-odour free white pepper from matured green pepper by bacterial fermentation*

Techniques have been standardized to prepare off-odour free white pepper from mature green berries through bacterial fermentation. The fermentation process takes place within five days as compared to 8-14 days in conventional. Fermentation process is also cheaper compared to conventional process. Panniyur-1 and Balankotta are the cultivars found highly suitable for preparing white pepper

- *Novel method of storing and delivering PGPR/ Microbes through biocapsules*

The novel invention of PGPR formulation as Biocapsule is an easy and reliable technology of storing and delivering PGPR bioagents in hard gelatin capsule. It is a preparation of viable microbial agents in a capsule form. The efficient plant growth promoting rhizobacteria (PGPR) for ginger namely *Bacillus amyloliquefaciens* was used in this formulation. It enhances storage durability, improves nutrient mobilization and disease resistance, reduces expenditure besides being ecologically safe. Yield of ginger increased more than twice when activated capsules were used

- *A seed coating composition and a process for its preparation*

This technology of PGPR ensures the viability of the seeds for long time. Population of coated PGPR was maintained up to sixteen months. Prevents desiccation and ensures a protection against environmental stress maintains shelf life up to 16 months. The processing does not need ultra low temperature; help to reduce the energy consumption. It also protects the seeds against storage pests which in turn enhances the

longevity of the seeds. Ensures enhanced germination and hence to establishes with the help of the introduced organisms on the seeds

- *Crop specific micronutrient mixtures*

The novelty of this technology is that it augments the uptake of essential nutrients by the plants. It improves yield, growth and quality of spices. It is recommended as foliar spray. It avoids the formation of insoluble precipitates on mixing with the standard common or complex fertilizers. An approximate increase of upto 15% in yield and a cost benefit ratio of 1:2.5 is realized by farmers.

- *Biocontrol agent- Trichoderma harzianum*

This talc based bioformulation based on *Trichoderma harzianum* is used for the management of *Phytopthora* foot rot and slow wilt diseases of black pepper, and rhizome rot of cardamom and ginger.

- *Biocontrol agent- Pochonia chlamydosporia*

This is bioformulation based on *Pochonia chlamydosporia* is used for the management of root knot nematode (*Meloidogyne incognita*) infesting black pepper plants in nursery and field.

- *Diagnostics for viruses infecting black pepper*

The method uses a single tube multiplex reverse transcription (RT) coupled polymerase chain reaction (PCR) assay (mRT-PCR) for simultaneous detection of two viruses viz., Cucumber mosaic virus and Piper yellow mottle virus in black pepper. The method is suitable for certification of black pepper planting material against viruses.

- *Diagnostic for viruses infecting cardamom*

The method uses a single tube multiplex reverse transcription (RT) coupled polymerase chain reaction (PCR) assay (mRT-PCR) for simultaneous detection of two viruses viz., Cardamom mosaic virus and Banana bract mosaic virus in cardamom. The method is suitable for certification of cardamom planting material against viruses.

- *Microbial consortium for black pepper*

This talc based bioformulation based on a consortium of PGPR is ecologically safe technology that enhances nutrient mobilization and efficiency in black pepper in the nursery and field. It can also be applied along with NPK fertilizers for enhancing growth.

- *PGPR talc formulation for seed spices*

This formulation is used either as soil or seed application to enhance growth of seed spices such as coriander, cumin, fennel and fenugreek.

- *Rapid method for multiplication of disease free planting material of spices*

This technology is based on a soil less nursery mixture using plug-trays, that helps in multiplication of disease free black pepper, ginger and turmeric, which not only save on seed cost but also is suitable for long distance transport

6. Business Planning and Development Unit (BPD)

The Business Planning & Development (BPD) unit of IISR is set up through World Bank funded National Agricultural Innovation Project (NAIP) of Indian Council of Agricultural Research (ICAR). The BPD unit in coalition with the already existing ITMU will act as a catalyst for attracting entrepreneurship development in this sector by developing integrated processing capacities, providing technical guidance and advice on quality maintenance and testing standards as well as creating conducive environment for its growth. The BPD unit envisages fostering sustainable business development by providing services like access to processing units for market testing of innovative products, technology/prototype development, research and development. The processing unit will be equipped with state of the art facilities for primary as well as secondary processing of spices and allied products as well as necessary facilities for practicing Good Agricultural Practices and Good manufacturing Practices in spice cultivation and processing.

7. Conclusion

An effective IP management regime is an essential pre requisite to improve innovation and technological advancement. Licensing and commercialization shall help in flow of monetary gains to researchers and also for recovery of cost of research. It will also provide opportunity for building partnership, efficient tech transfer and adoption of technologies. All these will contribute to enhanced income to farmer's and generation of employement. However, income generation should not be the primary motive, more importance to be given to advancement in research keeping in mind the national priorities of food security, sustainable use of natural resources and supporting marginal and small farmers and identifying opportunities for youth and women. With the help of new initiatives like ITM-BPD Unit the institute shall be enabled to make a larger impact through propagation of its technologies in a scientific manner to attain its goals of empowerment of farming community and providing quality spice and spice based products to the cons

Hi-tech farming: The success story from the "wonder farm in Kerala"

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1. Introduction

The basic "right for food" of the ever-enhancing population is the greatest challenge to be addressed by the "agriculture technology" world over. However, agriculture is becoming a less remunerative enterprise due to the small holdings, insufficient labour strength, high cost of inputs like manures, fertilizers and pesticides, non availability of quality planting materials, pests and diseases and low productivity. Sustainable agriculture backed by green technologies in an integrated farming system has been considered as a promising and potential pathway to solve this issue. It is high time that innovative technologies which can reduce costs while increasing returns be applied to agricultural lands to sustain and support the farming community. In this context, hi-tech farming becomes a promising solution, if applied logically.

High-tech farming or precision farming mainly refers to agricultural methods using the latest technology but in the true sense it is the application of the right technology to minimize loss and maximize production without compromise on ecology and ethics. It's a knowledge-based agricultural system not determined by the kinds of output but by the process. Its success entirely lies in how we apply the knowledge especially in the management of major agricultural inputs – i.e. land, water, and human effort. The advantage of precision farming is that the required quantity of inputs, mainly water and fertilizers, could be administered under controlled environment at the right time in the right place so as to get maximum yield. Hybrids could be used in hi-tech farms where the labour requirement would be lesser in comparison to conventional farms. Pest menace would be minimal in such farms.

Over the years, a lot of changes occurred in the agricultural systems world over. New varieties of many crops were bred to boost yield and resist pests and diseases. Weather monitoring systems were developed and this complemented with selection of suitable varieties to match specific weather conditions. However, the major leap in technological advancement was the use of machinery in agriculture to enable one man to do more work than 50 men used to do. Now we have advanced to the hi-tech situations wherein satellite navigation and UAV equipment enable us to direct and observe crops from faraway places.

India has one of the world's largest agricultural research networks, churning out a good deal of new technology. However, the majority of farmers still practice traditional farming, for want of adequate transfer of the new technology to the fields. A recent National Sample Survey report on farmers revealed that over 60 per cent of them lack access to new technology. In reality a sizable chunk of others too do not get to know all that is new and useful for them. The most embarrassing situation is that the extension workers who are directly responsible for the technology flow and dissemination themselves are not aware of the recent technologies for boosting productivity. The second major problem in technology adoption is the mindset of the farmers themselves. For instance, though the state of Kerala is bestowed with the ideal soil, climate and geographical situations suitable for commercializing vegetable productione have never taken care to develop this area as a major enterprise for achieving self-sufficiency and generating income for the state.

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Hi-tech agriculture is more meaningful and rewarding when we integrate the technology with our traditional know how for utilization of inputs and manage cropping for maximum production from every square inch of land without compromising the ecological balance. The Agricultural Research Station, Anakkayam has demonstrated this through its diversification of activities.

2. Technology for transformation: the case study from Agricultural Research Station, Anakkayam

The Agricultural Research Station (formerly Cashew Research station), Anakkayam, started in 1963 and situated in the agricultural heartland of Malappuram District which is functioning for the improvement of horticultural crops, with special emphasis on promotion of hi-tech farming in the state, is celebrating the year 2013 as its 50TH Anniversary. The ARS, Anakkayam is regarded as the role model within the state for its excellent performance in terms of effective land use, adoption and demonstration of advanced technology for enhancing production and internal revenue, farmers participatory seed village programmes including coconut hybrid seed production, efficient and timely execution of EAPs, employment generation and production programmes under SHG mode. The major activities integrated at this research station are;

a. Development of cashew-based cropping systems

The Agricultural Research Station (ARS), Anakkayam is conducting research to evolve suitable management practices for intercropping in cashew to raise additional income from cashew plantation through crop diversification and crop intensification. The cropping patterns ranging from 3-tier to 7-tier were formulated and applied in cashew plantation.

b. Rainwater harvesting and crop waste recycling

At the ARS, Anakkayam which was previously a drought-affected research station of KAU, three rainwater harvesting structures have been constructed recently. This ensures irrigation in the entire cropped land including nursery yards. The structures harvest about 100lakh litres of water during the rainy season. The structures are also utilized for growing fresh water fishes and azolla. The plentiful water available now allows us to maintain a good collection of water lilies and lotus plants which are also distributed to farmers at reasonable prices. A vermicompost unit is set up in the farm for production of vermicompost and vermi wash. The unit is now capable of producing produces about 200tonnes of vermicompost every year and meets the requirement of organic manures of the farm. The crop wastes and weeds are promptly converted into vermicompost and this keeps the entire field clean as well as pest and disease-free. The unit is an excellent model to demonstrate economic organic farming through effective “wealth from waste’ technology.

c. Germplasm management and advanced propagation unit

The nursery of our research station is spread over two hectares of land which contains green houses, mist chambers and polyhouses with facilities to control humidity, temperature and irrigation water flow.

Quality planting materials of almost all crops including grafts of elite varieties of cashew, mango, sapota, garcinia, jack, kokkum etc., local varieties and hybrids of coconut and arecanut,

rooted pepper cuttings, ornamental plants including commercial cut flowers, vegetable seeds and tissue culture banana plantlets are available for bulk supply at anytime at ARS, Anakkayam. The station is also undertaking large scale production and distribution of vegetable seedlings in pro-trays and poly bags including cool season vegetables like cabbage and cauliflower.

The research station maintains germplasm collections of various fruit crops and commercially important ornamental plants. The collection includes 120 clones of mango, 57 selections/clones of jack, 33 varieties of cashew, a germplasm collection of minor fruits, a huge collection of commercially important ornamental plants comprising 300 types of euphorbia, 100 types of crotons, 30 types of ixora, a beautiful collection of water lilies and aquatic plants, 100 varieties of hibiscus, more than 100 types/varieties of orchids, gerbera, anthuriums and indoor plants.Following are the salient achievements of ARS, Anakkayam within a short period of five years;

- ARS, Anakkayam has the best and biggest nursery in KAU
- The station produces the largest quantities of planting materials including vegetable seeds
- The station generates the highest income among any KAU stations compared to even the regional research stations and college farms of KAU.
- The station has evolved innovative propagation techniques which were even appreciated by researches from various SAUs.

The research station has set up clonal collections of early flowering mango, jack and other important fruit crops for further breeding work as well as multiplication and distribution to farmers

d. Protected vegetable production

Greenhouse cultivation makes use of the advanced technology, precision cropping under protected structures, and is most suited for short duration, short statured crops. This farming system can be successfully utilized for production of high value vegetables anywhere at any time. The best results under greenhouse cultivation have been demonstrated in the plains and in arid conditions such as in Tamil Nadu and Karnataka whereas it is yet to be perfected in our state. The results of experiments conducted by the Kerala Agricultural University at its Agricultural Research Station, Anakkayam, Malappuram District over three years are highly encouraging. The Agricultural Research Station, Anakkayam has demonstrated that the vegetable production can be enhanced to the tune of 5 - 10 times through protected cultivation at the same time, reducing the production cost and input requirement, especially labour requirement to one tenth compared to cultivation in open field. This means that a farmer has to work hard for 5 years in open field to produce the same quantity of vegetables (but of much poor quality) that he can easily produce in one year in a poly house*.* The crop can be harvested at least two weeks earlier than a crop in open field and the production can be undertaken year round irrespective of the vagaries in climatic conditions outside.

Our experiments on various vegetable crops reveal the power and potential of vegetable production under protected conditions and the major advantages that we observed in vegetable cultivation under protected conditions can be summarized as:

1. Yield increases by 5 to 10 times compared to the same crops in open fields
2. The vegetables are off much better quality with less or no pesticide load.
3. There was marked increase in growth rate of plants under protected conditions and this resulted in early harvest. The earliness in first harvest ranged from 8 days in tomato (Anagha) to 14 days in bittergourd (Preethi) compared to the crops in open.
4. Input requirement is minimized (labour, irrigation water and fertilizers)
   Water - The water requirement was 360 litres per day for 1000m^2 poly house as compared to 3500 litres per day in open
   *Labou*r - The requirement of labour was one tenth under protected condition as compared to cultivation in open
   Time - The crop can be harvested at least two weeks earlier than a crop in open field
   Space-Maximum use of land including aerial space
5. Any crop, any time: Production can be undertaken year round irrespective of the vagaries in climatic conditions outside. Even exotic vegetables and hybrids grow excellently and this opens up the scope for export oriented production of high value crops under cover.

e. Semi permanent towers for vegetable cultivation – "the technique for landless"

We have demonstrated a low-cost vegetable cultivation technique (below) for the landless under organic mode. This method allows us to grow vegetables inside or near the kitchen itself or on the flat roof terrace throughout the year. In a single bag we can accommodate 30 to 32 vegetable plants by utilizing the aerial space. This method is most ideal for growing leafy vegetables and greens including curry leaf without applying any pesticide.

f. Employment and income generation through hi-tech farming

The Station is one of the main centers of research for improvement of horticultural crops in the state, functioning with special emphasis on promotion of hi-tech farming in the state. The Research Station gives utmost importance for training rural youth in agricultural production and expanding their employment opportunities. Thus the station has developed a Hi-tech Krishi Karma Sena, a registered group of trained youth in hi-tech agriculture, with the prime objective of attracting youth to agriculture and promoting hi-tech agriculture in the state.

The Hi-tech Krishi Karma Sena of ARS, Anakkayam is the product of a "holiday" training in Hi-tech horticulture with 18 trainees from the members of a cluster of self-help groups in Malappuram district during 2012. The entire training programme was conducted as a voluntary social service on holidays for about 6 months without spending any amount from the KAU or other funding agencies and without sparing a single office working hour of the staff of the research station. All the expenses for miscellaneous items like refreshments to the trainees etc. were shared from the pockets of the participating staff and trainees. The trainees whole-heartedly worked in the ARS farm on holidays to accrue knowledge at the same time offering their man power free of cost for hi-tech activities of the station. The dedicated scientists and farm officers of the research station in return imparted them the techniques of hi-tech farming without accepting any remuneration, compensation or honorarium for working on holidays.

The team is growing fast with 126 active members at present, including youth and women. Hi-tech Krishi Karma Sena of ARS, Anakkayam is the only approved SHG in the state specifically trained in hi-tech farming and is of course the first of its kind in India.

The hi-tech Krishi Karma Sena of ARS, Anakkayam has already attracted the media through their active involvement in rehabilitation of the Vengad Gokulam of Guruvayur Devaswam Board, the State Department's Vegetable Development scheme for distribution of vegetables in grow bags in all the seven municipalities of Malappuram district, and setting up an organic vegetable garden in the Judicial Court Complex, Manjeri. In the year 2012-13, the Sena was entrusted with the works of construction of poly houses for the beneficiaries of the agriculture department schemes in three panchayaths each of Malappuram, Kozhikkode and Wayand districts. The Sena has also requested for empanelling them as an approved agency for undertaking such govt. approved works.

The Sena is competent to provide the following services from a single source:

- Protected cultivation - Layout and execution of protected cultivation structures such as poly houses, rain shelters, mist chambers, green houses, shade houses, TC hardening units etc.
- Repair and maintenance of poly houses, rain shelters, mist chambers, green houses, shade houses etc.
- Setting up of open precision farming units for fruits and vegetable cultivation.
- Designing and setting up roof terrace gardens.
- Design and installation of drip, sprinkler and mist irrigation systems.
- Design and installation of fertigation systems.
- Fabrication, setting up and maintenance of rainwater harvesting and storage structures for irrigation and fish farming.
- Undertaking contract farming
- Large scale production of planting materials
- j. Value addition and marketing of fruits, vegetables and spices

g. Fruits and vegetables processing unit

The ARS, Anakkayam has established a licensed processing unit for spices, fruits and vegetables with the financial assistance from the State Planning Board and NABARD. The activities in the processing unit includes free training to house wives in product diversification through value addition of locally available minor fruits and vegetables. At present the unit is producing more than 26 novel products including pickles, dried flakes, syrup, vinegar, chips, jam etc.

Five years agothe internal revenue of the research station comprising 10 hectares of purely rain-fed dry land was Rs.5 lakhs and its limited internal revenue was from the sale of cashew grafts and cashew nuts. The interspaces of cashew plantation were left unutilized mainly because of shortage of irrigation water in this station. Acute deficit of irrigation water during the summer season was one of the major threats to crop cultivation in this farm. This major constraint was overcome in the station through rainwater conservation.

Now, the research station is providing direct employment to about 100 families in and around Anakkayam Panchayat of Malappuram district. Thousands of farmers of the entire state of Kerala are depending on this research station to ensure their timely supply of planting materials. The network of vegetable farmers set up by our research station in the district have intensified their vegetable production since they get higher prices for their crop through the direct procurement by ARS, Anakkayam. Intercropping, rainwater conservation, crop diversification and application of integrated cropping systems have now resulted in enhancing the internal revenue of the station from Rs.4.9 lakhs (in 2006-07) to Rs.121 lakhs (during 2011-12) and Rs.2.6 crores during 2012-13.

The involvement of rural youth, including the trained SHGs working in the research station had enormously contributed to this revolutionary development. The web link entitled "A wonder farm in Kerala" http://www.civilsocietyonline.com/pages/Details.aspx?367 highlights the activities of ARS, Anakkayam world-wide.

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ABSTRACTS

P-1

Quantitative analysis of capsaicinoids in chilly varieties by High Performance Liquid Chromatography

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In India two species of chilly *viz*., *Capsicum annuum* and *Capsicum frutescens* are widely cultivated and most of the varieties belong to *Capsicum annuum* species. Capsaicinoids are the compounds responsible for the pungency and are also credited with the pharmacological properties. The Chilly cultivars Angar, Donna, Rati, Tejaswini, Trikas, and Veda are commonly available in Karnataka. However, these varieties have not been analyzed for their capsaicinoid content. Hence, an attempt was made to analyze the green form of chillies for their total capsaicinoids and the pungency level which are expressed in terms of Scoville Heat Unit (SHU). The present research compares the variations in these varieties and reports that among all the chilly varieties analyzed, Tejaswini showed a very high pungency level. All the varieties studied showed a pungency level greater than 3000-4500 SHU, which may serve as a potential source of capsaicin.

P-2

Evaluation of antioxidants and free radical scavenging activity of chilli cultivars and oleoresins

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Hot peppers (*Capsicum annum* L.) are remarkable source of antioxidant compounds, including vitamins, phenolic compounds, capsaicinoids and carotenoids. The concentrations of these compounds depend on cultivar, maturity, growing conditions and post harvest manipulation. Radical scavenging and antioxidant activity of ethanolic extracts of selected chilli varieties viz. *Byadagi, Sattur S4, Sangali sannam* and *Tomato chilli* and oleoresins were investigated. Antioxidant activity was found to be higher in the chilli variety *Byadagi.* Paprika oleoresin with 1,00,000 CU exhibited better activity for glutathione peroxidase, glutathione S transferase and glutathione reductase. Radical scavenging activity of methanolic extracts of chilli varieties and oleoresin was found to be concentration dependent. The study elucidated the bioactive property of the chilli and oleoresins extracts and proved as a potent source of natural antioxidants which could be exploited to its full extent in modern food processing industries.

P-3

Effect of different sources and levels of potassium on post harvest characters of paprika cv. KtPl-19 under drip fertigation system

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Fertigation studies on paprika (*Capsicum annuum* var. *longum*) were carried out at the College orchard, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to find out the effect of different sources and levels of potassium on post harvest characters of paprika. The treatment T_7 recorded the lowest physiological loss in weight and capsaicin content, the highest fruit firmness and shelf life and quality characters *viz.*, ascorbic acid content and oleoresin content in paprika. High performance liquid chromatographic study on capsanthin pigment revealed that the treatment drip fertigation with water soluble fertilizers at 100% RDF using MAP, Multi-K and SOP recorded higher area in the chromatogram.

P-4

Performance of Arka Coorg Excel - A new black pepper (*Piper nigrum* L.) variety at high altitude Kodagu region of Karnataka

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Black pepper (*Piper nigrum* L.) is one of the most important spices of India. It contributes a major share in total export of spices from India. Kerala, Tami Nadu and Karnataka are the traditional pepper growing states of the country. Comparative performance of Arka Coorg Excel revealed that the yield of green berries (12 year old vines) of this variety was higher (7.86 kg/vine) than the. Panniyur-1 (6.59 kg/vine). The average spike length of Arka Coorg Excel was 14.22 cm which was higher than other varieties. The number of berries per spike, wet and dry weight of berries and percent recovery were also higher in this variety.

P-5

Evaluation of essential oil profiles of selected wild *piper* species

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In this study, the essential oil profiles of wild *Piper nigrum* L., *Piper longum* L., *Piper chaba* Hunter. and *Piper colubrinum* Link. were compared. Essential oil extracted from the dried berrie/spikes of these species was subjected to GC-MS analysis for oil constituents. Oil content varied between 0.2-2.4% and was highest in *P. nigrum* (wild) and lowest in *P. colubrinum*. A range of 28-48 compounds were identified among these species. *P. nigrum* (wild) contained high amount of monoterpenes (pinene, δ-3 carene, limonene, etc.) followed by sesquiterpenes (β-caryophyllene, α-humulene, caryophyllene oxide etc). *P. chaba* and *P. longum* contained high aliphatic hydrocarbons (n-pentadecane, n-heptadecane etc.) whereas *P. colubrinum* showed high sesquiterpenes (β-caryophyllene, α-humulene, muurolene, caryophyllene oxide etc). Constituents such as β- Pinene, β-caryophellene, α-humulene, β-bisabolene and caryophyllene oxide were noted in all the four species. Beta-caryophellene was highest in wild *P. nigrum* and lowest in *P. longum*. Caryophyllene oxide was highest in *P. colubrinum* and negligible in *P. longum*. Beta pinene, known for its aroma and therapeutic properties was also present in all four species (highest in *P. longum* followed by *P. nigrum* while negligible in *P. chaba* and *P. colubrinum*). Constituents such as sabinene, δ-3-Carene, α-thujene, β- selinene and β-bisabolene showed variation among wild and cultivated *P. nigrum*.

P-6

Few unique black pepper accessions of high significance

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A few unique a black pepper (*Piper nigrum* L.) accessions have been collected, characterized and conserved by the Indian Institute of Spices Research, Kozhikode, Kerala. Priced catches include an accession with high dry recovery and another one with exceptionally long spike. A unique black pepper accession ('Narayakody' type) with very high dry recovery (46%) and high bulk density (502g l^{-1}) coupled with round, firm and bold attractive black coloured corns, located from a mixed farming plantation near Agaly in Palakkad district of Kerala, is one. Berries of this cultivar are of good quality [piperine (2.5%), oleoresin (9.26%), essential oil (2.4%)] and is an ideal commodity for GI registration as 'Agali black pepper' and holds promise as a novel source of gene(s) for increasing dry weight and bulk density. Another unique black pepper accession collected from Yemmigoondie Estate, Suntikoppa Post, Somwarpet Taluk, Kodagu district, Karnataka is characterized by very long spike (mean length 26.06 cm) long peduncle (1.3 cm), light purple shoot tip, drooping/hanging lateral branches, ovate-lanceolate, large leaves (15 × 8.2cm) with acuminate tips and long petiole (2.9 cm). Even though the spikes were very long, hitherto unreported in cultivated black pepper, number of spike and berries per spike were rather few. The round shaped berries are of small size with oil-2.4%, oleoresin-8.82% and piperine-2.53%. 'Undane', 'Bolt' and 'Ponmani' are another three bold berried accessions collected from farmers' plot, the former two from Wayanad district and the latter from Idukki district in Kerala.

P-7

Soil less nursery mixture for black pepper multiplication using plug trays

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Availability of quality planting material of high yielding varieties of black pepper (*Piper nigrum* L.) is a major production constraint in all black pepper growing countries. The present investigation was carried out to study the effect of different combinations of soil less coir pith based nursery mixtures on rooting and growth of black pepper cuttings in the nursery using plug-trays. Among the different nursery media combinations, coir pith with *Trichoderma* and vermicompost recorded significantly high nursery growth parameters than all other treatments. The present study confirms that composted coir pith with vermicompost and *Trichoderma* is an ideal potting medium for the nursery. Among the three different maturity stages of the rooted cuttings, maximum nursery growth was recorded in the terminal portion of the rooted cuttings (11-15th nodes). Similarly, higher nursery growth parameters were recorded in the single node rooted cuttings planted with full leaf. Use of *Trichoderma* and *vermicompost* enriched coir pith in black pepper nurseries minimizes use of chemical fungicides. *Trichoderma* that colonizes the root system of seedlings will help in preventing the infection by pathogens in the main field. Since there is no high additional cost involved, the use of *Trichoderma* enriched coir pith can also be adopted by commercial nurseries.

P-8

Machine generated potting mixture-effect on black pepper cuttings and nutmeg seedlings

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An experiment was conducted to find out the effect of machine made potting mixture on seedling growth of black pepper (*Piper nigrum* L.) rooted cuttings and nutmeg (*Myristica fragrans* Houtt.) seedlings. The treatments were soil, granite powder, FYM 2:0:1 (made mechanically); soil, granite powder, FYM 2:1:1 made mechanically); soil, sand, FYM 2:1:1 (made mechanically); soil, granite powder, FYM 2:1:1 (prepared manually). Height of black pepper plants in machine made potting mixture filled bags was on par with either sand or granite powder as one of the ingredients in potting mixture followed by soil, granite powder, FYM 2:1:1 (manually). Number of leaves and root length in all the treatments were on par except soil, granite powder FYM 2:0:1 (made mechanically). Effect of various treatments was significant regarding number of leaves in nutmeg seedlings.

P-9

Soil test based site specific fertilizer recommendation and its economic optimum for targeted yield of black pepper

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In order to devise soil test based fertilizer recommendation for targeted yield in black pepper field experiments were carried out in Wayanad (Kerala) and Madikeri (Karnataka) by creating fertility gradients with treatments receiving no fertilizers, half, one and one and half times of the recommended dose of N, P and K. Based on the yield under different treatments over three years and initial soil availability, nutrient required for per 100 kg yield (NR), contribution of nutrient from soil (CS) and contribution from fertilizer (CF) were standardized. Using these values fertilizer doses to obtain targeted yield of black pepper (var. Panniyur-1) was calculated for different soil test values and validated at Madikeri. The recorded yield levels were 5.5, 7.3 and 8.2 kg/std in the targets of 5, 7.5 and 10 kg dry/std, with a deviation of +11%, -2.2% and -18.0%, respectively during the first year. The yield increase as compared to the control was 39-104%. In second year, the yield levels were 5.9, 5.4 and 6.6 kg/std in the targets of 5, 7.5 and 10 kg dry/std, with a deviation of +17.8%, -28.3% and -33.5%,respectively. Third year recorded yield levels were 7.0, 8.7 and 9.7 kg/standard in the targets of 5, 7.5 and 10 kg dry/standard, with a deviation of +40.2%, +15.6% and -2.9% ,respectively. The economic optimum in terms of profitable response for money invested was also worked as Rs. 1.60/standard for N, Rs. 2.40/standard for P and Rs. 5.40/standard for K.

P-10

Bioefficacy of strobilurin fungicides Ergon 44.3% (w/w) [Kresoxim methyl 500 g/L SC] and RIL-070/FI(72WP) against *Phytophthora capsici* infecting black pepper

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Two new fungicides *viz*., Ergon 44.3% (w/w) [Kresoxim methyl 500 g/L SC] and RIL-070/FI(72WP) were evaluated *in vitro* and *in planta* against *Phytophthora capsici* causing foot rot disease of black pepper. The chemicals were tested *in planta* using the best concentration found effective *in vitro*. Ergon when tested from 10-6000 ppm *in vitro,* showed complete inhibition of mycelial growth and sporulation at 6000ppm though zoospore germination was completely inhibited at 2000ppm. The average ED50 and ED 90 values were 845.51ppm and 1740.71ppm, respectively. Foliar spray of the chemical followed by challenge inoculation showed an overall inhibition of lesion development (44.83%) over control and maximum inhibition (57.12%) was observed at 5 days at a concentration of 7000 ppm. RIL-070/FI at concentrations from 10-500 ppm when tested *in vitro* against *P. capsici* showed 100% mycelial inhibition at 50 ppm with ED 50 and ED90 values of 22.85 ppm and 45.71 ppm, respectively. For inhibition of sporulation, the maximum concentration required was 100ppm for which ED 50 and ED 90 values were 34.47 ppm and 47.47 ppm, respectively. The average ED 50 for *in vitro* inhibition was 29.23 and ED 90 value was 54.43ppm. When *P. capsici* was challenged five days after spraying of the chemical, 600ppm showed 100% inhibition of lesion development and the effect is reduced when challenged 10days after spraying. Soil application of the chemical at 400 showed 100% reduction in mortality. The *P. capsici* population was also reduced to 77.58%.

P-11

Evaluation of cardamom genotypes for growth and yield traits under hill zone conditions of Karnataka

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A field experiment was conducted to identify the high dry capsule yielding cardamom genotypes suitable for cultivation in the hill zones of Karnataka using eight genotypes. Significant difference among the growth and yield attributing traits was observed for all the genotypes. Among the clones evaluated for yield and yield attributes, clone CL-722 (311.70 kg/ha) recorded higher average dry capsule yield followed by PS-27 (275.58 kg/ha) and MCC-309 (254.34 kg/ha) over the years than the checks M-1 (216.34 kg/ha)) and M-2 (182.23 kg/ha). Among the yield attributing characters, maximum panicles numbers/plant (58.85), number of bearing suckers/plant (15.0), number of capsules /panicle (25.0) and more panicle length (50.08 cm) were observed in CL-722. The clone CL-722 recorded lowest percent damage by thrips **(**5.01), capsule borer (0.23) and capsule rot (0.48) besides lowest incidence to major diseases like clump rot (1.89), leaf spot (2.01) and leaf blotch (1.75). Among the clones, the performance of CL-722 was found to be promising with higher dry capsule yield followed by PS-27.

P-12

Sources of resistance to rhizome rot of cardamom (*Elettaria cardamomum* Maton)

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A study on the reaction of cardamom (*Elettaria cardamomum* Maton) to rhizome rot was done using 116 genotypes which consisted of germplasm accessions, hybrids, mutants and elite lines maintained in the research farm of ICRI Regional Station, Spices Board, Sakleshpur. Five to seven year old plants maintained in the germplasm block, hybrid evaluation plot or multiplication plot were monitored for symptoms of natural field infections during August 2012 and 2013. Disease incidence on at least 3-5 plants of each accession was scored on a 0-4 scale and percent disease index (PDI) calculated. Based on the average of PDI obtained during two years, the accessions were classified into five phenotypic groups. No disease developed on 9 accessions (SKP 103, SKP 105, SKP 158, SKP 165, SKP 166, SKP 180, SKP 206, SKP 296 & SKP 300) and were considered as resistant whereas 32 accessions were rated as tolerant (PDI 0.1-10), 35 as moderately tolerant (PDI 10.1-20) and 40 as susceptible (PDI 20.1-50). No accession was rated as highly susceptible (PDI 50.1 & above). Thus the accessions exhibited a wide range of field reactions to natural infections of rhizome rot pathogens indicating possible rich genetic diversity to biotic stress.

P-13

Response of cardamom to different levels of irrigation and fertilizer levels through drips

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In view of this to find out the water requirement of cardamom, an experiment was conducted during at ZAHRS, Mudigere, Karnataka, based on the cumulative pan evaporation. The experiment included three irrigation levels 100% pan evaporation (9 lt/day/clump), 66% pan evaporation (6 lt/day/clump), and 33% pan evaporation (3 lt/day/clump) and 5 fertilizer levels viz., 25% recommended dose of fertilizer, 50% recommended dose of fertilizer, 75% recommended dose of fertilizer, 100% recommended dose of fertilizer and conventional method. The results indicated that the irrigation (9 L/day/clump), with 100% recommended dose of fertilizer gave highest yield (205.35kg/ha). This was on par with irrigation (9 L/day/clump), with 75% recommended dose of fertilizer (199.25kg/ha). The lowest yield was obtained with the conventional method of irrigation (155.57 kg/ha).

P-14

Deficiency symptoms in cardamom under induced conditions

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A pot culture experiment was conducted to identify nutrient deficiency symptoms in small cardamom (*Elettaria cardamomum* Maton). The treatments included control, zero N, zero P, zero K, zero Ca, zero Mg, zero S, zero Cu, zero Fe, zero Mn, zero B, zero Zn and zero Mo. Complete Hoagland nutrient solution was drenched to potted plants until full establishment. After the establishment of the tillers, the treatment imposition was initiated by drenching 50-100 ml of Hoagland solution minus the nutrient corresponding to the each treatment, in the potted plants. The studies established distinctive visual deficiency symptoms for the macronutrient elements (N, P, K, Ca and Mg) and micronutrients (Zn, B, Mn, and Mo) in cardamom. The deficiency symptoms first appeared in the plants with zero nitrogen followed by zero potassium, zero zinc, zero calcium, zero magnesium, zero phosphorus, zero manganese, zero boron and zero molybdenum. The symptoms thus identified can be used as visual markers during early growth period of cardamom for identifying nutritional disorders.

P-15

Influence of moisture stress on quality of cardamom

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Studies were conducted on eight hybrid combinations of cardamom (*Elettaria cardamomum* Maton) to assess the influence of moisture stress on seed weight, essential yield and its composition. Moisture stress was imposed for two months from February second fortnight to April second fortnight. The results indicated that the seed weight varied between 67.0-72.2% and 65.0-71.5% in control while under stress it ranged between 59.7-72.4% and 65.9-72.2% during the first and second year, respectively. Essential oil content in capsules ranged between 4.3-5.5% and 4.6-5.6% in control while under stress it varied between 4.0-5.5% and 4.8-5.6% during the first and second years, respectively. Among the 23 constituents characterized by GC-MS, the dominant compounds were 1,8-cineole and α-terpinylacetate. 1,8-ineole ranged between 26.9-33.5% in control and 26.1-33.1% in stress and α-terpinylacetate ranged between 37.2-40.4% in control and 33.4-43.2% in stress. The essential oil yield was significantly higher under moisture stress in the second year. There was no significant effect of moisture stress on seed weight and major components of essential oil. However, minor constituents *viz*., α-thujene, α-pinene, myrcene, terpinolene and α-terpineol were slightly higher under moisture stress. There was significant difference among the accessions for seed yield.

P-16

Evaluation of mechanical weed cutter in cardamom plantation

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Cardamom is a highly labour intensive crop. Mechanisation has become the need of the hour for achieving precision and timeliness in cardamom cultivation. Weed management is essential during the initial years of planting. Manual weeding is commonly adopted in cardamom plantation. A field evaluation was conducted at ICRI Myladumpara to find out the efficiency and economic benefit for weeding using brush cutter against manual weeding. The experiment was laid out in blocks and independent't' test was used to compare the means. The study indicated that weeding in cardamom plantations using mechanical weed/brush cutter was found to be more economical against manual weeding. Mechanical weeding could save 17-25 man days ha^{-1}.

P-17

Collection and evaluation of ginger accessions for yield and quality in Tamil Nadu

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A study was taken up with a vision to develop a ginger (*Zingiber officinale* Rosc.) variety/ identify suitable existing cultivar with higher yield and quality attributes for high rainfall zone. In this context totally 24 ginger accessions including local strains and varieties (ZO-1 to 24) were collected from different ginger growing tracts *viz*., High Altitude Research Station, OUAT, Pottangi, Orissa (13), Horticultural Research Station, APHU, Chintapalli (3), Pechiparai (3), Shengottah (1), and Idukki (4) for evaluating their performance for yield and quality under Pechiparai region. Out of twenty four genotypes evaluated accession ZO-4 recorded higher fresh rhizome yield (22.16t/ha), ZO- 6 recorded highest dry recovery (22.47%), ZO-5 recorded highest oleoresin content of 9.56% and the genotype ZO- 17 recorded highest fibre content (11.2%).

P-18

Biochemical parameters of dry ginger varieties in Kodagu region of Karnataka

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This experiment was conducted at Appangala, Karnataka, located 1000 m above MSL with 2000-3000 mm rainfall per year to study the performance of seven released varieties of ginger (*Zingiber officinale* Rosc.) *viz*., Himagiri, IISR Mahima, IISR Rejatha, IISR Varada, Suprabha, Suravi and Rio-de-janeiro. The biochemical parameters were analyzed and the maximum essential oil (1.6%) and oleoresin (4.4%) were recorded in Suprabha. The maximum crude fiber (4.9%) was recorded in Rio-de-janeiro, IISR Rejatha and Suravi.

P-19

Mechanisms for plant growth promotion elicited by rhizobacteria in ginger

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Fortyfive rhizobacterial isolates, 11 different PGPR stains including the reference cultures of *Pseudomonas fluorescens* were evaluated for elicitation of growth promotion of ginger (*Zingiber officinale* Rosc.) *in vitro* and *in vivo. In vivo* testing of the PGPR strains increased the number of tillers, leaves as well as fresh weight of rhizomes of ginger. To define signal transduction pathways associated with growth promotion elicited by PGPR, various plant hormones were evaluated *in vitro.* It was observed that four isolates *viz*., RB-22, RB-144, RB-11 and RB-82 showed a PGPI of above 70 and the lowest index in RB-151. TLC analysis of growth regulators produced by the 11 isolates revealed that though all the cultures produce auxin and their related compounds, only two isolates *viz*., RB-141 and RB-11 produced both gibberellic acid as well as auxins. It was observed that all isolates produced salicylic acid in varying amounts with the maximum by the two reference cultures followed by the isolates RB-11 and RB-22. Maximum number of antibiotics was produced by the isolate RB-22 comprising of pyoluteorin, pyrrolnitrin, pyocyanin and unidentified metabolite and this was closely followed by RB-144, RB-66, RB-11 and P.f2 which produced three antibiotics. Antibiotic 2, 4 DAPG was produced by RB-66, RB-11 and P.f2 apart from certain unidentified ones. With respect to siderophore production, four cultures *viz*., RB-22, RB-82, RB-66 and RB-11 showed fluorescence under UV light, however, maximum zone in CAS plates was detected in the isolate RB-22 and RB-11.

P-20

Phenological variation in two species of *Curcuma*

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An attempt was made to study the effect of three different maturity stages [90 days after planting (DAP), 140 DAP & 180 DAP] on growth, yield and quality of two *Curcuma* species *viz*., *Curcuma aromatica* Salisb. and *Curcuma amada* Roxb. Plant height, yield and dry recovery showed considerable variation over the three growth stages. The two species differed significantly for plant height, dry recovery, yield, oil, curcumin and starch between the species as well as among the growth stages. Species x Growth stage was also significant. Fresh yield, dry recovery and starch gradually increased in both the species. Significant accumulation of photosynthate was evident even after 140 DAP. Though the two species behaved more or less uniformly for all the aerial growth attributes, yield and starch, differential behaviour of the two species was observed for curcumin, oil and protein content.

P-21

Performance of different turmeric cultivars for yield and quality in the agency area of north coastal Andhra Pradesh

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An experiment was carried out with 12 varieties of turmeric (*Curcuma longa* L.) during *kharif* season at the Horticultural Research Station, Chintapalli under rainfed conditions. The varieties highly differed in their growth characters, production potential and quality aspects. The experimentation revealed that the variety Roma exhibited maximum values for plant height (112.5 cm), number of tillers/plant (5.02), leaf length (61.96 cm), leaf breadth (16.37 cm), leaf area (1014.2 sq.cm), average weight of rhizome per plant (489.21 g), average weight of fresh rhizome per $3m^2$ bed (11.2 kg), curing percentage (24.9 %), dry yield (9.5 t/ha) and curcumin content (6.3%). In the present investigation, varieties NH-1, Chintapalli local, Cli.317, Rajendra Sonia, IISR-Kedaram, IISR-Pratibha, IISR-Alleppy Supreem were found to be early duration types (200 to 220 days).Varieties BSR-2, Suranjana, Rasmi were found to be medium in duration (230 to 240 days) where as Roma and Mega turmeric matured relatively late (250 days). On the basis of good performance Roma is recommended as a promising turmeric cultivar for general cultivation in Agency area of North Coast Andhra Pradesh.

P-22

Evaluation of turmeric germplasm of different durations against major diseases in Andhra Pradesh

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Field studies were conducted over a period of four years in augmented design with available germplasm lines (295 Nos) of turmeric (*Curcuma longa L.*) at the Horticultural Research Station, Jagtial and Turmeric Research Station, Kammarpally. These lines were screened against *Colletotrichum* leaf spot, *Taphirna* leaf blotch and rhizome rot diseases under natural conditions. Most of the short duration (6-7 months) and medium duration (7-8 months) lines were free from leaf spot while long duration (8-9 months) cultures were free from leaf blotch. The severity of leaf blotch and leaf spot ranged from 0.00 to 68.84% and 0.00 to 75.28%, respectively, and rhizome rot incidence ranged from 1.58 to 80.56% irrespective of the accessions. None of the accessions were free from all the diseases under study irrespective of the duration.

P-23

Evaluation of yield and quality of turmeric cultivars under southern dry zone of Karnataka

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Among the sixteen turmeric *(Curcuma longa* L.) cultivars tested in southern dry zone of Karnataka, maximum fresh rhizome yield of was observed in Salem (33.67 t ha^{-1}) on par with Rajapuri (32.67 t ha^{-1}), Prathibha (32.56 t ha^{-1}) and CLT-325 (20.99 t ha^{-1}) and the highest curing percentage was recorded in Salem (24.70) which was on par with CLT-325 (24.51)and Erode Local (24.16). Minimum curing percentage was found in the cultivar CLI-14 (20.01). Maximum cured turmeric rhizome yield was obtained in Salem (8.31 t ha^{-1}), CLT-325 (7.98 t ha^{-1}) and Co-1 (7.01 t ha^{-1}). With respect to quality in terms of curcumin content, PTS-24, Prabha, Prathibha, CLT-325, Salem and Rajapuri were superior (7.20%, 6.45%, 6.39%, 5.76%, 4.56% and 4.62% respectively) and suitable for export as per the international standard.

P-24

Construction of a normalized full length cDNA library from turmericfor rapid gene discovery

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The present work describes a simple and efficient method for constructing a normalized full length cDNA library from a high curcumin turmeric (*Curcuma longa* L.) variety, IISR Prathibha. The normalisation procedure was adopted to decrease the prevalence of abundant transcripts thereby facilitating assessment of rare transcripts. It combined switching mechanism at 5'-end of RNA transcript (SMART) technique and duplex-specific nuclease (DSN) normalization methods. Double-stranded cDNAs were synthesized from total RNA isolated from different tissues of turmeric and normalized using DSN. The normalized ds cDNAs were then ligated to pGEM-T vector and transformed into *Escherichia coli* JM109 by heat shock method. The methodology may be used for developing tissue specific and development stage specific libraries for functional analysis and manipulation of key genes involved in the curcuminoid and starch biosynthetic pathways in turmeric. The development of full-length genes has the power to improve quality of genome annotation as well as provide tools for functional characterization of genes.

P-25

Deep sequencing identifies candidate miRNAs from turmeric with possible regulatory roles on plant and human genes

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In the present study small RNA cDNA from four month old 'Mega Turmeric' rhizome was sequenced using illumina GA II sequencer. Blast analysis of unique small RNAs against miRNA registry database, miRBase 19, identified 33 miRNAs belonging to 19 conserved miRNA families. The study also identified 98 novel candidate miRNAs, 13 of which contained miRNA* sequences. Members of miRNA family designated as clo-miR (*Curcuma longa*) 166, 159, 396 and 156 showed significant expression levels while 169 and 408 were under expressed. Potential target genes were predicted for conserved miRNAs and novel miRNAs using mirTools 2.0. Major targets identified were transcription factors like ARF, AP2, MYB, TCP, WRKY related to plant growth and development, phenylalanine ammonia lyase or PAL (phenylpropanoid pathway enzyme leading to curcumin synthesis) and heat shock proteins related to stress response. Some of the novel turmeric miRNAs were found to target genes responsible for various human diseases like Alzhemer's, Huntingtin, polycystic kidney and hepatic disease, Wiskott - Aldrich syndrome, retinitis pigmentosa, etc. similar to earlier reports from rice. This is the first massive scale small RNA sequencing study performed in the family Zingiberaceae.

P-26

Influence of bavistin and BAP alone or in combination on pest free micropropagation and conservation of *Curcuma longa* L. and *Zingiber officinale* R.

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The present investigations were undertaken to standardize an efficient micropropagation and *in vitro* conservation protocol for *Curcuma longa cv.* NDH-98 and *Zingiber officinale* cv. Himachal Pradesh (Pullapally) using nodal explants. To find out the optimum concentration of bavistin (fungicide) without compromising the viability for multiple shoot and root induction, the experiment was conducted by adding different concentrations of bavistin 25 -100mg/l in MS basal and MS hormone medium (2.5mg/l BAP) with 3% sucrose and 0.45% clarigar. MS hormone medium containing 25mg/l bavistin developed maximum number of shoots per explant (6.2 in *C. longa* and 8.00 in *Z. officinale)* when compared with control (without bavistin) after eight weeks of inoculation at 25 ± 2°C. It was observed that bavistin alone in the concentration of 50 mg/l in MS basal medium produced number of shoots at par with control. Higher or lower concentration of bavistin in MS basal medium did not improve the shoot multiplication. The results strongly confirmed the reports on cytokinins like physiological functions of bavistin which promotes shoot multiplication *in vitro*. Rooting also occurred simultaneously on the same medium with 7.08 roots/ explant in *C. longa* and 5.33 roots/ explant in *Z. officinale.* The explants in all the treatments did not show any bacterial colony or fungal growth in the culture.

P-27

Effect of seed rhizome size, microbial bioinoculant (VAM) and bio-formulations on growth, yield and quality of turmeric cv. Salem

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Effect of seed rhizome size, microbial bio-inoculant (VAM) and bio-formulations on growth, yield and quality of turmeric cv. Salem was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi, Kamataka. Field trial on seed rhizome size was laid out with seven treatments, replicated thrice. Among seven seed rhizome sizes, the highest cured yield (10.41 t/ha), processing percentage (30.93), curcumin content (4.83%) and volatile oil (1.34%) were obtained by planting whole mother rhizome of size 25 g followed by cut mother rhizome of size 25 g. A separate field trial on the effect of microbial bioinoculant (VAM) and bioformations was also laid out with two main (with or without VAM) and nine sub treatments (bioformulations). Inoculation of VAM (30.10 t/ha) resulted in higher fresh rhizome yield than the un inoculated control (23.48 t/ha). The highest processing percentage (30.45%), curcumin content (4.42%) and volatile oil (1.17%) was observed in the crop inoculated with VAM. Among nine bioformulations treatments, the highest fresh rhizome yield (31.03 t/ha) was recorded in the treatment with RDF + panchagavya + amrit pani + mulch (sugar cane trash) + *Trichoderma* (2.5%) spray on mulch + agnihotra ash + triambakam homa ash.

P-28

Influence of organic manures and microbial inoculants on yield and quality attributes of Kasturi turmeric

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The experiment was conducted with the main objective of studying the combined effect of organic manures (OM) and microbial inoculants (MI) on yield and post harvest quality attributes of kasturi turmeric (*Curcuma aromatica* Salisb.). The treatments included the different individual as well as combined doses of organic manures *viz*., FYM (40 t ha^{-1}), vermicompost (VC) (25 t ha^{-1}) and neem cake (NC) (6 t ha^{-1}) in combination with microbial inoculants [*Azospirillum* (4% of OM) + AMF (2-3 g/ plant) + *Trichoderma* (2% slurry) + *Pseudomonas* (2% suspension) (MI)]. The results revealed that highest fresh rhizome yield of 456.99 g/ plant and 13.75 kg/ bed (3 × 1.2 m size) were recorded in the treatment VC 25.0 t ha^{-1} + MI. Volatile oil (6.60%), non volatile ether extract (6.73%) and starch (22.58%) were also highest in the same treatment. Lowest crude fibre content (2.13%) was also recorded in the above treatment. However, in case of curcumin content there was no significant difference between treatments.

P-29

Infectivity and multiplication of entomopathogenic nematodes against *Lema* sp. (Chrysomelidae: Coleoptera) infesting turmeric

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The infectivity and rate of multiplication of eight native isolates of entomopathogenic nematodes (EPNs), *Heterorhabditis* sp. (IISR-EPN 01), *Steinernema* sp. (IISR-EPN 02), *S. ramanai* (IISR-EPN 03), *Oscheius* spp. (IISR-EPN 04, 05 and 08), *S. carpocapsae* (IISR-EPN 06) and *O. gingeri* were evaluated against larvae of *Lema* sp. infesting turmeric (*Curcuma longa* L.). Among the tested species of EPNs, *Steinernema* sp. (IISR-EPN 02) and *O. gingeri* were more pathogenic to *Lema* sp. as they brought 100% mortality of the insect within 48 h post exposure, followed by *Heterorhabditis* sp. (IISR-EPN 01) and *Oscheius* sp. (IISR-EPN 08) after 72h of exposure. *S. ramanai* (IISR-EPN 03) and *Oscheius* spp. (IISR-EPN 04 and 05) took 96 and 120h, respectively to kill the test insect. No mortality was observed in the control. *Lema* sp. larva was the most suitable host for multiplication of infective juveniles (IJs) of *O. gingeri*, which yielded 11, 480 IJs/larva, followed by *Steinernema* sp. (IISR-EPN 02) (8,658 IJs/larva) and *Oscheius* sp. (IISR-EPN 05) (1,321 IJs/larva). However, *Heterorhabditis* sp. (IISR-EPN 01) did not multiply in larvae of *Lema* sp. The infectivity of the above EPNs against *Lema* sp. is being reported for the first time which opens up a new hope of utilizing them in insect pest management of turmeric.

P-30

Propagation studies in vanilla

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The study on vanilla (*Vanilla planifolia* Andr.) propagation was carried out at the Regional Station of Indian Cardamom Research Institute, Spices Board, Karnataka. Vegetative propagation using stem cuttings of different lengths having one, two, three or five nodes and one meter cuttings revealed that the longest cuttings *viz*., 1m ones followed by those having 5 nodes have performed better in terms of highest percentage of rooting, sprouts, vine length, number of leaves, vine fresh weight, root length and root fresh weight. Rooting) was observed in 15 days after planting the cuttings. Maximum percentage of rooting was found in 1m cuttings (88%) followed by 5 noded cuttings (81%). Leaf emergence was observed two months after planting. Leaf production was more in the1m cuttings (4.5) three months after planting. Yielding started 24 months after planting in the field. Fresh yield was significantly more in the plants of 1m cuttings (160 kg ha^{-1}) followed by 5 noded cuttings (108 kg ha^{-1}). The present study suggests that 5 node cuttings is a better choice for raising the nursery.

P-31

A study on rbcL gene region and its homology model of protein of selected Indian *Garcinia* species

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In the present study, plastid-encoded *rbcL* gene (enzyme ribulose- 1,5-biphosphate carboxylase), the first enzyme of carbon-fixation pathway, of 8 major Indian *Garcinia* species was studied. *Garcinia rbcL* gene sequences were of 1120bp length and were 99% similar with each other. Translated peptide, RuBisCO large subunit (RBCL) contained 430 amino acids and had a molecular weight of 47695 kD. The protein was found to be slightly negatively charged globular protein. 3D structure of the protein was designed using Modeller 9.10 and was validated using Ramchandran plot, having 95% amino acids in allowed region. ERRAT quality factor was calculated to be 77.25. Structural analysis indicated the presence of 2 H-T-H, 1 TIM and 1 Greek-key motif with a total of 11 α-helices and β-sheets each. Three active site locations were observed in the RBCL. Evolutionary analysis of the sequences by NJ method showed a very low evolutionary distance (<0.0005), indicating the inefficiency of *rbcL* in phylogenetic studies of *Garcinia*. The cladistic pattern was similar to that drawn using ITS region of *Garcinia* in which species with pentamerous petals clustered distinctly from that with tetramerous flowers.

P-32

Kudampuli GC9- a promising accession

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Kudampuli or Malabar tamarind is a well known spice used by people of Kerala in culinary preparations. The tree is much adapted to humid tropical areas receiving annual rainfall of more than 1500 mm and elevation ranging from 100-500 m above MSL. GC-9 is a clonal selection from the germplasm of the tree maintained at the Horticultural Research Station (TNAU), Pechiparai, Tamil Nadu. The volatile oil showed 55.94% and 66.9% antioxidant activity at 100 and 200-ppm concentrations, respectively. The grafts come to bearing from the third year onwards with more number of fruits per plant (257 or 258). It gives a mean yield of 64.04 kg/tree and 40 t/ha. GC9 is a high yielding type recording 24.0 per cent higher fruit yield than Pechiparai local. The dry recovery per cent is also high (15 %).

P-33

Hisar Bhoomit: A leafy type variety of coriander

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In this study we developed a higher green leaf yielding variety of coriander (*Coriandrum sativum* L.) *viz*., Hisar Bhoomit (DH-228). This variety also has high oil content and is resistant to stem gall disease. Besides, it is suitable for cultivation throughout the country. Its round shaped seeds are smaller in size with high volatile oil content i.e. 0.66%, which is much higher than average value for coriander and other released varieties (0.30%). This variety out yielded other varieties and National check Pant Haritima at Hisar and Coimbatore over three years and is suitable for cultivation throughout the year for leaf purposes. It was recommended for state release during XVIII Workshop/ Group meeting of All India Coordinated Research Project on Spices held at Bhubaneswar (Orissa) and recommended for inclusion in package of practices by the Horticulture Officers Workshop held on Jan.16-17, 2008 at CCS Haryana Agricultural University, Hisar.

P-34

Impact of drip irrigation technology in coriander cultivation: A case of rainfed condition from Rajasthan

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The study was conducted among the farmers of Pali district of Rajasthan state with the objective to analysis the utilization of recommended practices for the effective implementation of drip irrigation technology in coriander cultivation. The study was conducted with an ex-post-facto research design among 120 adopters of drip irrigation technology engaged in coriander cultivation. An adoption index was developed for analysing the extent of adoption of recommended practices of drip irrigation technology in coriander cultivation. The results showed that about one-fifth of the farmers belonged to the low adoption category. Items *viz*., type of the filter used, type of emitter used, placement of dipping point and root zone area wetted were the items which had low adoption scores. It was revealed that variables *viz*., farm size, annual income, scientific orientation and extension contact had significant and positive relationship with extent of adoption. The results of the study revealed the urgent need to plan and implement appropriate extension efforts for enhancing the adoption of recommended practices by coriander farmers.

P-35

Constraints perceived by the farmers in adoption of fenugreek production technology in Rajasthan

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The study was conducted in Pali district of Rajasthan in a block maximum numbers of Front Line Demonstrations on fenugreek were conducted during last five years. Five adopted villages and five non adopted villages were selected randomly and sixty trained and sixty untrained respondents were randomly selected for the study. Constraint related to plant protection measures was the major constraints perceived by the fenugreek growers in both the groups. Relatively lesser constraints perceived by the farmers were for marketing, soil treatment and basal fertilizer application.. Least perceived constraints were for method of sowing, seed rate, time of sowing, seed treatment and improved seed. The overall constraints faced by the beneficiary and non-beneficiary respondents were 37.81 MP and 57.78 MP. There were rank order correlations in seven aspects of constraints out of the eleven aspects of constraints. In the remaining four aspects of constraints *i.e*. basal fertilizer application, chemical control of weeds, plant protection measures and post harvest technology there were no rank order correlation.

P-36

Studies on the influence of season on quality parameters in mango cultivars

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Field experiments were carried out to study the response of seasons in mango at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam. Total soluble solids, reducing sugars, non reducing sugars, total sugars, total carotenoid content, ascorbic acid content and lower acidity in response to location, season and varieties were analysed. The highest total soluble solids (20.30^{o} Brix), reducing sugar (7.50%), non reducing sugar (13.50%), total sugar (21.00%), carotenoids (7.70 mg 100 g^{-1}) and lowest acidity content (0.20%) were registered by $L_2S_1V_3$ (Tenkasi, Main season, Kalepad) whereas the highest ascorbic acid content (29.50 mg 100 g^{-1}) was recorded in the combination of $L_1S_1V_1$ (Kanyakumari, Main season, Alphonso). The least total soluble solids (14.00 ^{0}Brix) was recorded in $L_2S_2V_8$ (Tenkasi, Off season, Rumani), reducing sugar (3.00%) was recorded in $L_2S_2V_8$ (Tenkasi, Off season, Rumani),non reducing sugar (7.65%) was recorded in $L_2S_2V_{10}$ (Tenkasi, Off season, Swarnarekha), total sugar (10.55%) was recorded in $L_2S_2V_8$ (Tenkasi, Off season, Rumani), carotenoids (3.80 mg 100 g^{-1}) was recorded in $L_1S_2V_8$ (Kanyakumari,Off season, Rumani), the highest acidity content of (0.47 %) was recorded in $L_1S_2V_1$ (Kanyakumari, Off season, Alphonso) and the lowest ascorbic acid content (16.50 mg 100 g^{-1}) was recorded in $L_2S_2V_3$ (Tenkasi, Off season, Kalepad) and was at par with L2S2V7(Tenkasi, Off season, Neelum) (16.40 mg 100 g^{-1}).

P-37

Effect of mulching and certain pre harvest treatments for extending the post harvest life of mango

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Investigations were undertaken to study the effect of mulching, bio inoculants and chemicals on the shelf life of mango ((*Mangifera indica* L.) cv. Alphonso. The experiment was laid out in randomized block design with nine treatments replicated four times with cv. Alphonso at farmer's field in Devadhanapatti. Pre harvest sprays were taken up under field condition and compared with a sprayed control as check. Storage studies were done by keeping fruits at ambient temperature. Pre harvest sprays with bio inoculants (*Pseudomonas fluorescens* FP7 along with chitin) were sprayed six times at 15 days interval starting from 15 days before expected flowering of mango trees. Calcium chloride, calcium nitrate, potassium sulphate and borax were sprayed 30 days prior to harvest. At the post harvest stage, the same treatment exhibited delayed ripening, lowest weight loss, reduced anthracnose infection, increased duration for de-greening and resulted in extended shelf life. It also registered the highest TSS, ascorbic acid and total sugars. Thus it can be concluded that mulching along with 6 sprays of *Pseudomonas fluorescens* FP7 (0.2%) with chitin (0.5%) and $CaCl_2$ (1%) at pre harvest stages 30 days before harvest could be recommended for extension of the shelf life of mangoes upto 20 days and also to restore the quality attributes of the fruits.

P-38

Strategies to enhance production and export of mango in India

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A study was undertaken using the secondary data drawn from both State and Central Government sources in respect of area, production and productivity and export of mango. India found to be the major producer and exporter of mango to the developing and the developed world. Tamil Nadu in India was found to be the leader in fruit production followed by Maharashtra. In respect of productivity of fruits, Himachal Pradesh and Tamil Nadu are the front runners followed by Madhya Pradesh. When we compare the fruit production over the years it is interesting to note that higher area under fruits have produced very meagre increase in fruit production due to low productivity. Percentage reduction in fruit productivity in a decade of time was found to be 2.68% and the mango productivity was 3.19%. In respect of productivity of mango, 2012–13 had witnessed highest production. Percentage decadal increase in production of mango was 36.22. To confirm the decrease in productivity, a case farm in Theni District of Tamil Nadu was assessed for its production and productivity of mango. It was found that the case farm was able to generate 558% higher productivity than the state average and 216% higher productivity than the national average.

P-39

Evaluation of banana cultivars for fiber extraction

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Grand Naine and Karpura chekkerakeli are the major banana cultivars grown in Andhra Pradesh. The scope of utilization of these varieties for fibre extraction was assessed by an experiment at Horticultural Research Station, Kovvur by boiling the pseudostems in different concentrations of sodium hydroxide (0.1%, 0.5% and 5%). Among the two varieties the highest fibre recovery was obtained by using mechanical means (2.34% and 2.22%) in Karpura chekkerakeli and Grand Naine varieties, respectively. Among different chemical treatments boiling of banana sheaths in 0.5% NaoH recorded higher recovery percentage i.e. 1.76% and 0.85% in Karpura chekkerekeli and Grand Naine, respectively. With regard to fibre yield, Karpura chekkerakeli recorded highest fibre yield mechanically (1280 kg/ha) followed by boiling of banana sheaths in 0.5% NaoH (1020 kg/ha).

P-40

Post harvest behaviour in different cultivars of banana belonging to different genomic groups

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Post harvest characters of eleven banana cultivars belonging to different genomic groups were studied to provide information on different physico chemical properties like physiological loss in weight, pulp to peel ratio, pH, TSS and shelf life. Among the varieties under study, lowest physiological loss in weight (31.25%) was recorded in FHIA 1, a tetraploid AAAA and in Amrutpani AAB (32.5%). Highest PLW was observed in Dwarf Cavendish (67.5%) and in Tella chekkerakieli (64.5%), which belong to AAA genomic group. The pulp to peel ratio was found to be higher in the variety, Amrutpani (4.15, 5.78 and 6.96) in all the three stages at harvesting, ripening and at the end of shelf life, respectively where as minimum was recorded in KBS -11(ABB) i.e., 1.27, 1.88 and 2.08 at harvest, ripening and at the end of the shelf life, respectively. There was a progressive increase in the TSS content in all the treatments from harvest to ripening and thereafter a declining trend was noticed till the end of shelf life. The highest TSS at ripening stage (24.5 brix) was observed in the varieties Tellachekkerakeli (AAA) and Amrutpani (AAB).Significant difference was also observed in all the varieties with regard to shelf life. Longest shelf life (14 days) was observed in the variety, FHIA 1 (AAAA) followed by Kovvur bontha and KBS -11(12 days).The variety, Tella chekkerakeli had poor shelf life of 7.67 days among all the varieties under study.

P-41

Marketing of organic oranges under Coorg conditions

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Participatory rural appraisal was carried out with organic growers to find out marketing channels followed for selling their produce. Results indicated that majority of farmers sold their produce to pre harvest contractors (35.56%) followed by 15.56% farmers to coffee collection depot (local marketing), private agencies (13.33%), marketing to wholesalers (8.89%) and self processing and selling (4.44%). It is also reported that some of the farmers have sold their produce through APMC, Madikeri, ITC and Pallada agro research foundation. Nearly 62.22% farmers have not got premium for their crop and only 11.11% farmers indicated that they have received only 20% premium. Farmers are not getting guidance for processing, packing and grading or value addition. These results imply that restructuring of wholesale markets and the privatization is imperative to avoid commission agents and to get genuine price to farmers. Policy makers need to provide incentives for organic crop and create awareness on processing and storage and value addition of organic oranges.

P-42

Effect of pre-harvest application of plant growth regulators and chemicals on yield and post harvest quality of guava

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A field experiment to study the effect of pre-harvest application of plant growth regulators and chemicals namely Giberellic acid, Naphthalene acetic acid, Calcium chloride, Zinc sulphate, Potassium sulphate on yield and post harvest quality of guava (*Psidium guajava* L. cv. Lucknow-49) was conducted at the Department of Horticulture, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam during the year 2012. In the present investigation, application of potassium sulphate (1%) significantly enhanced the quality parameters *viz.,* TSS (9.5%), total sugars (9.25%), reducing sugars (4.76%) and ascorbic acid (130 mg/100gm pulp). Minimum post harvest rot (17.64%) and acidity (0.25%) were also registered with potassium sulphate (1%). With the application of potassium sulphate (1%), an increasing trend in physiological loss in weight (4.38%) was observed during storage period of 8 days. Similarly, decreasing trend in firmness (4.86 lb/in^2) was also noticed during storage period of 28 days.

P-43

Evaluation of rambutan lines for quality and freestone fruits

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In this study, 50 accessions of rambutan (*Nephelium lappaceum* var. *lappaceum* L.) were collected and evaluated. Fruit colour ranged from red, maroon, purple, yellow and pinkish redwhile fruit weight varied from 12 g in CHESR-21 to 52.35 g in CHES R-1-2. The rambutan lines CHES R -1-2, CHES R-9, CHES R XIII-9, CHES R XIV-7, CHES R XIV-10, CHES R XIV-11, CHES R XV-3, CHES R XIX-11 and CHES R-27 were found better with high fruit weight, pulp thickness and less acidic and sourness than others. CHES R-27 recorded maximum pulp recovery (42.15%) and TSS 17.5^0 Brix. The lines with red fruit colour were CHES R-27, CHES R-26, CHES R-37, CHES R-11, CHES R VIII-6, CHES R X-9, CHES R XIII-9, CHES R XIII-10 and CHES R XIV-10. Yellow colour fruits line CHES R-14, CHES R XV-3 and CHES R XII-2 showed easy detachment of the flesh from the seed with freestone nature.

P-44

Processing features of some cashew varieties under northern transiton zone of Karnataka

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An experiment was conducted to know the processing features for kernel recovery and cashew apple of seven cashewnut varieties grown under northern transition zone of Karnataka. The trial was laid out using the cashew varieties *viz.,* Goa-11/6, Ullal-3, Ullal-4, UN-50, Vengurla-4, Vengurla-7 and VRI-3. The varieties differed significantly for nut weight (g). It ranged between 5.41 g (Goa-11/6) and 7.93 g (Ullal-4). All the varieties gave kernel recovery of more than 28 per cent except Ullal-4 (27.83%). Shelling percentage varied between 27.83 (Ullal-4) and 32.20 (Vengurla-4), whereas kernel weight ranged between 1.74 g (Goa-11/6) to 2.33g (Vengurla-4). From the commercial point of view, the bigger nuts are preferred particularly in the international market to get higher proportion of export grade kernels. Weight of apple differed significantly among the seven cashew varieties. Apple weight varied from 15.67 g (Vengurla-4) to 52.25 g (Ullal-4).There was significant difference among varieties for apple length. It ranged between 29.86 mm (Ullal-3) and 47.00 mm (UN-50). Significant difference among variety was also noticed for diameter of apple. It ranged between 21.48 mm (Vengurla-4) and 29.25 mm (Ullal-4). However, there was no significant difference among varieties for total soluble solids of juice. It varied between 11.03 ^{0}Brix (Ullal-4) and 15.55 ^{0}Brix (Vengurla-4). Among the genotypes Vengurla-4 and UN-50 were superior for the processing characteristics under northern transition tract of Karnataka.

P-45

New karonda varieties for table purpose

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In this study, forty accessions of karonda were collected and evaluated for table purpose and two promising lines (CHES K-II-7 and CHES K-35) were identified. The CHES K-II-7 selection has oblong fruits, dark blackish violet in colour, almost seedless (0.3 seeds/fruit) with red pulp. Average matured fruit weight was 12-14 g with 3000-3100 fruits per plants. Fruits are sweet in taste with TSS of 17.5^0 Brix. CHES K-35 showed similar characters except dark red fruits with the dark red pulp. It contains no seed or very few seed with TSS (14^0 Brix) . A 4 years old plant bears around 1200-1500 fruits per plant. The plants start bearing in two-three years after planting. Regular pruning is required to control the size of plants in high rainfall conditions of Kodagu. Pruning is generally recommended in the month of October. Harvesting is done 3-4 times at regular intervals. Planting karonda all along the field boundary can fulfil fruit requirements without any additional land, efforts and cost besides forming a live fence.

P-46

Essential oil content of tuberose (*Polianthes tuberosa* L.) as influenced by integrated nutrient management practices (INM)

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An experiment was conducted at the College of Horticulture, Vellanikkara, Kerala Agricultural University to study the effect of Integrated Nutrient Management Practices (INM) on essential oil content of tuberose (*Polianthes tuberosa* L.). The experiment consisted of six different treatments *viz*., T_1 - 100:50:50 kg NPK ha^{-1} + poultry manure 22.22t ha^{-1}, T_2- 50:50:50 kg NPK ha^{-1} + poultry manure 22.22 t ha^{-1} , T_3- 50:50:50 kg NPK ha^{-1} + coirpith compost 85.71 t ha^{-1}, T_4- poultry manure alone: 29.63 t ha^{-1}, T_5- biogas slurry alone: 500 t ha^{-1} and T_6- absolute control. Tuberose variety 'Prajwal' was used for the study. Percentage of concrete which indicates the essential oil content was more in flowers collected from treatments under biogas slurry (T_5). Improvement in concrete content under treatment with biogas slurry might be due to growth and yield improvement as a result of more availability of nitrogen and increased oxidizing and reducing capacity of oils in the flower petals due to application of biogas slurry.

P-47

Post-harvest storage life of garlic influenced by organic production practices

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Experiment was conducted using the variety G.41 during *rabi* season to study the post-harvest storage life of garlic (*Allium sativum* L.) under organic production practices. This experiment was conducted under four preceding crops of mung bean, french bean, bajra and soybean. Preceding crops and garlic were grown fully organically without using any chemicals. Organic manures (FYM -20t/ha, poultry manure -10t/ha and combinations of both - FYM 10t/ha + poultry manure 5 t/ha) were applied as per treatments. Among the preceding crops and various organic manures evaluated, pooled data of five years revealed that soybean in *kharif* season and garlic in *rabi* season alongwith application of poultry manure (10t/ha) recorded higher marketable yield. Almost 10 -25% lesser yield was recorded in organic farming after five years of experiments in comparison with inorganic farming. With regards to post harvest storage life of garlic, minimum weight loss was noticed in garlic bulbs harvested from plots which received only organic manures. The weight loss increased with the extended period of storage. Maximum storage losses of garlic bulbs were noticed in inorganic farming at 150 days of storage. The biochemical properties revealed that organically nourished bulbs recorded better quality than inorganic package.

P-48

Spice oleoresin: a value added product for better marketing

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Spice oleoresins are concentrated viscous liquids form of the spices derived through non-aqueous volatile solvent extraction of powdered and dried spices. Spice oleoresins are the true essence of spices representing their holistic character in terms of flavour, colour and taste. When whole or ground spices are used in foods, only a part of the active flavour constituents is tasted. A large percentage of the flavour is retained in the cellular structure of the spice and is lost in the finished food product. Oleoresins can replace whole/ground spices without impairing any flavour and aroma characteristic. Extraction of spice oleoresin not only provides new means to catch international market but also reduces post harvest loss due to its longer shelf life compare to raw spice. Oleoresins have consistency in flavour, much longer shelf life, zero bacterial contamination, ease of storage and handling, full release of flavour during cooking, convenience of use (can be blended to achieve the desired characteristics). Oleoresins are popularly used for food flavouring and colouring in the food processing industry. There is a vast demand for spice oleoresins in national and international markets. The demand of this product can be attributed to a sharp rise in the snacks food and fast food industry for producing a standardized effect on taste. Exports of these processed products, instead of raw spices, would also result in considerable value addition.

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Role of spices in processed food

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Spices have been used since antiquity as preservatives, colorants, and flavor enhancers besides its use in traditional medicine. Spices also act as antioxidants, digestive stimulants, and hypolipidemics antibacterial, anti-inflammatory, antiviral, and anticarcinogenic. Curry leaves and chilli powder are rich source of vitamin A while chillies and turmeric powder are rich sources of vitamins C. Antioxidant property of spices is another important attribute.Rosemary and sage exhibit stronger antioxidant activity. Spices also act as antimicrobial agent due to presence of phenolics, polyphenols, quinines, flavones, flaveniods, tannins and alkaloids. The optical isomers of carvone from *Mentha spicata* and *Anethum sowa* were more active against a wide spectrum of human pathogenic fungi and bacteria. Carvacrol, present in the essential oils of oregano and thyme, has been proved to be the most important fungitoxic compound. The essential oil of coriander is reported to be analgesic; dill and anise oils are antipyretic; coriander, celery, parsley and cumin oils are anti-inflammatory.

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Utility of spice extracts in the preparation of high protein spice *vadagam*

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An attempt was made to develop high protein spice *vadagam* by mixing 50% mixed pulse flour (equal proportions of green gram, bengal gram and peas flours) with rice and sago flour (1:1). High protein spice *vadagam* was prepared with three different spice combinations such as green chilli paste + cumin seed (V_5 S_1), tomato juice + cumin seed (V_5 S_2) and tomato juice + chilli paste (V_5 S_3) to improve the flavor and taste. These *vadagam* samples were packed in 400 gauge polythene bags separately and stored at room temperature. The data on quality traits were recorded and analyzed statistically. The sample V_5 S_3 recorded the higher value of acidity (0.20 g %), β carotene (12.35µg/100 g), ash (1.47 g/ 100g) and fibre (1.65 g/100g) than other spice combinations. Protein content ranged from 13.64 to 13.77 g/100g in all the samples. Regarding the storage period (180 days) an increasing trend was observed for moisture and acidity contents whereas a decreasing trend was noticed for pH, protein and β carotene. Storage period did not show any influence on the ash content and very little change was observed for fibre content. All the samples contained 0.10 and 0.08 mg/ 100 g of tannin before and after storage. The phytic content was recorded before and after storage for V_5 S_1 (19.54), V_5 S_2 (19.51) and V_5 S_3 (19.54 mg / 100g). All the samples were found highly acceptable for appearance, flavor, overall acceptability, colour and texture. The taste of the samples varied depending upon the type of spice used. Mild spicy taste was recorded in V_5 S_1 (4.0), mild sour taste inV_5 S_2 (3.8 – 4.0) and spicy taste with mild sour taste in V_5 S_3 (3.8 – 4.0). A slight increase in length and breadth was observed in the spice *vadagam* as compared to the non spice *vadagam*.

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Biological adulterants of traded black pepper with special reference to their detection using DNA markers

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Though conventional morphological, anatomical, organoleptic markers and analytical techniques have good resolution power in detecting synthetic adulterants, they are less useful in biological adulteration detection. DNA based markers assumes significance in this context. RAPD- SCAR markers are developed to detect papaya seed adulteration in branded market samples of traded black pepper powder. The SCAR markers developed could detect the presence of adulterant in all the model blends prepared at a concentration as low as 10g adulterant per kg of spice powder, confirming the suitability of the technique for adulterant detection. Three out of the five market samples analysed proved positive for papaya seed adulteration. SCAR markers were also developed for detecting the adulterant *Piper* species *viz*., *P. galeatum* and *P. atteunatum* in traded black pepper (*P. nigrum).* Another robust technique 'DNA barcoding' was perfected to detect chilli adulteration in traded market samples of black pepper powder suggesting for the first time the practice of recycling exhausted but fortified blackpepper with chilli pungent principle. Among the three different barcoding loci studied *viz*., *psbA –trnH*, *rbcL* and *rpoC1*, *psbA-trnH* proved to be the best loci enabling easy detection of the adulterants at band level itself. Out of the nine market samples analysed two proved positive for chilli adulteration. The result was also corroborated with HPLC data of the samples. The method proved efficient to detect adulteration even at very low levels (0.5% adulteration). SNPs specific to the adulterant *Piper* species *viz*., *P. galeatum* and *P. atteunatum* could also be detected using two barcoding loci (*rbcL*and *psbA –trnH*) which have the potential to develop as species specific barcodes.

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Studies on farmer innovations in cardamom post harvest processing

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Farmers have invented several devices for doing various post harvest processing. Washing and cleaning of cardamom could be achieved with the help of machine developed by a farmer. The cardamom drier using 'Biomass gasifier' developed by an enterprising farmer assures steady temperature which results in very good capsule colour. The drier is very easy to operate and the time required for drying is also less compared to other devices. The fuel material can be briquettes, coconut shell, coconut husk, wood chips or any dried agricultural waste. Cardamom polishing machine invented by a planter makes the process very simple, cost effective, and efficient. The quality and hygiene of the cardamom could be substantially improved by using this machine. It also helps to reduce the manual labour and is farmer friendly and saves time.

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Influence of different cooking methods on quality of turmeric

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An experiment was conducted to study the influence of different cooking methods on quality of turmeric (*Curcuma longa* L.). The treatment comprised of cooking of turmeric by traditional method (heap in boiling pan), boiling pan (level upto height of boiling pan), boiling pan with perforated iron drums, perforated vertical trays in cooker and steam cooker machine. The steam cooker machine developed with the galvanized iron sheet of specified thickness was mounted on the tractor trolley chase so that it is movable and cooking will be done in the field itself. Significantly minimum time (74.04 min), fuel (112.89 Kg) and labour (0.31 unit) were required for per ton cooking of turmeric in steam cooker machine. Significantly high quantity of turmeric (6.492 t/day) was processed in this unit and significantly high curcumin (5.15 %) was also recorded in this method. Highest recovery (23.50 %) as well as B:C ratio (1:2.64) were also recorded by this method.

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Standardization of processing method for high dry yield and quality of turmeric

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Experiments were conducted to assess the time taken for boiling of turmeric rhizomes to get good quality dried product and to assess the effect of curing on the quality parameters of cured turmeric using the variety BSR-2. The treatment details are: T_1 -Traditional rhizome boiling for 40 minutes and drying; T_2 -Traditional rhizome boiling for 60 minutes and drying; T_3-Traditional rhizome boiling for 90 minutes and drying; T_4-Improved processing for 10 minutes (using TNAU model boiler) and drying; T_5-Improved processing for 20 minutes (using TNAU model boiler) and drying; T_6-Improved processing for 30 minutes (using TNAU model boiler) and drying; T_7-Dipping in boiling water for 10 minutes and drying and T_8-Raw rhizome sliced with 3 mm thickness and drying. The initial weight of the sample taken for the experiment was 2.0 kg. The results of the study revealed that the final weight of the rhizome varied from 350 to 475g among the treatments. The final weight (475g) was the highest in the treatment T_5 .The percentage of dry rhizome recovery varied from 17.50 to 23.75% and the highest dry rhizome recovery was noticed in T_5. The time taken for drying ranged from 9 days to 24 days among the different treatments. Minimum time (9 days) was taken by the treatment T_8. Among the quality parameters, curcumin content (6.00 %) and oleoresin content (13.96%) were the highest in the treatment T_4. However, essential oil content was found to be higher in traditional processing of rhizome boiling and drying (T_1 & T_2). Hence, the improved processing method using TNAU model and drying may be adjudged as the best practice to enhance the high recovery and quality of turmeric.

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Effect of sodium bicarbonate on quality of steam boiled turmeric

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An attempt was made to know the effect of sodium bicarbonate on quality of steam boiled turmeric. Minimum time taken for steam boiling was recorded in T_7 (14.75 min) whereas maximum time taken for steam boiling was observed in T_1 (31min). Significantly minimum time taken for steam boiling was noted in rhizomes treated with sodium bicarbonate (19.28 min), where as maximum time was taken for steam boiling without treatment of sodium bicarbonate (21.85 min). The interaction between with and without sodium bicarbonate significantly influenced the time taken for boiling. Minimum time taken for steam boiling was found in (T_7 (13 min) with sodium bicarbonate whereas maximum time taken for steam boiling was observed in T_1 (32 min) without sodium bicarbonate. The mean recovery of steam boiled turmeric irrespective of treatments was found higher with sodium bicarbonate compared to without sodium bicarbonate at all the days after harvest. The treatment showed significant difference with respect to the recovery of steam boiled turmeric. Maximum recovery was found in T_7 (29.76%)-rhizomes treated with sodium bicarbonate- whereas minimum recovery of steam boiled turmeric (27.82 %) was observed without sodium bicarbonate. The interaction between the treatments with and without sodium bicarbonate significantly influenced recovery of steam boiled turmeric. Maximum recovery was found in T_7 (30.01 %) with sodium bicarbonate whereas minimum recovery was recorded in T_2 (26.04 %) without sodium bicarbonate. Sodium bicarbonate had no significant effect on essential oil, curcumin and oleoresin content of steam boiled turmeric.

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Chemical characterization of mango ginger oil

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Among the spices, turmeric and ginger have been extensively studied. *Curcuma amada* (Mango ginger) is a perennial, rhizomatous, aromatic herb belonging to the family Zingiberaceae. The oil was extracted from fresh and processed rhizomes using Clevenger's Hydro distillation apparatus and the oil yield was found to be the highest in processed form (0.27%), comparatively lesser in dried form (0.25%) and the least in fresh form (0.20%). Gas Chromatographic analysis of the oil samples revealed four major components namely myrcene (83.44%), β-pinene (6.36%), 1-nitro guanidine (3.12%) and α-pinene (0.71%). The level of major constituents was found to be the highest in fresh sample.

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Enhancement of nutmeg fruit (*Myristica fragrans Houtt.*) ripening by ethylene treatment

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The harvest maturity of nutmeg is judged by split opening of fruits. The time of splitting is random and it is a difficult operation to selectively harvest matured fruits. If unopened fruits are harvested, it need to be cut open to take out aerial (mace) and nut. Experiment was conducted by dipping fruits using varied concentrations and durations of ethrel (senescence hormone to promote ripening and opening of fruits). Fruits were dipped in ethrel at 0 ml, 0.5ml, 1ml, 2ml per litre of solution for one hour and two hours. Among the treatments, 0.5ml, 1ml, 2ml, 3ml took 24 hrs for opening whereas control took four days. Ninety five per cent of fruits were opened when treated with 0.5ml per litre for 1hour. It was concluded that nutmeg fruits dipped for 1 hour in 0.5ml per litre of ethrel solution attained uniform opening and will reduce the labour dependence for harvest besides good quality mace and nut after drying.

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Antioxidant potential of nutmeg in relation to myristicin content

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In the present study, mace and nut from 14 accessions of nutmeg (*Myristica fragrans* Houtt.) were analyzed both for essential oil constituents and antioxidant potential by DPPH method and phosphomolybdenum method using BHT as standard. The antioxidant activity of mace oil ranged between 46-95.9% whereas it was 20% for BHT by DPPH method. By phosphomolybdenum method antioxidant potential of 110-275 µmol ascorbic acid equivalents/ml was recorded for mace oil. The antioxidant potential of oil from nut was 43.3-96% by DPPH method and 115-272 µmol ascorbic acid equivalents/ml by phosphomolybdenum method. GC-MS analysis indicated that the chief constituents of both essential oils were sabinene, myristicin, elimicin, safrole, α-pinene, β-pinene, limonene and 4-terpineol. Highest antioxidant activity was recorded in mace (CRCN-21) having a myristicin content of 26.26%and in nut (CRCN-22) with 18.2% myristicin. Antioxidant activity was not pronounced in samples with high elemicin and safrole. The results indicated that a combination of methoxyl and methylenedioxy moieties in myristicin contributed to the higher antioxidant activity.

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In vitro evaluation of anti-aging properties of clove and cinnamon oils

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Anti-aging properties of oils of clove and cinnamon were studied *in vitro* using human dermal fibroblasts (HDF) and human keratinocytes (HaCaT). The IC_{50} values for clove and cinnamon oils in HDF were 120.29 ± 0.5 and 115.90 ± 0.3 µg/ml and HaCaT cells were 121.44 ± 0.2 and 115.20 ± 0.25 µg/ml, respectively. The antioxidant capacity of clove oil and cinnamon oil was 348 mmol/g and 282 mmol/g in HaCaT cells, respectively. Clove oil and cinnamon oil inhibited hydrogen peroxide (H_2O_2) induced RBC haemolysis by 74.63 ± 1.4 and 71.04 ± 0.2% ,respectively. The reducing power of clove and cinnamon oils at 400 µg/ml was 44.55 ± 0.13 % and 53.41 ± 0.1%, respectively to that of ascorbic acid (AA) at the same concentration. Both clove oil and cinnamon oil stimulated the collagen-I in HDF cells as determined by ELISA and RT-PCR experiments. Nitric oxide levels induced by lipopolysaccharide in mouse macrophages (RAW 264.7 cells) were abrogated by clove and cinnamon oils by 48.26 ± 1.1 % and 41.66 ± 1.5 %, respectively at 50 µg/ml. Clove and cinnamon oils delayed cellular senescence in HDF cells as observed by the decrease in β-galactosidase levels. The DNA damage in HDF cells caused by OH radicals via the Fenton reaction was reduced by clove oil and cinnamon oil. The results demonstrated that clove oil and cinnamon oil protects the skin from oxidative damage induced by hydroxyl radicals, H_2O_2 and nitric oxide.

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DNA barcoding for discriminating the economically important *Cinnamomum verum* and its adulterants

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Cinnamomum verum (true cinnamon), a high value spice, is often adulterated with its inferior species such as *C. cassia* and *C. malabatrum*. The presence and detection of the spurious species in traded barks (whole or powder) of true cinnamon is also posing a problem. Here we report the application of DNA barcoding method to detect these adulterants in traded market samples of true cinnamon using the barcoding loci *rbcL, matK* and *psbA-trnH.* The PCR success rate, sequencing efficiency, inter and intra specific divergence and occurrence of single nucleotide polymorphisms (SNPs) were utilized to assess the potential of each barcode loci to authenticate *C. verum* from its related adulterants. The amplification and sequencing success was 100% for *rbcL* and *psbA-trnH* while *matK* failed to amplify the market samples. *rbcL* locus showed higher interspecific divergence while *psbA-trnH* exhibited lower interspecific divergence. SNPs specific to *C. cassia* were detected in *rbcL* locus 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. Out of the three loci, *rbcL* locus proved to be efficient in tracing out adulterants in traded cinnamon. The SNP sites in this locus can be exploited in designing *C. cassia* specific primers, enabling kit development for easy detection of adulterants at the band level itself thereby bypassing the cost of sequencing.

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Post harvest processing of the fruit rind of *Garcinia gummi-gutta* (L.)- chemical and physical evaluation

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The study involves estimation of total fats, carbohydrates, proteins, minerals, phenolics, flavonoids, hydroxy citric acid, pH, ash value and moisture along with HPTLC profiling of the methanol extracts of processed fruit rind of *Garcinia gummi-gutta* L. The acidity of the processed fruit rinds were less compared to the fresh rinds (pH 2.76), while the pH of smoke dried samples and oven dried samples were comparable (2.17 and 2.16 respectively). The ash contents were same for both the samples, 0.048%. The total phenolic contents of the methanolic extracts were 15.4±0.9 mg/g for smoke dried samples and 19.09±1.3 mg/g for oven dried samples. However, there was a drastic decrease in the flavonoid content of smoke dried samples (6.62±0.46 mg/g), compared to oven dried samples (19.56±0.24 mg/g). In concurrence with the phenolic and flavonoid contents, the DPPH radical scavenging activity was higher for oven dried samples (IC_{50} 128.45±6.15 µg/ml) compared to smoke dried samples (IC_{50} 185.35±3.56 µg/ml). The moisture content of smoke dried rinds (76.61%) was higher compared to oven dried rinds (13.49%). Ssmoke drying enhanced the softness and flexibility of the rinds compared to oven drying and also imparted characteristic smoky odour to the fruit rinds.

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Biochemical parameters of Malabar tamarind (*Garcinia gummigutta*) at high altitude and high rainfall Kodagu region of Karnataka

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Malabar tamarind (*Garcinia gummigutta*) is an indigenous, tropical, underexploited spice and oilseed crop belonging to the family Clusiaceae. The fruits are valued for its nutritional and medicinal properties. The dried fruits with a dark hard rind are rich in acids (about 30%) which mainly composed of tartaric and phosphoric acids and traces of reducing sugars. The principal acid which is found in the fruit rind is (-) hydroxycitric acid (HCA) which has the property of lowering body fat. In the present study, biochemical parameters like total soluble solids, titrable acidity, ascorbic acid, reducing sugar and total sugar of fresh fruits were estimated fromr 25 accessions. IC 549111 recorded maximum TSS of 12.3% followed by IC 549112 (11.4%). Among the accessions, IC 549117 and IC 549124 recorded the highest ascorbic acid content of 1.5 mg/100g. The highest reducing sugar of 36.5% and total sugar of 38.7% was recorded in IC 549128.

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Effect of postharvest treatments on tartaric acid of tamarind pulp (cv. PKM 1) during storage

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Tamarind (*Tamarindus indica* L.) is an excellent multipurpose tree spice crop belonging to the family Fabaceae. Tamarind pulp is an excellent source of tartaric acid which used for many culinary preparations. The present study was conducted to assess the effect of food additives, packaging materials and storage environment on tartaric acid content for a period of six months storage. This postharvest experiment consists of five food additives, four packaging materials and two storage conditions. The treatments additives, packaging materials and storage environment had significant influence on the acidity of the pulp. Among the different postharvest treatments, the highest acidity of 17.25 (M_1), 17.30 (M_2), 17.35 (M_3), 17.42 (M_4), 17.45 (M_5) and 17.49 (M_6) per cent was recorded by pulp treated with ascorbic acid @ 2.0 per cent and packed in palmyrah leaf bag stored under refrigerated condition ($A_2P_4S_1$). While the lowest acidity of 15.50 (M_1), 15.51 (M_2), 15.52 (M_3), 15.56 (M_4), 15.57 (M_5) and 15.58 (M_6) per cent was observed in the pulp treated with sodium chloride @ 4.0 per cent, packed in aluminium foil and stored under ambient condition ($A_1P_2S_2$).

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Studies on preparation and storage of tamarind syrup

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An attempt was made to standardize the protocol for the preparation of tamarind syrup. The chemical compositions of tamarind syrup and changes in chemical constituents during storage at ambient temperature have been studied. Higher amounts of mean TSS (71.61%), ascorbic acid (6.85mg/100g), reducing sugar (14.20%) were noticed in the recipe having 45% juice + 70% TSS + 1.5% acidity and 0.5% salt whereas total sugar (58.26%) was highest in recipe having 40% juice + 70% TSS + 1.5% acidity and 0.5% salt. Among the treatments, the tamarind syrup prepared with 40% juice + 70% TSS + 1.5% acidity was superior to other recipes with respect to sensory quality and also was microbiologically safe. The benefit cost ratio of the product was above 1.5. Hence, commercial production of the product could be taken up as a small scale enterprise. The beverage retained its characteristic colour, aroma and taste up to 3 months of storage at room temperature.

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Studies on the physical characteristics of the tamarind fruit and the performance of the tamarind deseeder

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A machine was fabricated to deseed tamarind fruits. The average values of length, width, thickness, geometric mean diameter, sphericity index, surface area, bulk density, true density, density ratio and porosity of the tamarind fruits obtained from different locations were 113.38 mm, 19.09 mm, 11.03 mm, 28.77 mm, 0.28, 2619.69 mm^2, 493.67 kg/m^3, 959.24 kg/m^3, 51.53, 48.47, respectively where as the corresponding values of seeds were 16.1 mm, 11.25 mm, 6.78 mm, 11.08 mm, 0.7, 400.24 mm^2, 781.65 kg/m^3, 10.61.18 kg/m^3 , 73.67, 26.33, respectively. Angle of repose of tamarind fruit and seeds ranged between 33.42^o and 27.07^o, respectively. The average static coefficient of friction on various test surfaces varied from 0.61 to 0.95 for fruit and 0.39 to 0.52 for seeds. The cutting force required for horizontal and vertical direction of tamarind fruits was 44.2 kgf and 49.67 kgf, respectively. It was observed that the mechanical drying of tamarind at 70^{o}C had higher moisture removal rate followed by mechanical drying at 60^{o}C, 50^{o}C, 40^{o}C and sun drying. A tamarind deseeder was fabricated with the principle of impact load for creating failure over the fruit by the pegs inserted on the wooden roller and shearing force over the failed fruits for removing the seed from the pulp through a semi-circular shaped mesh which has oblong holes of 9 x 25 mm surrounded below the drum. The deseeding efficiency was 74.15% with 45 kg/h capacity.

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Studies on pre packaging for enhancing of shelf life in curry leaf

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Investigations to study the post harvest extension of shelf life were taken up in curry leaf (*Murraya koenigii* Spreng). Curry leaves packed in 100 gauge polythene bag with no ventilation recorded a significantly longer shelf life (15 days) followed by packing with 500 gauge (6 days). In contrast, the leaves packed in 300 gauges showed higher levels of physiological loss in weight (58.33%) and loss of moisture content. Maximum retention of chlorophyll and protein levels in leaves were higher in the packaging of leaves with 100 gauge polythene bags with no ventilation (0.477 mg/g and 0.422 mg $g^{-1,}$ respectively). The corresponding values in respect of curry leaves packed in 500 gauge polythene bags with no ventilation were 0.371 mg/g and 0.368 mg g^{-1}. The essential oil content, volatile oil was maximum in leaves packed with 100 gauge polythene bags with no ventilation (0.175%) followed by leaves packed in 500 gauge with no ventilation (0.156%). On the contrary, the unpacked leaves registered lower content of essential oil.

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Storage studies in coriander

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The present study on storage of coriander (*Coriandrum sativum* L.) was conducted at the Horticultural College and Research Institute, Periyakulam (TN) with the aim of understanding the influence of different packaging materials on storage of coriander seeds. The variety CO-4 is used in the study. The seeds were treated with bavistin @ 2g per kg before packing. Nine different packaging materials were used. The seeds were packed in different packaging materials and kept at ambient temperature for six months and the biometrical observations were taken at fortnight intervals. The data on different storage parameters indicated that gunny bags without ventilation had the lowest physiological loss in weight (2.7%) after six months of storage. It was followed by 200 gauge polythene bags without ventilation (4%). The highest physiological loss in weight was observed in control (10.2%). From the study it was concluded that coriander seeds treated with bavistin and packed in gunny bags can be stored for long period without any spoilage under ambient condition.

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Influence of storage environment and varieties on shelf life of coriander leaves

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The shelf life of harvested green leaves of coriander (*Coriandrum sativum* L.) is very short and different varieties vary for this trait. Use of zero energy chambers has been very useful for short term storage of fruits and vegetables. These chambers have also been found very useful for storage of leafy vegetables. Freshly harvested leaves of five coriander varieties subjected to cleaning, trimming, washing and draining were packed in polyethylene bags (200 gauge).The packed leaves were kept at room temperature and in zero energy chambers for ten days and physiological loss (PLW %) in weight was recorded on alternate days. Physiological loss (PLW %) in weight increased with increasing period of storage in all the varieties of coriander under both environments. Zero energy chamber stored leaves had significantly lower PLW (7.35%) than room temperature stored leaves (12.97%) and among different varieties minimum PLW was observed in DH-228 (8.43%) as compared to maximum (10.91%) in 'Pant Haritima' after 10 days of storage.

P-69

Supply chain management: A way to meet export standards

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A supply chain is a set of three or more organizations linked directly by one or more of the upstream or downstream flows of products, services, finances and information from a source to a customer. Supply chain management then endorses a supply chain orientation and involves proactively managing the two-way movement and coordination of goods, services, information and funds (i.e. the various flows) from raw material through the end user. Several factors are behind the successful supply chain management. Firstly, the cost and availability of information resources between entities in the supply chain allow easy linkages that eliminate time delay in the network; secondly the level of competition in both domestic and international markets requires organizations to be fast, agile and flexible and third customer expectations and requirements are becoming much more stringent. So to satisfy the consumer, SCM system should operate with the two main objectives 'Timeliness' and 'Quality'.

P-70

Fruit ripening using ethylene

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Experiments were conducted with different levels of temperature (20, 25 and 30^{o}C), ethylene concentration (100, 200 and 300 ppm) and exposure time (15, 20 and 25h). From the study it was observed that the banana fruit exposed with 200 ppm ethylene for 25h and subsequently stored at 20^{o}C was found to be the best. For mango fruits, the ripening temperatures such as 16, 23 and 30^{o}C, ethylene concentrations of 400, 500 and 600 ppm and 15, 20 and 25h of exposure time were carried out. The mango fruit exposed with 600 ppm ethylene concentration for 25h and subsequently stored at 23^{o}C was found to be the best. For the papaya fruits, three levels of exposure time of 15, 20 and 25h, ethylene concentrations of 400, 500 and 600 ppm, ripening temperatures of 20, 25 and 30^{o}C were tried and physicochemical changes were recorded. The fruits exposed to 600 ppm ethylene for 25h and subsequently stored at 30^{o}C were found to be the best.

P-71

Shelf life and quality of modified atmosphere packed Grand Naine banana fruits during ambient temperature storage

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Experiment was carried out at the Fruit research station, Sangareddy, Medak to understand the effect of various post harvest packaging treatments like modified atmosphere packing on shelf life of banana cv. Grand Naine by packing the fruits with different levels of perforations (0.5 mm) at ambient temperature condition. Physico-chemical characters were recorded at specific day intervals to study the shelf life of banana fruit under ambient conditions with different perforation levels. Fruits were packed in poly propylene bags with 5 pores, 10 pores, 15 pores, 20 pores, 25 pores, 30 pores, without pores and unwrapped control kept under ambient storage conditions and packs seal with help of electrical sealer. Among the treatments, 5 pores followed by 10 pores recorded lower physiological loss in weight, colour index, spoilage and higher firmness, total soluble solids, ascorbic acid, reducing sugars, total sugars and thereby recorded more shelf life (11.00 and 10.60 days) over control. It was observed that the physiological loss in weight, colour index, spoilage rates increased and fruit firmness decreased in all the experiments irrespective of the treatments with the advancement of duration. Total soluble solids, reducing sugars and total sugars increased initially and then decreased towards the end of the storage period.

P-72

Modified atmosphere packaging of Grand Naine banana at low temperature

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The experiment was conducted at the Fruit research station, Sangareddy, Medak to find out the effect of different levels of perforations in polypropylene bags on shelf life of banana fruits. The experiment was carried out in CRD with factorial concept. Grand Naine banana fruits were harvested at 90-95% maturity and packed in poly propylene bags (100 Gauge, 28 × 22 cm). The bags were perforated with 5 pores, 10 pores, 15 pores, 20 pores, 25 pores, 30 pores, without pores and compared with unwrapped control. The diameter of each opening of hole was 0.5mm. Fruits were kept under cold room condition (15$\pm$ 1^{o}C). Physico-chemical characters were recorded at five days intervals up to the end of the shelf life. Fruits packed in polypropylene bag with 5 pores registered the highest firmness, total soluble solids, ascorbic acid, reducing sugars, total sugars which coupled with lowest physiological loss in weight, colour index and spoilage which contributed highest shelf life. The shelf life of fruits packed in polypropylene bag with 5 pores can be extended successfully for about 22 days at cold room condition.

P-73

Studies on physiochemical characters and postharvest qualities of Nendran ecotypes of banana

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The present study was undertaken with the objective of analysing the physiochemical characters and postharvest qualities of Nendran ecotypes of banana (*Musa* spp.) belonging to AAB genomic group. Twelve Nendran ecotypes were used. Suckers of the twelve Nendran ecotypes of banana with almost uniform size were collected from different parts of Kerala and maintained at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram at spacing of 2.0 × 2.0 m.' Koonoor Ethan' recorded the highest fruit weight (503.4g), peel weight (132.2g), pulp weight (362g) and ascorbic acid content (23.0%). 'Chengazhikodan' recorded the highest TSS (30.7%), total sugars (30.7%), reducing sugars (13.2%) and non-reducing sugars (17.5%). 'Kaliethan' recorded the highest titrable acidity (0.74 %), pulp/peel ratio (6.0) and longest shelf life (12.6 days). 'Vellayani Nendran' recorded the lowest values for all the traits. Overall, 'Chengazhikodan' was found to be the tastiest and 'Koonoor Ethan' had the best shelf life.

P-74

Analysis of the physiochemical characters and shelf life of 'Palayankodan' ecotypes of banana

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Six 'Palayankodan' ecotypes were used in this study. Suckers of 'Palayankodan' ecotypes of almost uniform size were collected from different parts of Kerala and maintained at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram at a spacing of 2.0 × 2.0 m. Ripe fruits were used for biochemical analysis. PKNNR recorded the highest values of the traits such as TSS (27.90%) and reducing sugars (17.09%). There was no significant difference among the 'Palayankodan' ecotypes with respect to tritable acidity and total sugars. The highest acidity was recorded in 'Motta Poovan' (0.44%) and the lowest value was observed in 'Vellapalayankodan' (0.24%). The highest total sugar content was found in 'Chandra Bale' (17.29%) and the lowest value was recorded in 'Motta Poovan' (16.57%). 'Vellapalayankodan' recorded the highest value for sugar/acid ratio (68.53). Among the six 'Palayankodan'ecotypes, 'Vellapalayankodan' (8.65 days) recorded the longest shelf life and least shelf life was observed in 'Motta Poovan' (5.24 days). 'Motta Poovan' recorded the lowest values in all the traits. PKKNR was found to give the tastiest fruit and 'Vellapalayankodan' provided better shelf life.

P-75

Drying behavior and quality evaluation of osmotically pretreated mandarin orange segments

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An experiment was carried out to evaluate the drying behaviour and quality of osmotically pretreated mandarin orange segments. The experiments were conducted according to Response Surface Methodology using Central Composite Design. The best pre-treatment was found with steaming at 100.88°C for 215.19 seconds. Osmotic dehydration was optimised at temperature of 37.50 °C, time of 277.50 minutes, agitation of 52.50 rpm, sugar concentration of 44.13% and vacuum drying was optimized at temperature at 56.08 °C, duration 1868 minutes, and pressure of 36.22 kPa. The final quality of the osmotically dehydrated orange segments was found to have a moisture content of 55.11± 3.59%, water activity of 0.767± 0.036, total sugar of 34.83± 2.76%, vitamin C content of 421.244± 3.799 mg/100g, colour (L*, a*, b*) 53.21± 1.55, 11.49± 0.66, 21.26± 4.12, texture (firmness and stickiness) 0.163± 0.03 N, 0.0016 ± 0.00009 N and antioxidant of 71.34 ± 1.39%.

P-76

Effect of pretreatments on processing of sapota pulp and preparation of sapota value added products

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An attempt was made to know the effect of pretreatments to avoid the blackening reaction during processing and storage of sapota [*Manilkara achras* (Mill) Forsberg] pulp. Sapota pulp was heated in hot water at 60ºC for 20 min and treated with 0.05% sodium benzoate, 0.05% citric acid, 2% ascorbic acid, 2% malto dextrin and 2% tetra calcium phosphate and stored at ambient and cold (5±1ºC) temperatures. The pulp treated with 2% ascorbic acid showed low non enzymatic browning (0.730%), tannin content (0.097%) and higher acidity (0.50%) and ascorbic acid (38 mg/100g) at both storage temperatures followed by the sapota pulp with 2% malto dextrin. The rate of spoilage was more in the pulp stored without preservative at ambient conditions than cold room temperature. Among all the treatments, the pulp treated with 2% malto dextrin had maximum score for flavour (8.2), taste (8.2), consistency (8.0) and overall acceptability (8.6) at 0 day which decreased at the end of storage period (90 days). The pulp treated with 2% ascorbic acid at both temperatures recorded maximum score for colour (9.0) followed by the pulp treated with 2% malto dextrin. Based on the organoleptic evaluation the sapota pulp with 2% malto dextrin was selected for further development of sapota products such as sapota milk shake, sapota toffee and sapota jelly.

P-77

Evaluation of value added RTS beverage of sapota during storage

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The present investigation was carried out to study the quality of ready to serve (RTS) beverage of sapota (*Manilkara achras* (Mill.) Fosberg) blended with other fruit pulps during storage. Fruit pulp was enzymatically digested by using pectinase enzyme (1000 & 2000 ppm) and incubated for 4h at 40°C. The RTS had 20% pulp, 10°B and 0.3% acidity. Blends were prepared from enzymatically (1000 ppm and 2000 ppm pectinase enzyme) digested sapota pulp by mixing with enzymatically digested pineapple, papaya, grapes, carrot and beetroot pulp in different ratios. The RTS was stored in properly sealed glass bottles for 4 months. During storage it was observed that there was an increasing trend in reducing sugars and decreasing trend in acidity, total sugars, ascorbic acid, β- carotene content, anthocyanin content and antioxidant activity throughout the storage period. However, it was noticed that TSS did not change during storage. RTS prepared from digested sapota pulp blended with grape pulp in the ratio of 70:30 was found to be satisfactory and had storage life of 4 months.

P-78

Influence of packaging and ventilations on the quality of sapota under ambient conditions

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An attempt was made to study the effect of packaging and ventilation on the post harvest shelf life and quality of sapota [*Manilkara achras* (Mill) Forsberg] cv. Kalipatti under ambient conditions. Three different gauges of low density polyethylene bags (100,200,300 gauges) with 3 different ventilations *viz*., 0.8, 1.2, and 1.6 per cent were used. Among the all gauges of LDPE and ventilation polybags of 200 gauge with 1.2% ventilation followed by fruits packed in 200 gauge with 0.8 and 1.6 % ventilation recorded significantly lowest ripening, spoilage, higher firmness, TSS, ascorbic acid content, sugars and lower TSS: Acid with a shelf life of 11.99 days.

P-79

Storage quality of canned peaches under different covering media

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Peeled peach (*Prunus persica* L.) slices of cv. "Quetta" were canned in different covering media treatments containing three levels of calcium chloride and calcium lactate (0.0%, 0.25% and 0.5%) with or without 5% lime juice in 30% sucrose syrup. Physico chemical and organoleptic evaluations were carried out at 0, 90, 180 days of ambient storage. Cans from all the treatments were maintained in vacuum (kg/cm^2) and drained weight (%) as per F.P.O specifications during entire 180 days of storage. Canned samples irrespective of the treatments showed significant increase in TSS (%), AIS (%), NEB (%) and slight reduction in titrable acidity (%), ascorbic acid (mg/100g) and calcium content (mg/100g) during advancement of storage period. There was also a decrease in TSS (%), pH and increase in turbidity (JTU) covering media with advancement in storage period. Organoleptic evaluation of the canned samples revealed decline in the colour, texture, taste, flavour and overall acceptability scores during storage. However minimum decline was observed in the treatments with 30% sucrose + 0.5% calcium chloride + 5% lime juice and 30% sucrose + 0.5% calcium lactate + 5% lime juice. Economics of the product revealed that the treatment with 30% sucrose was marginally more profitable compared to rest of the treatments in terms of BEP (5.06 can) and margin of safety (19.94 can). Thus quality of the canned peaches can be improved by incorporation of calcium salts and lime juice in covering media.

P-80

Post-harvest management of rambutan

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Recently, with the identification of a promising selection of a red line called N18 by the Homegrown Nursery and Farms, Kanjirapally, Kerala, rambutan cultivation in these regions is steadily increasing. Bud grafted plants start bearing fruits from third year onwards. June through August is the fruiting season in Kerala. It may take up to five months from flowering to fruit ripening and should be harvested after attaining full maturity on the tree. An added advantage of this crop is that the fruits can retain on the trees for an additional 20 to 30 days after full ripening without compromising the quality. Harvesting can be easily done using cut and hold device to remove the bunch stalk along with a portion of the twigs, which in turn, aids in pruning. Careful handling of fruit in the field is required to avoid mechanical injury. It was found that drops greater than 30 cm onto other fruits can injure the hairs, which eventually leads to blackening within a few days. Since the water content of the fruit on the tree fluctuates throughout the day, harvesting early in the morning or late in the evening maximises fruit water content and reduces the risk of desiccation. The fruits after sorting and grading are packed in specially prepared boxes for shipping or stored at 15 ^{o}C.

P-81

Strategies for optimization of fruit quality in stone fruits

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Fruit quality is defined as the degree of excellence or superiority. Fruit quality includes many parameters such as fruit size, fruit weight, fruit colour, fruit firmness, soluble solid contents etc. In recent years the production and fresh marketing of stone fruits has increased rapidly. The development of high quality fruit is influenced by many practices like mineral nutrition, plant growth regulators, irrigation techniques, tree training and pruning, crop load management etc. Effect of these practices depends on their magnitude, duration, plant stage. Optimal fruit quality in peaches and nectarines was obtained at 3.0% leaf N concentration. Optimal K nutrition usually leads to high photosynthetic rates and reallocation of sugars and organic acids that will enhance fruit quality. Boron fertilization increased SSC, anthocyanins in fruits and plays an important role in the metabolism of phenolic compounds. Fruit let thinning will increase fruit size while also reducing total yield, and thus a balance between yield and fruit size must be achieved. Fruit size can be enlarged by application of growth regulators such as synthetic auxins and gibberellins.

P-82

Suitability of two jackfruit varieties for the development of fruit bars

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In the present investigation an attempt was made to assess the suitability of locally grown two jackfruit (*Artocarpus heterophyllus.Lam*) varieties *viz*., soft flesh (local 'koozha') and firm flesh ('varika') for the development of fruit bar. Fruit bars are prepared by drying fruit pulp with sugar and preservatives in sunlight or dryers to a desired level of moisture. Fruit bars were standardized from the two varieties of jackfruit individually (control) and along with pre identified blends of other fruit pulps namely papaya (65:35), mango (60:40), pineapple (80:20), plantain (50:50), grapes (60:40). Among these pre identified blends, the best accepted blend for both the varieties were evaluated organoleptically by a panel of ten expert judges with the help of a score card using 5 point hedonic scale for their quality parameters like appearance, colour, flavour, taste and texture. Results highlights that in 'varika' variety overall acceptability of 'varika' blended with mango in the ratio 60:40 was distinguished to have the best acceptance (4.45) closely followed by control 'varika' bar (4.32) and 'varika' bar blended with grapes (4.03). Overall acceptability in koozha highlighted that control 'koozha' jackfruit bar tops to have the best acceptance followed by 'koozha' blended with mango in the proportion 60:40. Least score was obtained for 'koozha' fruit bar blended with pine apple.

P-83

Preparing of cashew apple syrup using different cashew apple varieties

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The experiment was carried to find out the suitable varieties for syrup making by using eight distinct cashew (*Anacardium occidentale* L.) varieties *viz*., BPP-4, BPP-5, BPP-8, BPP-9, 'Dhana', 'Priyanka', VRI-1 and VRI-2. Among the varieties 'Priyanka' recorded highest fruit weight (76.48 g), fruit girth (5.79 cm), fruit length (7.53cm), fruit volume (58.11cm^3) and juice recovery percentage (79.73%) followed by BPP-8. The highest quantity of syrup was obtained with variety 'Priyanka' (11.04 Kg) followed by BPP-8 (4.56kg) from 100 fruits. Organoleptic evaluation of syrup was carried out at different days of storage in every variety. The overall acceptability ranged from 5.41 to 5.71, 5.86 to 6.04 and 6.34 to 6.47 at 0, 30 and 60 days after storage respectively. The overall acceptability of the product is increasing with the days of storage irrespective of varieties under study and the highest was recorded in 'Priyanka' followed by BPP-5, BPP-8 and the lowest was observed in BPP-4. Overall, it was found that 'Priyanka' and BPP-8 are suitable for large scale production of cashew syrup.

P-84

Home made processing, value addition and marketing of underutilized fruits- a case study

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Under-utilized fruit crops like rambutan, passion fruit, avocado, sour sop, litchi, garcinia, cherry, fig, karonda, malayan apple, longan, lime, sour orange and wild fruits etc. have tremendous potential for making a variety of new post harvest product of commercial and nutritional status besides medicinal properties. Theses fruits, once used by our forefathers, are grown only in patches, in very small quantity especially for own consumption. The major reason for their reduced utility is the change in the food habit of people. The Central Horticultural Experiment Station (CHES), Chettalli, Coorg, Karnataka has under taken a case study involving few planters to know about the usage, storage, value addition and marketing of some of these fruits grown in this region. The post harvest products from fruits such as passion fruit squash, ginger +lime squash, kachampuli syrup(panampuli-black vinegar), litchi and peach preserves, sour orange squash and marmalade, cape goose berry and mulberry jam are being made by the planters besides wine from litchi, ginger, fig, rose petals, cherry and cape gooseberry. Lot of demand is noticed for the products of passion fruit squash, ginger +lime squash, kachampuli syrup and sour orange squash and marmalade. Price of the product ranges from Rs. 400-800 for 750 mL bottle.

P-85

Effect of varieties and drying methods on quality of dried onion slices

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In the present investigation, minimum time taken for drying onion slices was found in Pusa White Flat under solar drying (24.35 hours) while better recovery under sun drying (13.82%), lower dehydration ratio in electrical drying (6.77%), highest reconstitutability ratio under electrical drying (0.75), higher dry matter content (13.80%) in sun dried onion slices and higher rehydration ratio with solar dried onion slices (6.30, 5.70, 5.45 and 5.20) were recorded in Bhima Shweta during initial, first, second and third MAS. Higher ascorbic acid content was recorded in Pusa White Flat under electrical drying (27.47, 26.46, 26.10 and 25.60 mg/100g) during initial, first, second and third MAS, respectively. Highest reducing sugars content in electric drying (17.55, 18.35, 19.33 and 20.74%), higher non-reducing sugars in sun drying (41.75, 40.80, 40.62 and 39.88%) and higher total sugars content under electric drying (58.49, 58.51, 59.33 and 59.42%) and lowest browning were observed in Pusa White Flat dried under electrical drier (0.25, 0.35 and 0.51) during first, second and third MAS. The highest score for colour and appearance was recorded in Pusa White Flat dried under electric drier (4.45, 4.23, 4.01 and 3.91) and highest scores for taste and flavour of the slices were recorded in Belagavi Local under electric drier (4.55, 4.40, 4.30 and 4.10).The highest score for texture under electric drying (4.20, 4.13, 4.01 and 3.90) and highest score for overall acceptability in electric drying (4.22, 4.11, 4.01 and 3.90) were found in Pusa White Flat during initial period, first, second and third MAS, respectively.

P-86

Post-harvest storage life and organoleptic evaluation of organically produced yellow onion

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The present experiment was conducted in yellow onion (*Allium cepa* var *cepa* L.) variety *Phule Suvarna* to study the effect of organic practices on post harvest storage life and organoleptic quality of yellow onion bulbs. The results revealed that the post-harvest storage loss of stored bulbs increased steadily as the period of storage advanced. The organic treatment combination of M1S2 (3% panchakavya + 50% FYM + 50% poultry manure) registered the lowest total loss of 42.65 and 45.78 % for crop I and crop II respectively at 120 days after storage. The inorganic treatment consisting of 100% recommended dose of NPK fertilizers (M4S10) exhibited the highest total storage losses. Similar kind of response was also observed in sprouting and rotting per cent of stored bulbs. Organoleptic evaluation revealed that all organically nourished treatments particularly poultry manure combination (poultry manure combined with neem cake/ vermicompost/ pressmud/ digested coir pith) were superior, delicious and had higher score than inorganic fertilizer treatments. However organoleptic parameters such as colour, flavor, texture, taste and over all acceptability were not significantly different among the various organic manures and organic growth stimulants combinations.

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A comparative study on different drying methods of *Moringa oleifera* leaves for powder production

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The leaves of the *Moringa oleifera* (drum stick) tree are very nutritious. Presently the leaves along with stems are dried in open yards under sun drying which advocates impurities and micro organism contamination and also resulting in non appealing colour of the dried product. In order to upgrade the method of drying for better quality end product, an attempt was made to study the effect of different drying methods on the colour of the end product. Harvested moringa leaves (PKM –I) variety were stripped, washed and dried in polyhouse dryer, forced flow mechanical dryer (CIAE-IEP model) and under sun and shade for comparison. It took 6 hours for drying from an initial moisture content of 85% (w.b) to 5% (w.b) in polyhouse dryer, 3 hours in mechanical dryer, one day under sun and two days under shade drying. The colour scores measured using Hunter colour lab revealed that mechanical drying followed by polyhouse drying was superior to shade and sun dried samples.

Indian Society for Spices

The Indian Society for Spices was founded in 1991 for the advancement of research and development of spices, aromatic, medicinal and related crops. The society aims at providing a forum for research workers on these crops for exchange of ideas, and as a catalytic link between research and development organizations and the industry. The society organizes symposia, conferences and seminars in collaboration with other organizations on aspects relevant to spices, aromatic and medicinal crops. The society fosters to the professional interest of research workers on spices, medicinal and aromatic crops through its journal, the Journal of Spices and Aromatic Crops, which is available free of cost to members. Members also receive publications of the society at reduced cost and can participate in scientific meetings and other functions of the society.

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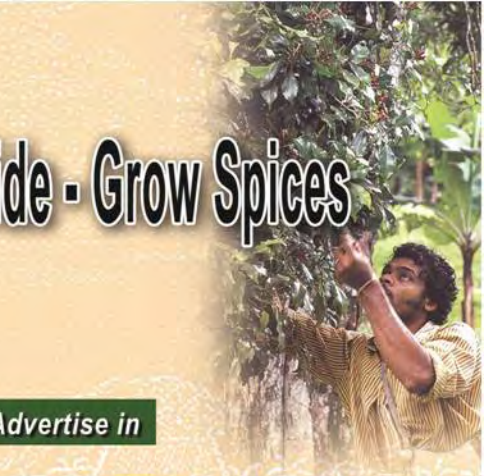

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