MAJOR SPICES-
PRODUCTION AND PROCESSING

IISRPUB-34

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INDIAN INSTITUTE OF SPICES RESEARCH
(Indian Council of Agricultural Research)
Calicut - 673012, Kerala

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Edited by

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FOREWORD

India is a traditional producer, exporter and consumer of a variety of spices. The oriental spices, which were traded from this subcontinent, have influenced the world history, besides adding quality and flavour to the food consumed by mankind. With a variety of spices in its inventory, about one third of global demand of spices is met by the Indian exports. In terms of value, spices exports from India have grown US $ 133 million in 1990-91 to US $ 430.2 million in 2003-04. However, the spice production and trade in the country is facing stiff challenges ever since the globalisation of agricultural economy has come into vogue. High production costs and declining exports are the problems of the day.

It is needless to say that all-out efforts are needed to revive, sustain and develop
onomy in the country, which supports a sizeable proportion of small
farmers. The book titled is a guide in all respects, which throws light
and post harvest processing methods of several important spices.
This book covers ten important spices crops excluding seed spices grown in different parts of the country.

The book is presented in a popular and lucid style with appropriate regional references. It is also a blend of practical insights of all processes and methods, from the seed to the consumer, as well as vast amount of scientific knowledge accumulated through more than two decades of research by many pioneering institutions. It will be of immense use to all practitioners in spice sector including farmers, extension functionaries and academicians.

I take this opportunity to appreciate the editors, Dr. V. A. Parthasarathy, Director, IISR and Dr. P. Rajeev for excellent editing. All the contributors of this valuable reference guide have taken earnest efforts to highlight a multi disciplinary perspective of scientific publishing.

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SPICES RESEARCH AND DEVELOPMENT – AN OVERVIEW

V.A. Parthasarathy, M. S. Madan

India is the land of spices. The flavour and fragrance of Indian spices had a magic spell in human civilization and culture since very ancient days. In the middle ages taxes and rents were frequently paid in pepper and the term "pepper corn rent" was very much in vogue in those days, as indicated in the literature. Spices was also an icon of love as Queen of Sheba chose spices to express her love to King Solomon. The lure for spices attracted the Greeks, Turks, Arabs, Romans, Chinese and Europeans to India, ultimately leading to colonial rule. The British colonial rule came to its end in 1947 with the Indian independence movement. The spices trading history is thus entwined with world history itself. Annals of history reveal the importance of Indian spices growing at a magnificent pace across the nations. Indian spices have carved out a niche of its own in the spices world, over the years. There are 109 spices listed in the ISO, the international organization of standardization (table 1).

India is the largest spice producer and consumer of spices. Over the years, the world trade in spices has made a quantum jump to more than 4.5 million tonnes valued at US $ 1, 500 million. India contributes to about 45-50 per cent of the world demand with a total area of around 2.5 million under spices cultivation. India produces around 2.8 million tonnes of spices annually, of this 10 per cent of the total produce is exported to over 150 countries. The USA, Europe, Australia, Japan, Middle East and Oceanic Countries are the major importers of Indian spices.

India has been a traditional producer, consumer and exporter of spices. An estimated quantity of more than 9.9 million tonnes of spices and herbs valued at US$ 20 billion are being traded globally every year. With variety of spices in its inventory, almost one third of the world demand is being met by Indian exports. In terms of value, spice exports from India has grown from $133 million in 1990-91 to US$ 430.2 million in 1999-2000, registering an average growth rate of more than 25% per annum. Spice exports contributed about 19.37% of the total export earnings of all agricultural commodities valued at Rs.7270.76 crores (1997-98) and the unit value earned by spices (Rs.61546/ton) is 3.6 times more than that of other horticultural exports. In recent years under the WTO regime, the country has to face many challenges both in production and export marketing of spices. India has lost its monopoly supply to new entrants in the world trade for spices. There is a falling exports and increased imports of spices. During 2000-2001, the export has shown a decline of 3% in terms of quantity and 20% in rupee value. In dollar terms the decline is 25%. The trend continued during the post-QRs free trade period i.e. during 2001-02. Exports declined by 12%, both in terms of quantity and value. Our failures have arisen mainly from poor marketing strategy, non-competitive pricing and absence of quick, flexible response to the changes in the international market; i.e. absence of a 'market oriented production' strategy to name some weaknesses of the Indian spice industry. table -2 indicates the position of India in international spice trade.

Production

Spices, being the low volume and high value commercial crop, play an important role in the agricultural economy of the country. Almost all States in the country produce one or other spice. The total value of spices exported was about Rs.2200 crores during the crop year 2002-03. About 8% of total spices production in the country is exported. Share of export in total production varied from mere 0.19% in cardamom to 41.13% in chillies during 2002 - 03 (table 3).

Export

Spice export was consistently moving up during the last one decade with an increase of 210% in quantity and 622% in value. The country commands 46% in global trade in terms of quantity and 28% in terms of value. Export during 1999-2000 made an all time record in terms of value. Compared to this previous year, export has registered an increase of six per cent in rupee value and the increase was three per cent in terms of dollar value. However during 2002–03, the export has shown a decrease. In the total spices export earnings during 2000-01, pepper contributed about 46 per cent followed by spice oils and oleoresins (15%) and chilli (13%). The value added products in the export basket constituted 37% of the total event. During 2000-01, export of pepper, small cardamom and garlic registered a positive change both in terms of quantity and value of exports as compared to previous year. In all other commodities there was a negative growth both in terms of quantity and value. In terms of quantity, overall, there was a decrease of 9.75% during 1999-2000. The decrease in quantity was more pronounced in large cardamom (29.78%), ginger (-11.14%), turmeric (11.70%), and curry powder (-16%). Unit value realised was more pronounced in black pepper (Rs. 205.46/kg), small cardamom (Rs.501/kg), and oils and oleoresins (Rs. 1010.49/kg). Overall export realisation was only 96% of the target fixed for 1999-2000 in quantity and 106 % in rupee and 105% in dollar terms of value. Export target of spices for the year 1999-2000 was 2.178 lakh tonnes valued Rs. 1780 crores (US $ 408.4 million). Targeted growth rate was 6% in rupees terms and 3.5% in dollar terms for the period. During eighties, except black pepper, all other commodities have registered a negative growth rate in volume exported. But oils, oleoresing and the value added spice products' export achieved the maximum growth rate of 42.93% in volume and 25.91% in value terms. Overall, there was a negative growth rate of 3.6 recorded for total spices during the period between 1978-79 to 1987-88. During the period from 1988-89 to 1997-98, except in cardamom (small), exports of all other commodities achieved a positive growth rate both in volume and value terms. Chilli and ginger performed well. Unit price rise was more for pepper than for all other commodities exported. During this decade almost all the crops have recorded a positive growth rate in terms of value because of the continued rising trend in prices.

Over the twenty years period (1978-79 to 1997-98), on an average around 5.77% and 13.27% growth rate was estimated for spices export both in volume and in value terms. There was a better performance by 'hot spices' like pepper, chilli and ginger apart from oils and oleoresin export.

Over the years, India's share of world spices market has not appreciated much as it should be and its monopoly as a supplier of spices is threatened by countries like China, Brazil, Vietnam, Pakistan, Egypt, Turkey and other African and Caribbean countries. India also faces shortage of exportable surplus because our domestic demand for spices is admittedly high resulting in supply fluctuations. Sharp fluctuations in the quantum and value of exports and in the unit value realization have characterized the spices trade in recent years. The problem is further made complex due to low productivity of spice crops resulting in Indian spices priced high, rendering them uncompetitive in the international markets.

Under the influence of WTO regime there is a fall in exports of many spices from India. Spices export during the post-QRs free trade period, i.e. during April-March, 2001-02, decline in export was 12%, both in terms of quantity and rupee value. It is noteworthy that during the last three years, import of spices has increased considerably whereas, export from India has declined quantitywise during this period even though there was a growth in earnings. During 1997-98 the quantity exported was 240863 MT,and the figure came down to 230000 MT in 2000-01.

New Developments and Emerging Opportunities:

There are some positive developments world over promoting the growth of the spice industry, which needs immediate consideration as given below:

- Increasing awareness about the naturality of spices and its substitution for synthetic colouring and flavouring agents.
- Emergence of 'nature food', 'yogic food', 'organic food', and emphasis on 'back to nature'.
- Increase in use of spice oils, oleoresins, pigments and flavourants etc.
- Increasing demand for spicy ethnic food items from countries like India, China, Mexico etc.
- The multinational food chains have spread all over the world, and are changing the taste of the world through their spicy menus.
- The long established health claims for spices and herbs in countries of origin are being accepted by consumers in the West – Eg:- products based on garlic, turmeric as well as cloves, cardamom etc.
- There is a 'hot trend' in spice consumption world over; i.e. an increased consumption of hot spices like pepper, ginger, chillies etc. Demand for organic spices is increasing in developed countries.
- The prevailing trend for convenient foods and that too highly flavored, signaling the enormous potential for increased

use of spices.

- An increased demand for spice oils and oleoresins and spices in other firms, such as encapsulated spices, in recent years.

In the European market there is a shift towards ready mixes like curry pastes, ketchups and sauces which reduced the intake of curry powder.

Table 1. ISO list of plant spices

	Botanical name of the plant	Family	Common name	Name of plant part used as spices
1.	Acorus calamus	Araceae	Sweet flag, myrtle flag, calamus, flag root	Rhizome
2.	Aframomum angustifolium	Zingiberaceae	Madagascar cardamom	Fruit, seed
3.	Aframomum hanburyi	Zingiberaceae	Cameroon cardamom	Fruit, seed
4.	Aframomum koranima	Zingiberaceae	Korarima cardamom	Fruit, seed
5.	Aframomum melegueta	Zingiberaceae	Grain of paradise. Guinea grains	Fruit, seed
6.	Allium ascalonicum	Liliaceae	Shallot	Bulb
7.	Allium cepa	Liliaceae	Onion	Bulb
8.	Allium cepa var. aggregatum	Liliaceae	Potato onion	Bulb
9.	Allium tuberosum	Liliaceae	Indian leek, Chinese chive	Bulb, leaf
10.	Allium fistulosum	Liliaceae	Stony leek, Welsh onion, Japanese bunching onion	Leaf and bulb
11.	Allium porrum	Liliaceae	Leek, winter leek	Leaf and bulb
12.	Allium sativum	Liliaceaee	Garlic	Bulb
13.	Allium schoenoprasum	Liliaceae	Chive	Leaf
14.	Alpinia galanga	Zingiberaceae	Greater galangal, Longwas, Siamese ginger	Rhizome
15.	Alpinia officinarum	Zingiberaceae	Lesser galangal	Rhizome
16.	Amomum aromaticum	Zingiberaceae	Bengal cardamom	Fruit, seed
17.	Amomum kepulaga	Zingiberaceae	Round cardamom, Chester cardamom, Siamese cardamom, Indonesian cardamom	Fruit, seed
18.	Amomum krervanh	Zingiberaceae	Cambodian cardamom	Fruit, seed
19.	Amomum subulatum	Zingiberaceae	Greater Indian cardamom, large cardamom, Nepalese cardamom	Fruit, seed
20.	Amomum tsao-ko	Zingiberaceae	Tsao-ko cardamom	Fruit, seed
21.	Anethum graveolens	Apiaceae (Umbelliferae)	Dill	Fruit, leaf, top

22. Anethum sowa	Apiaceae (Umbelliferae)	Indian dill	Fruit
23. Angelica archangelica	Apiaceae (Umbelliferae)	Garden angelica	Fruit, petiole
24. Anthriscus cereifolium	Apiaceae (Umbelliferae)	Chervil	Leaf
25. Apium graveolens	Apiaceae (Umbelliferae)	Celery, garden celery	Fruit, root, leaf
26. Apium graveolens var. Rapaceum	Apiaceae (Umbelliferae)	Celeriac	Fruit, root, leaf
27. Armoracia rusticana	Brassicaceae (Cniciferae)	Horse radish	Root
28. Artemisia dracunculus	Asteraceae (Compositae)	Tarragon, estragon	Leaf
29. Averrhoa bilimbi	Averrhoaceae	Belimbing, bilimbi cucumber tree	Fruit
30. Averrhoa Carambola	Averrhoaceae	Carambola, caramba	Fruit
31. Brassica junceae	Brassicaceae	Indian mustard	Seed
32. Brassica nigra	Brassicaceae	Black mustard	Seed
33. Bunium persicum	Apiaceae (Umbelliferae)	Black caraway	Seed, tuber
34. Capparis spinosa	Capparidaceae	Caper, common caper, caper bush	Floral bud
35. Capsicum annuum	Solanaceae	Capsicum, chillies, paprika	Fruit
36. Capsicum Frutescens	Solanaceae	Chillies, bird's eye chilli	Fruit
37. Carum bulbocastanum	Apiaceae (Umbelliferae)	Black caraway	Fruit, bulb
38. Carum carvi	Apiaceae (Umbelliferae)	Caraway, blond caraway	Fruit
39. Cinnamomum Aromaticum	Lauracea	Cassia, Chinese cassia	Bark, leaves
40. Cinnamomum Burmanii	Lauraceae	Indonesian cassia	Bark
41. Cinnamomum Loureirii	Lauraceae	Vietnamese cassia	Bark
42. Cinnamomum Tamala	Lauraceae	Tejpat, Indian cassia	Leaf, bark

43. Cinnamomum Zeylanicum	Lauraceae	Sri Lankan cinnamon, Indian cinnamon	Bark, leaf
44. Coriandrum Sativum	Apiaceae (Umbelliferae)	Coriander	Leaf, fruit
45. Crocus sativus	Iridaceae	Saffron	Stigma
46. Cuminum Cyminum	Apiaceae (Umbelliferae)	Cumin	Fruit
47. Curcuma longa	Zingiberaccae	Turmeric	Rhizome, leaf
48. Cymbopogon Citrates	Poaceae	West Indian lemongrass	Leaf
49. Cymbopogon Nardus	Poaceae	Sri Lankan citronella	Leaf
50. Elettaria cardamomum	Zingiberaccae	Small cardamom	Fruit, seed
51. Elettaria cardamomum	Zingiberaceae	Sri Lankan cardamom	Fruit, seed
52. 1 Ferula assa-foetida 2 Ferula foetida 3 Ferula narthex	Apiaceae (Umbelliferae)	Asafoetida	Rhizome
53. Foeniculum Vulgare	Apiaceae	Bitter fennel	Leaf, twig, fruit
54. Foeniculum Vulgare	Apiaceae	Sweet fennel	Leaf, twig, fruit
55. Garcinia cambogia	Clusiaceae	Garcinia, Camboge	Pericarp of the fruit
56. Garcinia indica	Clusiaceae	Garcinia, Kokum	Pericarp of the fruit
57. Hyssopus Officinalis	Lamiaceae	Hyssop	Leaf
58. Illicum verum	Dliciaceae	Star anise, Chinese anise	Fruit
59. Juniperus Communis	Cupressaceae	Common juniper	Fmit
60. Kaempferia Galangal	Zingiberaceae	Galangal	Rhizome
61. Laurus nobilis	Lauraceae	Laurel, true laurel, bay leaf, sweet flag	Leaf
62. Levisticum Officinale	Apiaceae	Garden lovage, lovage	Fruit, leaf
63. 1 Lippia graveolens 2 Lippia berlandieri	Verbenaceae	Mexican oregano	Leaf, terminal shoot
64. Mangifera indica	Anacardiaceae	Mango	Immature fruit (rind)

65. Melissa officinalis	Lamiaceae	Balm, lemon balm, melissa	Leaf, terminal shoot
66. Mentha arvensis	Lamiaceae	Japanese mint, field mint, corn mint	Leaf, terminal shoot
67. Mentha citrata	Lamiaceae	Bergamot	Leaf, terminal shoot
68. Mentha x piperita	Lamiaceae	Peppermint	Leaf, terminal shoot
69. Mentha spicata	Lamiaceae	Spearmint, garden mint	Leaf, terminal shoot
70. Murraya koenigii	Rutaceae	Curry leaf	Leaf
71. Myristica argentea	Myristicaceae	Papuan nutmeg Papuan mace	Kernel Aril
72. Myristica fragrans	Myristicaceae	Indonesian type nutmeg, Indonesian type mace, Siauw type mace	Kernel Aril
73. Nigella damascena	Ranunculaceae	Damas black cumin, love in a mist	Seed
74. Nigella sativa	Ranunculaceae	Black cumin	Seed
75. Ocimum basilicum	Lamiaceae	Sweet basil	Leaf, terminal shoot
76. Origanum majorana	Lamiaceae	Sweet marjoram	Leaf, floral bud
77. Origanum vulgare	Lamiaceae	Oregano, origan	Leaf, flower
78. Pandanus amaryllifolius	Pandanaceae	Pandan wangi	Leaf
79. Papaver Somniferum	Papaveraceae	Poppy, blue maw, mawseed	Seed
80. Petroselinum Crispum	Apiceae	Parsley	Leaf, root
81. Pimenta dioica	Myrtaceae	Pimento, allspice, Jamaica pepper	Immature fruit, leaf
82. Pimenta racemosa	Myrtaceae	West Indian bay	Fruit, leaf
83. Pimpinella anisum	Apiaceae	Aniseed	Fruit
84. Piper guineense	Piperaceae	West African or Benin pepper	Fruit
85. Piper longum	Piperaceae	Long pepper, Indian long pepper	Fruit
86. Piper nigrum	Piperaceae	Black pepper, white pepper, green pepper	Fruit
87. Punica granatum	Punicaceae	Pomegranate	Seed (dried with flesh)

88. Rosmarinus Officinalis	Lamiaceae	Rosemary	Terminal shoot, leaf
89. Salvia officinalis	Lamiaceae	Garden sage	Terminal shoot, leaf
90. Satureja hortensis	Lamiaceae	Summer savory	Terminal shoot, leaf
91. Satureja montana	Lamiaceae	Winter savory	Leaf, twig
92. Schinus molle	Anacardiaceae	American pepper,	Fruit, wall (rind) Califomian pepper tree
93. Schinus terebenthifolius	Anacardiaceae	'Brazilian pepper'	Fruit
94. Sesamum indicum	Pedaliaceae	Sesame, gingelly	Seed
95. Sinapis alba	Brassicaceae	White mustard, yellow mustard	Seed
96. Syzygium Aromaticum	Myrtaceae	Clove	Flower bud
97. Tamarindus indica	Cesalpiniaceae	Tamarind	Fruit
98. Thymus serpyllum	Lamiaceae	Mother of thyme, wild thyme, creeping thyme	Terminal shoot, leaf
99. Thymus vulgaris	Lamiaceae	Thyme, common thyme	Terminal shoot, leaf
100. Trachyspermum Ammi	Apiaceae	Ajowan	Fruit
101. Trigonella Foenumgracecum	Fabaceae	Fenugreek	Seed, leaf
102. Vanilla planifolia syn. Vanilla Fragrans	Orchidaceae	Vanilla	Fruit (pod)
103. Vanilla tahitensis	Orchidaceae	Vanilla	Fruit (pod)
104. Vanilla pompona	Orchidaceae	Pompona vanilla	Fruit (pod)
105. Xylopia aethiopica	Annonaceae	Negro pepper, Guinean pepper	Fruit
106. Zanthoxylum Bungei	Rutaceae	Chinese prickly ash pepper, Sechuang pepper	Fruit
107. Zanthoxylum acanthopodium	Rutaceae	Chinese pepper	Fruit
108. Zanthoxylum Piperitum	Rutaceae	Japanese pepper	Fruit
109. Zingiber officinale	Zingiberaceae	Ginger	Rhizome

Table 2. Average World Import of spices and India's contribution

Period	Quantity[1] (mt)	Value[1] (US $ million)	Indian export[2]	
			Qty. (mt)	% Share
1970-75	220 000	300.6	57748	*26.25*
1978-80	311 500	737.5	104084	*33.41*
1981-85	350 000	1000.0	78597	*22.46*
1991-93	450 000	1600.0	151725	*33.72*
1993-95	500 000	1750.0	180247	*36.05*
1995-98	992 680	2135.7	227907	*22.96*
1999-00	1196912	2716.8	235764	*19.70*
2001-02	1381152	2534.5	253655	*18.36*

Source: 1. International Trade Centre, UNCTAD/WTO (ITC) estimates
2. Estimates based on Spices Board of India data.

Table 3. Crop-wise World import of spices and India's share (2001)

World: (Q: tons, V: '000 US$)
India: (Q: tons, V: Rs. Lakhs)

Item	World (2001)[1]		India (2000-01)[2]	
	Q	V	Q	V
Pepper whole	224948	482472	18475.6	32140.0
Pepper ground	20760	70918	1556.2	3041.5
Capsicum*	294368	424034	62447.7	22973.3
Vanilla	4412	240183	22.2	505.1
Cinnamon whole	68874	107165	166.8	108.5
Cinnamon, crushed, ground	10961	16380	15.7	9.0
Cloves whole/stem	53256	209716	154.6	216.3
Nutmeg/mace/cardamom	39883	253381	2401.4	10098.2
Spice seeds	182619	249314	53414.0	81687.3
Ginger	231383	190280	6288.0	2682.1
Spice mixtures	237613	296105	5841.0	4299.6

Source: 1. Global Spice Markets Imports 1998-2002, International Trade Centre, UCTAD/WTO.
2. Spices Board, Ministry of Commerce, Govt. of India.
Note: * For India- Chilli

Value added spices:

During 1960s curry powder emerged as the most sought after value added spice product and during 1970s the focus shifted to spice oils and oleoresins including mint oil. Today these products are the leading

Table 4. Production and export of spices in India

Crop/ Product	Production (2002-03)(P)			Export 2004-05 (E)		Share in Total Export	
	Area (ha)	Production (mt)	Yield (Kg/ha)	Qty. (mt)	Value (Rs. Lakhs)	Qty. (%)	Value (%)
Black Pepper	223060	70600	317	14150	12140	4.22	5.52
Cardamom (S)	73125	11920	218	650	2390	0.19	1.09
Cardamom (L)	30008	5300	209	950	1134	0.28	0.52
Chilli	831630	846160	1017	138000	49901	41.13	22.68
Ginger	85930	307370	3577	13000	5950	3.87	2.70
Turmeric	149410	527960	3534	43000	15650	12.82	7.11
Coriander	282530	172350	610	33750	8266	10.06	3.76
Cumin	521250	134753	259	13750	10190	4.10	4.63
Celery	2940	4500	1531	4100	1301	1.22	0.59
Fennel	22898	27602	1205	7100	2530	2.12	1.15
Fenugreek	50596	64221	1269	13750	2661	4.10	1.21
Other seeds[1]	NA	NA	NA	11100	2614	3.31	1.19
Clove	2127	1374	646	-	-	-	-
Garlic	107150	136130	4070	2250	560	0.67	0.25
Nutmeg	8675	2184	252	1250	2235	0.37	1.02
Saffron	2880	6.53	2.27	-	-	-	-
Cinnamon	718	1661	1028	-	-	-	-
Other spices[2]	13920	14310	1028	8500	3960	2.53	1.80
Vanilla	2545	257	101	38	2759	0.01	1.25
Curry powder	-	-	-	7750	6610	2.31	3.00
Mint products[3]	-	-	-	9300	40777	2.77	18.54
Spice Oils & Oleoresins	-	-	-	5600	46375	1.67	21.08
TOTAL[4]	2500030	3023200	-	335488	220000	100	100

Source: DASD & Spices Board, Govt. of India. NA = Not Available, P= Provisional and E = Estimate

Note :

1. Includes mustard, aniseed, bishops weed (ajwan seed), dill seed, poppy seed etc.
2. Include tamarind, asafoetida, cambodge, cassia, saffron spices (nes) etc.
3. Mint oils, menthol & menthol crystal
4. 2001-02 Total.

contributors in value terms. The Indian spice industry has achieved 45% of its total spice exports in the form of value added spices during 2000-01, compared to just 4% achieved during 1976-77. Indian spice industry is on the move to adopt latest innovations in technology. Super Critical Fluid Extraction for spice oils and oleoresins, Cryogrinding process for spice powders and mix masalas were introduced by several leading manufacturers in order to upgrade the quality of the product.

Spice oleoresins

Oleoresins are natural isolates obtained by extracting the comminuted (powdered) spice with suitable solvents and recovering the solvent mostly by evaporation. The residue is called oleoresin. The type of solvents used to extract oleoresin includes hydrocarbons, chlorinated hydrocarbons, alcohols, ethers, ketones and carbon dioxide. Oleoresin is a blend of volatile and nonvolatile components that are soluble in the solvent. The volatile part called as essential oil consists of several compounds with varying boiling points. The volatile part of oleoresin imparts flavour and aroma to the product.

The non volatile part of oleoresin consists of several group of chemical compounds such as carotenoids, steroids, alkaloids, anthocyanins, glycosides etc. The non volatile part contribute towards taste, colour, pungency, texture and antioxidative properties of the product. Oleoresins are commercially important because of the consistency in flavour, taste, antioxidant properties, increased shelf life and less storage space as it is a highly concentrated product. Some of the commercially important spice oleoresins prepared in India are from chilli, paprika, black pepper, ginger, turmeric, cinnamon, cassia, coriander, cumin, fennel, fenugreek, pepper mint etc.

Properties of oleoresins

Oleoresin consists of volatile and non volatile part. The concentration of volatile part range between 10 and 20%. The general standard of black pepper oleoresin is 25% volatile oil and 35% non volatile piperine and other alkaloids. The volatile pat i.e., the essential oil, consists of aliphatic compounds, isoprenoids, benzenoids, and miscellaneous compounds.

Aliphatic compounds

They are generally derived from fats or amino acids. They consists of alcohols or aldehydes which relate to the odour of the oil. In many essential oils aliphatic esters are important flavour and fragrance compounds occurring widely in nature.

Terpenoids

Isoprenoid is the basic compound from which terpenoid, carotenoids, steroids and rubber are formed. Isoprene is formed from acetyl-CoA via mevalonic acid and dimethyl allyl pyrophosphate. The terpenoids are built from two isoprene units (monoterpenoid) or three isoprene units (sesquiterpenoids). Some of the terpenes of importance are myrcene, ocimene, limonene, a and b-pinene. The quantitatively most important monoterpene hydrocarbons are limonene and the pinenes.

The most important sesquiterpene hydrocarbon ($C_{15}H_{24}$) quantitatively occurring in spice oils is caryophyllene which is present in clove oil upto 20% and in black pepper up to 28%.

Some of the other flavour imparting monoterpene compounds are linalool, terpinene-4-ol, a and b-thujone etc.

Benzenoids

Some of these compounds are very significant due to their spicy odours. Major among those are cumic aldehyde, carvacrol, thymol, cinnamaldehyde, anethole, eugenol, myristicin etc.

Miscellaneous compounds

Nitrogen and sulphur compounds also play an important role for the organoleptic quality of oleoresin.

Non-volatile constituents

As described earlier oleoresin is a blend of volatiles, non-volatiles and pungent principles. Apart from the volatile isoprenoids and benzenoids there are the non volatiles such as pigments, alkaoids etc. Some of the major pigments are á-carotene, capsanthin, capsorubin, zeaxanthin and criptoxanthin of paprika oleoresin. In turmeric oleoresin a series of benzenoid pigments such as curcumin, demethoxy curcumin and bis-demethoxy curcumin assume great importance.

Major alkaloids in black pepper and capsicum oleoresin are piperine, chavicine, iso piperine, iso-chavicine, capsaicin, homocapsaicin, dihydrocapsaicin, nordihydro capsaicin, homo capsaicin, homo dihydro capsaicin, piperyline, piperittine, piperanine, piperolein A, piperolein B, Zingerone etc.

Oleoresins and essential oils are complicated mixtures of hundreds of chemical compounds, most of them occurring in parts per million or even less. Many of the minor naturally occurring compounds are not commercially available. It is not easy to substitute these natural products with synthetic reconstituted incomplete products. Major oleoresins extracted from various spices and herbs, plant parts used for extraction and the oil content in the oleoresis are depicted in table 5.

The oleoresin scenario in India is very bright. We export almost all spice oleoresins.

The export scenario of Indian oleoresin is displayed in Table 6. The consistency and flavour of oleoresin depends on the quality of raw material. There are cultivars / varieties rich in oleoresin and oil in all the major spices. In black pepper CV. Kottanadan, Kumbhakodi, Aimpiriyan and the new IISR Malabar excel are some examples. Agro climatic conditions and cultural practices also influence the recovery oil and oleoresin to great extent. A good example is the Curcumin content of turmeric. Great difference to the extent of up to 40-50% difference is observed between different parts of the Country.

Indian Institute of Spices Research located at Calicut, Kerala has good repository of high oleoresin spice varieties or cultivars.

Table 5. Major oleoresin, oil content in oleoresin and plant parts used for extraction

Oleoresin	Plant Parts	Yield of oleoresin (%)	Oil content (%)
Anis	Dried seeds	12-16	10-14
Caraway	Dried seeds	5-7	13-15
Carrot seed	Seeds	8-12	3-5
Coriander	Fruits	7-10	7-8
Cumin	Seeds	5-7	30-35
Fennel	Seeds	7-10	16-21
Fenugreek	Fruits	3-4	~25
Laurel	Dried leaves	7-10	5-7
Marjoram	Dried leaves	8-12	9-14
Origanum	Dried leaves	10-16	7-9
Pepper mint	Dried leaves	5-8	18-20
Sage	Dried leaves	10-16	9-12
Thyme	Dried leaves	8-11	8-9
Lemon peel	Dried peel	2.5 - 3	75-80
Orange peel (bitter)	Dried peel	2-2.5	70-80
Orange peel (sweet)	Dried peel	3-5	70-80
Cassia	Bark	6-8	N.A
Cinnamon	Bark	8-10	N.A
Clove	Buds	10-12	70-80
Ginger	Rhizome	4-10	21-30
Mace	Aril	27-32	8.5-22
Nutmeg	Seed	18-26	10-80
Black pepper	Fruits	10-15	15-25
Turmeric	Rhizome	8-12	3-7
Vanilla	Beans	30-60	-

Source: Zachariah and Parthasarathy, 2006 Chemical Industry digest Annual January 2006

Table 6. Export of spice oleoresin from India

Product (s)	Quantity (mt)	Value (In Rs. Lakhs)
Pepper oleoresin	988.16	7029.65
Cardamom oleoresin	2.13	195.08
Chilli oleoresin	10.95	178.11
Paprika oleoresin	1305.82	13290.01
Ginger oleoresin	125.60	1363.94
Turmeric oleoresin	265.22	2751.31
Coriander oleoresin	8.64	79.01
Cumin oleoresin	10.58	114 50
Fennel oleoresin	5.4	45.81
Nutmeg oleoresin	105.55	860.29
Mace oleoresin	23.26	339.40
Cinnamon oleoresin	0.07	2.82
Cassia oleoresin	21.65	475.66
Clove oleoresin	4.29	89.45

Zachariah, T.J. and V.A.Parthasarathy. 2006. Spices oleoresins - Prospects and potential. Chemical Industry digest Annual January 2006 . Pp. 153 - 158.

BLACK PEPPER

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1.0. INTRODUCTION

Black pepper of commerce is produced from the berries of the vine *Piper nigrum* L. Black pepper is one of the most ancient and historic crops of India and is native to the forests of Western Ghats. Old Sanskrit and Tamil literature show that the spice was highly valued from very ancient times. Black pepper from the Malabar region of India is known for its quality and has been the main item for trade between India and Europe for more than 3,500 years. From time immemorial, trade in spices of Malabar was the monopoly of Arabs. They collected valuable spices including black pepper and sold them in the Mediterranean ports from where they were distributed all over the Europe. The Arabs had kept the source of these precious commodities as a trade secret and many European countries frantically tried to find out the source of spices. The voyages of Vasco-da-Gama and other great navigators such as the Chinese Admiral Zheng He of 15th and 16th centuries had their primary objective of discovering a direct route to the land of spices, namely, India. In olden days spices were considered as valuable as gold itself. In England, throughout the medieval period, 'pepper rent' was exceedingly common and the tenant was obliged to supply his landlord with a fixed quantity of black pepper as rent. The consumption of black pepper grew phenomenally in the days of Roman Empire and it became the most typical spice in medieval Europe. It was a status symbol of fine cookery and description of a lavish feast invariably mentioned black pepper, if not other spices. Black pepper reigned as a paramount spice for several centuries. The rise of French cuisine during the 17th century put an end to over spicing of food and milder spices and herbs slowly replaced black pepper. The price of black pepper dropped dramatically with the decrease in demand. Despite the drop in price black pepper continues to remain as favourite spice all over the world today.

1.1. Area and production

Black pepper is grown in about 26 countries including India, Indonesia, Malaysia, Sri Lanka, Thailand, China, Vietnam, Cambodia, Brazil, Mexico and Guatemala. The total global area under black pepper is around 404,000 ha producing about 180,000 tonnes/year. In India black pepper is cultivated in around 223,060 ha with an annual production of 70,600 tonnes (tables 1 & 2). In India, black pepper cultivation is mainly confined to Kerala, Karnataka and Tamil Nadu, and to a certain extent in Andaman and Nicobar Islands and North-Eastern states. Kerala alone contributes about 95% of total production of black pepper. However, the crop has a great potential to be grown in non-traditional areas such as Andhra Pradesh, West Bengal and also in north-eastern states such as Assam, Meghalaya, Manipur, Tripura and Arunachal Pradesh. The crop has great scope for area expansion especially in Assam where every rural household has a homestead garden with shade trees and arecanut palms that can be effectively utilized for trailing black pepper vines. Black pepper is mostly cultivated in Upper Assam in Upper Assam, Jorhat, Sibsagar and Kamrup districts in Recent estimates indicate that Assam has 2685 ha under cultivation producing 3690 mt of black pepper annually.

1.2. Composition and uses

1.2.1. Composition

The aroma, flavour and medicinal property of black pepper is attributed to the volatile oils. Pepper oil contains a range of organic compounds, which belong to the group of terpenes and hydrocarbons. The major aroma compounds of black pepper are ß- caryophyllene, sabinene, myrcene, limonene and linalool. The non-volatile part of black pepper which is extracted using organic solvents is called black pepper oleoresin. The major pungent alkaloid present in black pepper is piperine. In general, black pepper contains about 3-5% volatile oil, 8-

Table 1. Area and production of black pepper in India

Year	Area (ha)	Official estimate of production (mt)	Yield (kg/ha)	Trade estimate of production (mt)
1991-92	184,200	52,010	282	60,000
1992-93	189,390	50,760	268	60,000
1993-94	190,990	51,320	269	50,000
1995-96	198,870	70,230	353	60,000
1996-97	180,260	55,590	308	60,000
1997-98	181,530	57,330	316	65,000
1998-99	189,840	70,160	370	75,000
1999-2000	209,670	50,120	239	58,000
2000-01	213,860	63,670	298	79,000
2001-02	218,220	61,460	282	80,000
2002-03 (P)	223,060	70,600	317	65,000

(P)=Provisional
Source: Spices Board (www.indianspices.com)

Table 2. Area and production of black pepper in India in major states

State	1998-99		1999-2000		2001-02		2002-03	
	Area	Production	Area	Production	Area	Production	Area	Production
Kerala	230,890	64,340	184,370	56430	203,960	58,240	208,610	67,360
Karnataka	4390	10340	6850	1650	9700	2220	9990	2260
Tamil Nadu	4100	900	610	120	4110	910	4000	870
Pondicherry	110	10	10	10	NA			
Andaman & Nicobar Islands	430	80	430	80	45	90	550	110
All India	239,920	75,670	192,270	58,290	218,220	61460	223,150	70600

Area=ha; Production=metric tonnes
Source: Spices Board (www.indianspices.com)

16% oleoresin and 2-6% piperine. However, starch is the predominant constituent ranging from 35% to 40% in black pepper.

1.2.2. Uses

Black pepper is the most widely used spice in the world and has occupied a proud place in the cuisines of both East and West. Black pepper is used either as a whole as dried berries, or in powdered form, and as oils and oleoresin extracted form the berries. It is an indispensable item in the preparation of sauces, soups, curry powders and pickles. Black pepper is preferred in the USA while mild-flavoured white pepper is generally consumed in Europe. Considerable amount of black pepper is used in the preparation of processed meat of all kinds in many countries. The oleoresin fraction of black pepper has bactericidal and fungicidal properties. It is much employed in indigenous medicine systems as an aromatic stimulant for enhancing salivary and gastric secretions and also as a stomachic. Oil of black pepper, obtained by steam distillation of crushed black pepper, is used in the flavouring of sausages, canned meat, soups and beverages. Black pepper hulls, recovered after the preparation of white pepper, is used for flavouring tinned foods.

2.0. BOTANY AND IMPROVEMENT

2.1. Botany

P. nigrum belongs to the family Piperaceae. Black pepper is a perennial climber which can grow to considerable height, even up to 40-60 m, on large trees. Black pepper has two types of branches namely, orthotropic branches and plagiotropic branches. Orthotropic branches are straight, upward growing , with monopodial growth habit and after climbing on a support they become woody with a thick bark and form the central axis of the vine column. The nodes are swollen and each node has a leaf. At each node there may be 10-15 short adventitious clinging roots which adhere to the support while climbing. At the axil of each leaf of the orthotropic branches there is an axillary bud which develops into a plagiotropic branch. The plagiotropic branches are laterally growing with sympodial growth habit and produce flowers and fruits. The plagiotropic branches do not produce aerial roots and the leaf size and shape are slightly different from that of the orthotropic branches. The leaves of black pepper are variable in size (15-21 cm x 6-15 cm) and shape and serve as major features for distinguishing various cultivars. Black pepper is a shallow rooted plant with the root system within 30-60 cm of the soil surface. It consists of about 6-7 main roots with a network of side roots. June after the receipt of a few monsoon rains. In localities where South West Monsoon rains are not considerable, the vine may flower with the North East monsoon rains. The flowers are very small and are borne on pendulous spikes which have a catkin like appearance. The fruit is small, usually globular but sometimes slightly elongated or oval, dark or pale green turning to red or orange red when ripe.

One of the most interesting features of the cultivated black pepper vine is that it may be male, female or bisexual. However, purely male vines occur very rarely in nature. A majority of the cultivated black pepper vines are bisexual. The percentage of bisexual flowers ranges from 85 to 99 in improved varieties. But in some cultivars

Table 3. Black pepper diversity in Kerala

Sl. No.	Cultivar	Remarks
A. Central and South Kerala		
1.	Aimpirian	High yielding, performance excellent in higher elevations, good in quality, but late maturing, vigorous vines.
2.	Arakulam munda	Moderate and regular bearer, medium in quality, well adapted.
3.	Balankotta	Cultivar with large droopy leaves, moderate and irregular bearing.
4.	Chengannurkodi	Moderate yielder from South Kerala, medium in quality.
5.	Cheppakulamundi	Moderate yielder from Central Kerala, medium in quality
6.	Jeerakamundi	Cultivar with small leaves and short spikes, alternate bearing nature, small berries.
7.	Karimunda	Most popular cultivar suitable for most of the black pepper growing areas, high yielder and medium in quality, shade tolerant.
8.	Kottanadan	A high yielding cultivar from South Kerala, drought tolerant type.
9.	Kuthiravally	A cultivar with long spikes, high yield and good quality.
10.	Kuttianikodi	A moderate yielder from Central Kerala with relatively long spikes and good spiking intensity.
11.	Malamundi	A moderate yielder, medium in quality.
12.	Narayakodi	Popular in South Kerala, moderate yielder with medium quality, not easily affected by foot rot.
13.	Neelamundi	A good yielder from Central Kerala, medium in quality, tolerant to *Phytophthora* infection.
14.	Nedumchola	A cultivar with small leaves and short spikes, moderate yielder.
15.	Neyyattinkaramundi	A cultivar from Central Kerala, medium in quality and yield.
16.	Perumkodi	A cultivar from Central Kerala, moderate in yield and quality.
17.	Poonjaranmunda	A cultivar originally from Central Kerala, sporadically found in gardens of North Kerala, moderately good in yield and quality.
18.	Thommankodi	A cultivar from Central Kerala, moderately good in yield and quality.
19.	Thulamundi	A Central Kerala cultivar, medium in yield and quality.
20.	Vattamundi	A moderate yielder from Central Kerala.
21.	Vellanamban	Moderate yielder, medium in quality.
B. North Kerala		
22.	Cheriyakaniakadan	Moderate and early bearing cultivar.
23.	Kalluvally	Good yielder, medium quality with high dry recovery, drought tolerant.
24.	Kottan	Moderate yielder, medium in quality.
25.	Manjamundi	Moderate yielder, medium in quality.
26.	Perambramunda	Moderate yielder, medium in quality.
27.	Vadakkan	Medium in quality and yield with relatively large berries.
28.	Valliyakaniyakadan	A cultivar with large leaves, medium in yield and quality.

like Cheriyakanniakadan, bisexual flowers are only 1.64% and 98.36% are female flowers. Cultivars like Mundi, Perambramunda and Perumkodi also have a higher percentage of female flowers.

2.1.1. Cultivar diversity

Cultivar diversity (tables 3, 4 & 5) is one of the principal features of diversity in black pepper. The cultivars are evolved directly from wild *P. nigrum*. Natural selection and conscious selection by human endeavor for various traits have created diversity in cultivars. Most of the vernacular names of black pepper cultivars indicate a specific feature of the vine such as colour or appearance of the vine, leaf shape, spike features or the place from which the vine originated initially. More than 100 cultivars are known today and 60-65 of them are being cultivated commonly in various regions. There can be some duplicates in the number of cultivars existing since many of them are known by different names at various places. Some of the local varieties are confined to only small pockets and are considered as cultivars of less importance.

Table 4. Black pepper diversity in Karnataka

Sl. No.	Cultivar	Remarks
1	Bilimallegesara	Moderate yielder with light green spikes.
2	Kurimalai	Moderate yielder with medium quality.
3	Karimaratta	Moderate yielder with uniform bearing.
4	Karimalligesara	Moderate yielder with dark green spikes.
5	Malligesara	Common cultivar,. good in yield.
6	Uddagara	Good in yield and medium in quality.

Table 5. Less important black pepper cultivars of Kerala and Karnataka

Kerala		Karnataka
1 Annarvarayan	24. Karuthakaniakadan	1. Arasinagunda
2 Aralumuriyan	25. Karuthapirimunda	2. Doddigai
3 Aranavalan	26. Kothamangalamkodi	3. Doddalae
4 Arimulaku	27. Kumbhakkodi	4. Giddaghere
5 Arikotta	28. Kurialmundi	5. Ghanthuvali
6 Arivally	29. Kuzhivelikodi	6. Kudhirugunda
7 Cheruvally	30. Kottiyanikodi	7. Kumpta local
8 Chettanvally	31. Maramodiyan	8. Nastigunda
9. Chankupazhuppan	32. Marankodi	9. Palulauta
10. Chumalakodi	33. Mundi	10. Shimoga local
11. Cholamalkodi	34. Natesankodi	11 Sullia local
12. Irumaniyan	35. Orumaniyan	12. South Kanara local
13. Kallubalankotta	36. Padappan	13. Sagar local
14. Kanjirakkodan	37. Oerumkarimunda	14 Vokkalgunje
15 Kaplanganmundi	38. Pirimundi	15. Vokkalu
16. Karimkodi	39. Thekkan	
17. Karimkotta	40. Thottamundi	
18. Kumbanadan	41. Uthirankkotta	
19 Kottaram	42. Vellamundi	
20. Malabar	43. Veluthakaniyakadan	
21. Malanadan	44. Velutha pirimunda	
22. Karivilanchi	45. Wayanadan	
23. Karivally	46. Yohannankodi	

2.2. Improvement

Cultivated black pepper, unlike wild *P. nigrum*, is bisexual. Clonal selection, hybridization and open pollinated progeny selection are the methods commonly used for breeding new varieties of black pepper. Black pepper is a predominantly self pollinated (geitonogamy) perennial vine propagated by stem cuttings. Pepper Research Station (Kerala Agricultural University), Panniyur (Kannur District, Kerala) as well as Indian Institute of Spices Research, Calicut are the pioneers in black pepper breeding in the country.

2.2.1. Selection

Wide variability for yield and quality characters, occasionally even within a cultivar, is common in black pepper. Clonal selection in highly popular cultivars like Karimunda and Kottanadan have resulted in identifying superior varieties such as Sreekara, Subhakara, PLD-2, etc.

2.2.2. Hybridization

Hybridization procedure involves the removal of the anther lobes of the female spike (female parent) before the emergence of the stigma with a fine needle. Usually only the upper 2/3 part of the spike is retained and the rest is removed. Emasculated spikes are covered with butter paper bag or finely perforated polythene cover. Un-dehisced anthers from the spikes of male parent are collected on the previous day evening prior to pollination and kept in a vial in a desiccator. Next day morning, the anther lobes are taken out, gently crushed, and the dehisced pollen grains are mixed with a drop of water. The pollen suspension is then applied on the stigmas of the emasculated spike with a small camel hair brush, after removing the bag/cover from the spike. The spikes are again bagged/covered after pollination. Pollination is repeated for 3-4 days. The bag/cover is retained till the development of the berries. In some varieties, where the female phase matures much earlier to the male phase (protogyny), emasculation may not be necessary and direct repeated pollinations will be sufficient to produce hybrids. Panniyur-1, the first high yielding hybrid variety of black pepper released from Pepper Research Station, Panniyur, has gained much popularity among the farming community

2.2.3. Open pollinated progeny selection

Two black pepper varieties, namely, Panniyur-2 and Panniyur-5 have been released, so far, through open pollinated progeny selection. IISR Sakthi, an open pollinated progeny of Perambramunda tolerant to foot-rot disease, has been proposed for release by IISR, Calicut. The varieties developed/released through the above strategies and their salient features are given in table 7.

2.2.4. Breeding for pest and disease resistance

Root knot nematode (*Meloidogyne incognita*) is a serious problem in some black pepper tracts and a nematode tolerant cultivar, Pournami, has been developed through germplasm selection. *Phytophthora* foot rot is another very serious disease of black pepper. Coll. 1041, a clone of Thevanmundi, is highly tolerant to foot rot disease at Valparai (Tata Tea Ltd., Tamil Nadu), a highly disease affected area. This has been proposed for release as IISR Thevam. Four accessions of cultivated black

Table 6. Improved varieties/hybrids of black pepper and their salient features

Name	Pedigree	Released from	Yield (kg/ha)	Oleo-resin (%)	Pip-erine (%)	Esen. oil (%)	Remarks
Panniyur-1	F_1 of Uthirankotta x Cheriyakaniyakadan	Pepper Research Station, Panniyur (Kerala Agriucultural University)	1242	11.8	5.3	3.5	Suited to all black pepper growing regions. Not suited to heavily shaded areas.
Panniyur-2	Open pollinated progeny selection of Balankotta	-do-	2570	10.9	6.6	3 4	Shade tolerant
Panniyur-3	F_1 of Uthirankotta x Cheriyakaniyakadan	-do-	1953	12.7	5.2	3 1	Late maturing. Suited to all black pepper growing regions.
Panniyur-4	Clonal selection from Kuthiravally	-do-	1277	9 2	4 4	2.1	Performs well under a variety of conditions. Stable yielder.
Panniyur-5	Open pollinated progeny selection of Perumkodi	-do-	1098	12.3	5 5	3 8	Tolerant to nursery diseases and shade
Panniyur-6	Clonal selection of Karimunda	-do-	2127	8 3	4.9	1 3	Suited to all black pepper tracts
Panniyur-7	Open pollinated progeny of Kalluvally	-do-	1410	10 6	5.6	1.5	Suited to all black pepper tracts.
Subhakara	Clonal selection from Karimunda	Indian Institute of Spices Research, Calicut	2352	12 4	3.4	6.0	Suited to all black pepper growing regions.
Sreekara	Clonal selection from Karimunda	-do-	2677	13.0	5.1	7 0	Suited to all black pepper growing regions
Panchami	Germplasm selection	-do-	2828	12.5	4 7	3 4	Late maturing type suited to all black pepper growing areas.
Pournami	Germplasm selection	-do-	2333	13 8	4.1	3.4	Tolerant to root knot nematode (*Meloidogyne incognita*)
PLD-2	Clonal selection from Kottanadan	Indian Institute of Spices Research, Calicut and Central Plantation Crops Research Institute, Research Centre, Palode.	2475	15.5	3.3	3 5	Suited to Thiruvananthapuram and Kollam districts of Kerala.
*IISR Thevam	Clonal selection of Thevanmundi	Indian Institute of Spices Research, Calicut	21481	8 2	1 6	3.1	Tolerant to *Phytophthora* foot rot disease. Suited to high altitudes and plains.
*IISR Malabar Excel	F_1 of Cholamundi x Panniyur-1	-do-	1440	13.5	3 0	3.2	Suited to high altitudes and rich in oleoresin
*IISR Girimunda	F_1 of Narayakodi x Neelamundi	-do-	2880	9 7	2 2	3.4	Suited to high altitudes.
*IISR Sakthi	Open pollinated progeny of Perambramundi	-do	2253	10.2	3 3	3 7	Tolerant to *Phytophthora* foot rot disease.

* Proposed for release

pepper namely, Accs. 816, 841, 1084 and 1114 are relatively resistant to *pollu* beetle and are being used in breeding programmes to develop resistant varieties.

2.2.5. Breeding for drought tolerance

Screening of germplasm against moisture stress has resulted in identifying few promising Karimunda lines namely, KS-69, KS-51 and KS-114. These drought tolerant lines are under yield evaluation at IISR, Calicut.

2.2.6. Breeding for high altitude areas

Most of the black pepper varieties are not specifically bred for high altitudes. Evaluation of 100 hybrids at Valparai at 3000 ft above MSL (Tata Tea Ltd., Tamil Nadu) led to the identification of two hybrids namely, HP-813 and HP-105, which are proposed for release as IISR Malabar Excel and IISR Girimunda, respectively. IISR Thevam is another proposed variety performing well at higher altitudes.

3.0. SOIL AND CLIMATE

3.1. Soil

Black pepper grows successfully between 20^0 North and 20^0 South of Equator and from sea level up to 1500 m above mean sea level. Black pepper plantations are established on a wide variety of soils, their texture varying from sandy loam to clayey loam. Moisture availability is a major factor that governs the suitability of establishing black pepper plantations. Well-drained deep loamy soil, rich in organic matter with good water holding capacity and pH ranging from 5 to 6 are adequate for growth of the plants. Well-drained soil with near neutral pH, high organic matter and high base saturation enhances productivity. The major black pepper growing soils in India can be broadly classified into four major orders namely, mollisols (forest loam), alfisols (red loam), oxisols (laterite), entisols (alluvium) and alfisols (red loam). Soils of high yielding black pepper gardens are generally sandy to loam textured with near neutral pH, high in exchangeable bases, organic carbon and micronutrients, especially zinc. The soil conditions ideal for plant growth and development are adequate drainage, good water holding capacity of soil, and absence of rock or hard substratum within 1 m of the soil surface.

3.2. Climate

Black pepper is crop of humid tropics requiring 2000-3000 mm rainfall with a relative humidity of 60%-95% with little variation in day length throughout the year. The black pepper growing tracts in India receives rainfall during monsoon seasons namely, South West monsoon (June to September) and North-East monsoon (October-November) and the pattern of rainfall is bimodal. The rainfall is received in 120 to 135 rainy days and the summer months are dry. The distribution of rainfall, drainage and moisture holding capacity of the soil are more important than the total quantum of rainfall. Once the flowering process sets in, there needs to be continuous though not heavy rainfall for proper fruit set. A dry spell for a few days during this critical period will result in spike shedding and reduction in yield. Though the crop comes up even in low rainfall areas, uniform distribution of rainfall is important for obtaining higher yield. Black pepper does not tolerate excessive heat and dryness. Long spells of dry periods are harmful. The crop tolerates temperature between 10°-40°C. Optimum soil temperature for root growth is 26°-28°C. A hot and humid climate is good for growth and development though continuous high humidity encourages the incidence of diseases.

4.0. NURSERY MANAGEMENT

Black pepper can be propagated through seeds and by vegetative means. Owing to its heterozygous nature, seedlings will not breed true to types. Hence black pepper is propagated vegetatively mainly from stem cuttings.

4.1. Production of planting material

4.1.1. Mother plant selection

The mother plants selected for production of planting materials should possess the following desirable attributes: regular and high yield, healthy vines free from pests and diseases and preferably 5-12 years of age.

4.1.2. Conventional method

Mother plants possessing desirable attributes mentioned above are selected during October-November. Runner shoots from these vines are kept coiled on wooden pegs fixed at the base of vines to prevent shoots from coming in contact with soil. The runner shoots are separated during February-March and 2-3 nodal cuttings of 20 cm length are made. These are planted either in nursery beds or polythene bags filled with potting mixture (made of soil, sand and farmyard manure in 1:1:1 ratio) after trimming the leaves. Dipping the lower cut end in IBA 1000 ppm solution for 45 seconds will substantially increase rooting. Sufficient holes are to be provided at the base of polythene bags to ensure good drainage. Three node cuttings should be planted by keeping one node below the soil. The cuttings after planting should be kept under shade. Light irrigation is to be provided daily to maintain a humid and cool atmosphere around the cuttings. The cuttings will strike roots and become ready for planting in May-June when 4-5 leaves are produced.

4.1.3. Rapid multiplication method

Rapid multiplication technique also called as Sri Lankan method utilizing bamboo splits is recommended for large scale production of planting materials. A suitable area having good drainage is selected and leveled. Overhead shade is provided by using 50% shade net. Coconut leaves can also be used for roofing. Trenches of 30 cm width, 45 cm depth and of convenient length are taken and filled with soil, sand and farmyard manure (1:1:1). Bamboos of 8-10 cm diameter are selected and cut into 1.25-1.50 m long pieces and split into halves keeping the septa intact. Coal tar is smeared to prolong the life of bamboo splits. The bamboo splits are arranged at an angle of 45° alternatively either side on straight wooden poles or strong supports fixed on small supports from ground and tied to each other with coir rope at the free end. Rooted cuttings are planted in the trench, one for each bamboo split.

As the cuttings start growing, the bamboo splits are filled with rooting mixture composed of farmyard manure, coir dust and sand in equal proportions. Each tender node is tied carefully to the bamboo using banana fibre, so that every node is in contact with the rooting medium. For rapid growth, daily irrigation through rose can is essential. Nutrient solution consisting of urea

(1 kg), super phosphate (0.75 kg), muriate of potash (0.5 kg) and magnesium sulphate (0.25 kg) in 250 litres of water can be applied as foliar spary for good growth. Alternatively, spraying the vines with cow dung solution 0.1% once in a month also encourages plant growth. When the vines reach the top of the bamboo, the tip is nipped off and the vine is crushed at the base of 3rd or 4th node from the ground, to activate the buds. After 7-10 days, the vine is cut at the crushed point and removed from the bamboo with the roots intact and with the adhering soil. The vine is cut into single nodded pieces and each cutting is planted in a polythene bag filled with potting mixture of soil, sand and farmyard manure (1:1:1) or mixture with solarized soil fortified with biocontrol agents or vermicompost.

After planting in the bamboo, the first harvest of cuttings can be done after 3-3½ months and the subsequent harvest at every 2-2½ months. Each rooted vine can give about 10 cuttings in one harvest and about 40 cuttings will be obtained in a year. A shed of 6 m x 24 m would accommodate 600 bamboo splits. On an average 20,000 cuttings can be produced annually by this method. The method is thus advantageous for producing a large number of rooted cuttings within a short period, throughout the year. The cuttings are also robust due to the abundance of roots leading to more than 90% establishment in the field.

4.1.4. Serpentine method

This is the best propagation technique for black pepper. Three node cuttings planted in polythene bags are kept in a corner of the nursery. When the plant develops two leaves they are trailed horizontally in polythene bags containing potting mixture kept below each tender node. Each node should be pressed into the mixture in polythene bags with 'V' shaped midribs of coconut leaves. As new shoots arise, these are to be trailed horizontally in polythene bags containing potting mixture. Once 20 nodes get rooted, the first 10 polythene bags with the rooted nodes should be separated by cutting at the inter nodes. The internodal stub should be pushed back into the potting mixture. These stubs also produce a secondary root system. Daily irrigation is to be given using a rose can. After 3 months these cuttings are ready for planting in the field. On an average, 60 cuttings can be obtained in a year by this method from each mother cutting. The serpentine method is simple, less costly, quick and can be adopted by small and marginal farmers. The recovery percentage is higher compared to rapid multiplication technique.

4.1.5. Pit method

A pit of 2 m x 1 m x 0.5 m dimension is dug in a cool, shaded area. Single node cuttings 8-10 cm long and their leaf intact, taken from runner shoots of field grown vines are planted in polythene bags of 25 cm x 15 cm (200 gauge) size. Sufficient drainage holes are to be provided at the bottom of the bag. Soil, sand and farmyard manure in equal proportion (1:1:1) are mixed and used for filling the bag. The single nodes are to be planted in the bags in such a way that leaf axil rests above the potting mixture. The bags with the planted single nodes should be arranged in the pit. Approximately 150 bags can be kept in a pit. After keeping the bags in the pit, the pit should be covered with a polythene sheet. This sheet may be secured in position by placing stones or weights on the corners. The cuttings should be watered at least five times a day with a rose can.

After two to three weeks of planting, the cuttings will start producing roots. After initiation of rooting, watering may be reduced to three to four times a day. After 1 month, shoots start emerging from the leaf axil. At this stage it is advisable to keep the pit open for about 1 hour per day so that the cutting will not suffer from any shock when they are taken out of the pit. Two months after planting, the cuttings can be taken from the pit and kept in a shaded place and watered twice a day. These cuttings will be ready for field planting after about another two and a half months. By this method, 80-85% success can be obtained.

This method is simple, less costly and quick. The cuttings are ready to be planted in the field after about 4-4½ months as compared to 6 months in bamboo method. This method is suited to small and marginal farmers. Saving of planting material is also possible since single nodes are used instead of three nodes in the conventional method.

4.2. Management of diseases and pests in the nursery

Various diseases, nematodes and insect pests occur in the nursery and affect the growth of cuttings.

4.2.1. Phytophthora *infections*

Phytophthora fungal infections are noticed on leaves, stem and roots of cuttings in the nursery. Dark spots with fimbriate margins appear on the leaves, which spread rapidly resulting in defoliation. The infections on the stem are seen as black lesions which result in blight. The symptoms appearing on the roots are rotting on the entire root system.

Spraying Bordeaux mixture 1% and drenching nursery soil with copper oxycloride 0.2% at monthly intervals prevent the disease. Alternatively, metalaxyl 0.01% or potassium phosphonate 0.3% could also be used. The potting mixture may be sterilized through solarization. To the sterilized mixture, biocontrol agents such as VAM @ 100 cc/kg of soil (containing 500 infective propagules) and *Trichoderma harzianum* @ 1g/kg of soil (containing 10^8 cfu/g) may be added at the time of filling of nursery mixture in polythene bags. *Pseudomonas fluorescence* (IISR-6) may also be added the potting mixture @ 1 g/ kg of soil (containing 10^8 cfu/g) to enhance growth of cuttings. Since the biocontrol agents protect the root system only, the aerial portion should be protected with chemicals. If Bordeaux mixture is used, care must be taken to prevent dripping of the fungicide to the soil. Alternatively, systematic fungicides such as metalaxyl and potassium phosphonate which are compatible with *T. harzianum* may be used.

4.2.2. Anthracnose

The disease is caused by the fungus *Colletotrichum glocosporioides* which infects the leaves causing yellowish brown to dark brown irregular leaf sports with a chlorotic halo. Spraying Boardaux mixture 1% alternating with carbendazim 0.1% is effective against this disease.

4.2.3 Leaf rot

The disease is caused by the fungus *Rhizoctonia solani* and is often serious during April-May when warm humid conditions prevail. The fungus infects both leaves and stems. Grey sunken spots and mycelial threads appear on the leaves and the infected leaves are attached to one another with the mycelial threads. On stems, the infection occurs as dark brown lesions which spread both upwards and downwards. The new flushes subtending the points of infection gradually droop and dry up. A prophylactic spray with Bordeaux mixture 1% prevents the disease.

4.2.4. Basal wilt

The disease is mainly noticed in nurseries during June-September and is caused by the fungus *Sclerotium rolfsii*. Grey lesions appear on stems and leaves. On the leaves white mycelial threads are seen at the advancing edges of the lesions. The mycelial threads later girdle the stem resulting in drooping of leaves beyond the point of infection and in advanced stages the rooted cuttings dry up. Small whitish to cream coloured grain like sclerotia bodies appear on the mature lesions. The disease can be controlled, if noticed early, by adopting phytosanitary measures. The affected cuttings along with defoliated leaves should be removed and destroyed. All the other cuttings should be sprayed with carbendazim 0.2% or Bordeaux mixture 1%.

4.2.5. Viral infections

Vein clearing, mosaic yellow specks, mottling and small leaf are the most obvious symptoms for identifying viral infections in the nursery. As viruses are systematic in nature and black pepper is vegetativly propagated, primary spread occurs through planting material . When infected plants are used as source of planting material, the cuttings will also be infected. Hence selection of virus-free healthy mother plants is very important. Secondary spread of the disease occurs through insect vectors such as aphids and mealybugs. Regular monitoring of the nursery for insects and spraying with dimethoate 0.05% should be restored whenever they are seen. Besides, regular inspection and removal of infected plants should also be done.

4.2.6. Nematode infestation

Root-knot nematode (*Meloidogyne incognita*) and the borrowing nematode (*Radopholus similis*) are the two important nematode species infesting rooted cuttings in the nursery. The damage caused to roots by nematodes result in poor growth, foliar yellowing and interveinal chlorosis of leaves. *R. similis* causes elongate dark brown necrotic lesions on roots at points of entry, which coalesce and result in root rotting. *M. incognita* causes elongate thick swelling on thick primary roots and typical galls or knots on secondary and fibrous roots. These galls gradually disintegrate leading to rotting of tissue.

For management of nematode infestation, the nursery mixture can be sterilized by solarization. The solarized nursery mixture may be fortified with biocontrol agents such as *Pochonia chlamydosporia* or *Trichoderma harzianum* @ 1-2g/kg of soil, the product containing 10^8 cfu/g of substrate. A prophylactic application of nematicide is also necessary to check the nematode infestation if serious. For this, three equidistant holes of 2-3 cm depth are made around the cuttings and phorate 10 G @ 1g/bag or carbofuran 3 G @ 3g/bag placed in these holes and covered with soil. A light irrigation should be given to ensure adequate soil moisture.

4.2.7. Leaf gall thrips

Leaf gall thrips infest tender leaves causing the leaf margins to curl downwards and inwards resulting in the formation of marginal, tubular, hypophyllous galls. As the infested leaves grow they become crinkled, malformed and reduced in size and may also turn chlorotic later at the margins. Spraying dimethoate 0.05% on new flushes is effective for managing the pest infestation.

4.2.8. Scale insects

The mussel scale (*Lepidosaphes saphes*) encrusts main stems and mature leaves of older cuttings resulting in chlorotic patches, yellowing and drying of leaves and mortality of cuttings. Spraying neem oil 0.3% or Neemgold 0.6% or fish oil rosin 3% twice at 21 day intervals is effective against the pest infestation. In case the infestation is severe, spraying of dimethoate 0.1% may be undertaken. *Protopulvinaia longivlvata* is observed on mature leaves of older cuttings. The pest infestation results in yellowing and wilting of affected plants and the subsequent attack by sooty mould which accelerates the deterioration of the infested plants. The pest infestation can be controlled by spraying dimethoate 0.05%

4.2.9. Mealybugs

Mealybugs such as *Planococcus* sp., *Pseudococcus* sp. and *Ferrisia virgata* infest tender shoots and leaves and cause the plants to wilt. The pest infestation can be managed by spraying dimethoate 0.05%. Colonies of root mealybug (*Planococcus* sp.) occur at the basal portion of the stem under the soil and on roots causing yellowing, wilting and mortality of cuttings. The pest infestation is generally more serious on cuttings affected with *Phytophthora* and nematodes. The pest infestation can be controlled by drenching chlorpyriphos 0.075% and also by undertaking control measures against *Phytophthora* and nematodes.

4.2.10. Gall midge

Maggots of the gall midge *Cecidomyia malabarensis* develop within tender leaf petioles, leaf veins and shoots of cuttings resulting in swelling of infested tissue. The pest infestation is more common during the monsoon season and can be controlled by spraying dimethoate 0.05%.

5.0. PLANTING AND AFTERCARE

5.1. Planting

5.1.1. Selection of site

The land that is proposed for planting black pepper should be cleared of weeds and undergrowth. In level and low lands proper drainage channels should be provided to prevent water stagnation during periods of high rainfall. Areas having 1%-3% slope are ideal for planting black pepper. Planting in slopes facing south should be avoided so that the vines are not subjected to the scorching effect of the southern sun during summer. In sloppy lands adequate soil and moisture conservation measures are to be adopted. The site should also be fenced with suitable materials to prevent entry of animals and trespassing by humans.

5.1.2. Standards

Black pepper vines require a support for its growth, development and yield. These supports are called standards. Providing ideal supports plays an important role in successful establishment of black pepper vines. Since the black pepper vine is productive for more than 15 years, selection of standards assumes great significance. The standards used for trailing black pepper vines are of two types namely, living and non-living. The non-living standards include reinforced concrete posts, granite pillars and teak poles. Such non-living standards are more commonly used in Malaysia, Brazil and Indonesia where climatic conditions are cooler and cloudy. However, owing to the high capital investment and also due to their relative non-availability, they are not very popular in India. Moreover, some of the non-living standards like concrete poles get heated up during prolonged summer period under Indian conditions resulting in drying of clinging roots and, therefore, resulting in poor crop growth under exposed situations. The ideal living support should have the following traits :

a. It should establish easily and grow rapidly to provide shade and support for the establishment of the crop
b. It should tolerate regular and heavy pollarding/pruning
c. It should not compete for resources and should not harbour pests and pathogens
d. It should have a deep root system without being allelopathic in the black pepper rhizosphere
e. It should have rough bark and be strong enough to support the clinging roots of black pepper vine
f. It should provide useful products at the end of the pepper cropping cycle

A variety of trees are used as living standards for black pepper cultivation in India. In homesteads gardens in Kerala, black pepper is usually trained on arecanut and coconut and also on mango, jack, etc. When intercropped in cardamom and coffee plantations, especially in Kodagu and Chickmagalur districts in Karnataka and Idukki and Wyanad districts in Kerala, black pepper is trailed on various forest trees that provide shade. It is cultivated both as a pure and mixed crop along with arecanut in the plains of Uttar and Dakshin Kannada districts in Karnataka. In Andhra Pradesh, which is a newly emerging black pepper growing region of India, the vines are trailed on coconut and oil palm. In north-eastern states especially Assam, most of the homestead gardens have arecanut palms where black pepper vines can be trailed.

However, such standards are not ideal to establish large plantations under organized cultivation as monocrop at a normal spacing of 2.5 x 2.5 m. Therefore, on a plantation scale, *Erythrina indica* is the common live standard planted for trailing black pepper especially in Kerala. Other common standards used are *Garuga pinnata*, *Gliricidia sepium*, *Leucaena leucocephala*, *Ailanthus malabarica* and *Grevillea robusta*.

For raising living standards, seedlings are preferred to rooted cuttings since seedlings have a tap root system and do not compete with black pepper for resources. Living standards should be planted 3-4 years in advance so as to attain sufficient height at the time of planting of black pepper. In case stems/stem cuttings of *E. indica*, *G. sepium* or *G. pinnata* are used, they are to be cut to suitable lengths during March-April and stacked in shade. The stacked stems start sprouting in May. After the first rain in May-

June the sprouted stems are planted at the edge of the pits dug for planting black pepper vines. The cuttings of standards are to be planted in narrow holes of 40 to 50 cm depth. The soil should be well pressed around the standards to avoid air pockets and keep the standards firm in the soil.

After establishment, the side branches are pruned to enable the standard to grow erect. After complete establishment, periodical pruning is important to allow sufficient light penetration into the black pepper canopy. Normally pruning of live standards has to be carried out one week prior to fertilizer application. At the beginning of rainy season, heavy pruning is done, leaving only one or two twigs at the top of the trees, while at the end of the rainy season a moderate pruning is carried out, leaving three or four twigs at the top of support trees. Shade regulation by pruning branches of standards in black pepper gardens is an important cultural practice to allow sufficient light for crop growth and productivity and also to reduce the incidence of diseases. Whenever, *E. indica* is planted as standard, application of phorate 10 G @ 10 g may be done twice a year during May-June and September-October to control nematodes and stem and root borer. In case *G. sepium* is planted, the base of the standard is to be observed periodically for infestation by sapling borer which may be controlled by removing the frass and injecting quinalphos 0.1% into the bore hole and plugging the opening with clay.

5.1.3. *Spacing*

Spacing of black pepper vines varies considerably and depends on the spacing at which the standards are planted. Under monocropping system the optimum spacing is 3 m x 3 m, which can accommodate 1100 standards/ha whereas in sloppy land 3 m x 2 m spacing is recommended. When non-living standards are used, much closer spacing (1.5 m x 2.0 m) is recommended.

5.1.4. *Planting*

Pits of 50 cm x 50 cm x 50 cm at a distance of 30 cm away from the base of supporting tree are taken with the onset of monsoon. The pits are filled with a mixture of topsoil, farmyard manure @ 5 kg/pit and 150 g rock phosphate. Neem cake @ 1 kg and *Trichoderma harzianum* @ 50 g may be mixed in the pit at the time of planting. Two rooted cuttings are planted individually in the pits on the northern side of each standard. At least one node of the cutting should be planted below the soil for proper anchorage.

5.2. Aftercare

5.2.1. *Training*

Training is an essential step for establishment of black pepper vines. As the cuttings grow, the shoots are to be tied to the standards regularly using suitable materials for anchorage. For the production of leader shoots from the nodes, the vines are to be lowered into the soil during the first year after planting. In this method, the leaves are removed from vines after they attain a height of 1 m and they are brought down and 3/4th of the basal portion is buried around the standard and covered with good top soil. This induces a good root system and also helps in production of more leader shoots from the nodes. Three to five leader shoots are enough to produce sufficient laterals and to form a full canopy around the trunk of the standard.

5.2.2. Shading

The young vines should be protected from hot sun during summer especially in open areas by providing shade. The young vines are to be covered with dry arecanut or coconut leaves or twigs of trees during summer which should be removed with the onset of rains.

5.2.3. Mulching

Mulching increases infiltration of water, conserves moisture, regulates temperature, decreases evaporation, suppresses weed growth, enhances microbial activity and also improves soil fertility. Mulching around the basins of black pepper vines with organic materials especially green leaves @10 kg/ vine to a radius of 1 m is required at the end of North-East monsoon. Mulching should be repeated once the applied mulch is decomposed. Live mulch (cover crops) such as *Calapagonium mucanoids* and *Mimosa invisa* can also be grown to provide soil cover and to prevent soil erosion. These cover crops are to be cut back regularly from the base to prevent them from twining along with black pepper vines.

5.2.4. Irrigation

Moisture requirement of black pepper vines vary with stages of crop growth. Moisture stress is one of the most serious constraints affecting the productivity of black pepper. Blossoming, spiking, flowering, spike elongation and setting are the sensitive periods for black pepper. Following summer, the first 16 weeks could be considered as critical period for shoot growth, flower bud differentiation, spike emergence, flower opening and fertilization, berry formation and development. Spike development ceases if there is a prolonged dry spell immediately after good summer showers. A high correlation between rainfall received during second half of May (responsible for spike formation) and June and setting of black pepper berries has been observed. Irrigating black pepper vines @ 100 litres per vine (hose irrigation) once a week during summer is recommended. The water is to be applied in basins taken around the plants at a radius of 75 cm. In case drip irrigation is adopted, 7 litres of water per day through drip during October to May is recommended.

5.2.5. Weeding

Weeds are a major problem in black pepper plantations that are not maintained properly. The weeds growing in the basins *remove considerable quantities of moisture* and nutrients and should be removed. Digging around the standards and vines 1 m away from the base, twice during the year, during the onset of South-West monsoon and towards the end of North-East monsoon prevents weed growth and conserves moisture. Cover crops like C. *mucunoides* and *M. invisa* can also be grown not only to prevent soil erosion during rainy season but also to control weeds.

5.2.6. Multiple cropping

Multiple cropping is the practice of growing two or more crops in the same field simultaneously. A systematically planted black pepper garden would provide adequate interspace for cultivation of other crops especially during the pre-bearing period because of the negligible shade effect by the vines. The factors that assume significance in multiple cropping are probable competition for nutrients, moisture and sunlight between black pepper and other crops and its effect on black pepper yield. The goal of intercropping is to produce a higher yield on a given piece of land, by making use of the space that would otherwise be wasted with a single crop. However, careful planning is required before selection of crops, taking into account the soil, climate and crops and it important not have crops competing with each other for space, nutrients, water or sunlight.

Black pepper roots extend up to about 90 cm from the base and so ample space is available for multiple cropping without affecting black pepper. In black pepper gardens receiving well-distributed mean rainfall of not less than 1500 mm/year, the competition for soil moisture is less and in such areas multiple cropping is feasible. In any multiple cropping programme, competition for soil nutrients such as N, K, Ca and Mg is a potential danger and inadequate manuring will adversely affect the yield of black pepper vines. Growing Congo-signal grass (*Brachiaria muziziensis*) and manuring with NPK fertilizers at the rate of 50 kg/ha in the interspaces in a black pepper garden, where the plants are spaced at 2.7 m x 2.7 m, will increase the physico chemical properties and fertility of the soil besides yield of black pepper. It will also increase the organic matter and nutrient status of soil, reduces soil erosion, bulk density, soil temperature and aluminum toxicity. Growing banana cv. Mysore Poovan as an intercrop during the initial 3 years, in between rows of black pepper spaced at 2.7 m x 2.7 m, and fertilizing at the recommended dose of NPK increases the growth and establishment of black pepper, enhances soil productivity and reduces ambient temperature in the plantations.

Multiple cropping in black pepper gardens is a routine practice in Kerala and parts of Karnataka. A variety of crops are grown along with black pepper, such as elephant foot yam, colacasia, ginger , turmeric, perennial fodder grass, vanilla and banana. At higher altitudes, black pepper is grown along with coffee, cardamom and tea. Black pepper is also trailed on coconut and arecanut palms in most of the areas. In these cases the rooted black pepper plants are planted away from the base of palms and as and when the vines grow, they are trailed along the ground and then trailed on to the trunk of coconut or arecanut palms. The varieties Sreekara, Subhakara and Panniyur-5 perform well as intercrops in coconut and arecanut gardens. Multiple cropping with black pepper as one of the component crops also offers immense scope in north-eastern states.

6.0. MANURING

6.1. *Nutrient requirement*

Nitrogen, phosphorus, potassium, magnesium and micro nutrients are the most important nutrients for growth, development and yield of black pepper and their influence depend on their ratios in the soil as well as in the plant. Studies on nutrient uptake by adult (8 years old) Panniyur-1 vines conducted at IISR, Calicut, indicated that it removes 292, 56 and 405 kg/ha of N, P and K, respectively, per year, whereas by cv. Karimunda it is 183, 49 and 376 kg/ha of N, P and K, respectively, per year.

The availability of phosphorus depends on the dynamics of phosphorus fixation in the soil and uptake by the plant and in the process, soil pH and organic matter content play a vital role. Bone meal and mussoorie rock phosphate are better phosphorous sources in acid soil for the black pepper varieties Panniyur-1 and Karimunda than super phosphate for obtaining higher yields. Black pepper vines require large quantities of potassium for growth and fruiting. A soil fertility survey carried out in major black pepper growing tracts of Kerala and Karnataka indicated that 10% of the gardens surveyed were low, 31% medium and 59% high in available potassium status. Among the sources, potassium sulphate has a positive influence on quality (oleoresin 13.5% and piperine 6.1%) of black pepper berries. The response to application of lime to black pepper is noticed mainly due to correction of soil acidity and positive effects of calcium and magnesium (50 kg/ha each) application.

Among the micronutrients, the most important for black pepper nutrition are zinc, molybdenum and boron and acid soils are most likely to be deficient in these nutrients due to leaching or precipitation. Molybdenum content increases absorption of organic matter as it forms a complex which makes it more available to the plants for absorption. Boron deficiency is normally seen in coarse-textured soils low in organic content especially in high rainfall areas. Studies carried out at IISR, Calicut, showed that application of NPK at 150:60:270 kg ha^{-1} with micronutrients Zn, B and Mo at 5:2:1 kg ha^{-1} resulted in highest yield in var. Subhakara and Sreekara. Foliar application of zinc sulphate 0.25% was on par with soil application in increasing the yield of black pepper. Black pepper was also found to respond to molybdenum application under deficient conditions.

The fertilizer recommendations for black pepper growing regions in India is given in table 7.

During the first year of planting, one third of fertilizers, second year two thirds of fertilizers and third year onwards recommended full quantity of fertilizers may be given to the plant. The quantity may be given in equal halves, one half during May-June and the other during September-October. Sufficient moisture should be ensured in the soil at the time of fertilizer application. The fertilizers are to be applied at a distance of about 30 cm all around the plant and covered with a thick layer of soil.

Table 7. Fertilizer recommendations for black pepper growing regions in India

Location	Quantity per mature plant
Panniyur Region (Kerala)	Urea 180 g, rock phosphate 275 g or super phosphate 400 g, muriate of potash 110 g.
Kozhikode Region (Kerala)	Urea 198 g, rock phosphate 303 g or super phosphate 550 g, muriate of potash 308 g.
Karnataka and Tamil Nadu	Urea 144 g, rock phosphate 220 g or super phosphate 280 g, muriate of potash 220 g.
Assam and other north-eastern regions	Urea 220 g, rock phosphate 220 g or super phosphate 250 g, muriate of potash 230 g.

Care should be taken to avoid direct contact of fertilizers with roots of black pepper. Organic manures in the form of farmyard manure or compost @ 10 kg/vine and neem cake @ 1 kg/vine can be applied during May-June.

6.1.1. *Integrated nutrient management*

Integrated nutrient management involving application of NPK fertilizers and organics like farmyard manure, compost and green leaves enhances soil fertility. Higher yields of black pepper have been obtained due to application of *Azospirillum* and chemical fertilizers in addition to farmyard manure. Studies conducted at IISR, Calicut, indicated that manuring black pepper vines @ 10 kg cattle manure or compost or green leaves/ vine along with NPK @ 50:50:150 g/vine/ year and liming @ 500 g/vine during alternate years during April-May resulted in higher yields. Application of coir pith compost @ 1.25 t/ha integrated with half the recommended fertilizer dose and *Azospirillum* sp. @ 20 g/vine also resulted in higher yield and fertility build up in black pepper gardens.

6.1.2. *Fertilizer use efficiency*

Slow release fertilizers are useful to minimize fertilizer losses by leaching and will supply the nutrients for a longer duration resulting in increased yields. Application of slow release formulations such as neem oil coated urea increases ammoniacal N and total N in the soil and the yield of black pepper vines. Addition of organic matter increases the use efficacy of applied nutrients by improving the soil buffering capacity, soil structure and health. Addition of nutrients without effecting a change in the pH of the soil towards optimum would not give any worthwhile results. Liming will eliminate adverse effects of exchangeable aluminium and iron by correcting the pH and provides better nutrient availability for growth and performance. Direct addition of rock phosphate @ 80 kg P_2O_5 /vine/year is as efficient as super phosphate for var. Panniyur-1 and Karimunda with respect to soil P availability, yield response and relative agronomy efficiency.

Method and time of fertilizer application considering factors like crop growth stage, nutrient requirements, soil conditions, and nature of fertilizers influence the crops response to fertilizers. Some phosphate fertilizers, like rock phosphate can be directly applied in acid soils to meet phosphorous requirement. Better utilization efficiency of applied nitrogen can be achieved by supplying at the time when crop needs it. Potassium uptake by black pepper is more or less continuous throughout the different stages of growth. In order to minimize leaching loss, split application is generally recommended as black pepper is raised as a rainfed crop in heavy rainfall areas.

6.1.3. *Organic manure*

Several kinds of organic manures like farmyard manure, compost, poultry manure and organic cakes like neem and groundnut cakes are used by farmers in India. The organic ions released by the decomposition of organic matter forms complex with Fe and Al, thereby preventing P fixation and making more P available to the plant. The organic ions/acids also form chelates with the micronutrient cations Zn and Cu, thereby making them available to the crop. Addition of organic matter also promotes growth of beneficial microbes and reduces the population of pathogenic organisms leading to reduced disease incidence. Experiments conducted with different organic composts at IISR, Calicut, showed that application of organics increased pH to neutrality, improved the fertility status of the soil by significantly increasing the availability of major, secondary and micronutrients and build up of microbial population. For nutritional management under organic farming, a judicious application of a combination of organic manures such as farmyard manure @ 5 kg/vine, neemcake @ 1 kg/vine and vermicompost @ 1 kg/vine per year can be made during May-June. Biofertilizers such as phosphobacteria and *Azotobactor* can also be applied @ 100 g/vine mixed with farmyard manure.

7.0. DISEASES AND THEIR MANAGEMENT

The major diseases affecting black pepper vines in the field are *Phytophthora* foot rot, stunted disease, spike shedding due to anthracnose and *pollu* disease. Phyllody disease is also seen in some areas.

7.1. *Phytophthora* foot rot

Phytophthora foot rot caused by *Phytophthora capsici* is the most serious disease affecting black pepper and occurs mainly during the south-west monsoon season. Crop loss surveys conducted in Kerala indicated that the disease caused vine death to the extent of 3.7% in Kozhikode District leading to yield loss of 119.6 tonnes and 9.4% death leading to yield loss of 904.9 tonnes in Kannur District annually. In small holdings the crop loss could also be total as entire plantations succumb to *Phytophthora* infections in a single season.

7.1.1. Symptoms

The pathogen *P. capsici* infects all parts of the vine and the expression of symptoms depends up on the site of infection and extent of damage. On tender leaves dark coloured spots appear with characteristic fimbriate advancing margins. When the conditions are ideal the lesion spreads on the entire lamina within a few hours resulting in defoliation. The succulent shoot tips of freshly emerging runner shoots trailing on the soil turn black when infected. Spike infection occurs on any part of the spike resulting in blackening and shedding of spikes. Infection on a branch results in die-back of affected branches. Infection on the runner shoot sometimes times reaches the collar and causes sudden wilting followed by shedding of leaves and spikes. The branches break up at nodes and the entire vine collapses within a month. Infection on the collar through the roots of upper tier of roots closer to soil surface also leads to sudden wilting of vines. If the damage is confined to feeder roots, the expression of symptoms is delayed till the cessation of rain and the vine starts showing declining symptoms such as yellowing, wilting, defoliation and drying up of a part of the vine during October-November onwards. These vines may recover after the rains and survive for more than two seasons till the root infection culminates in collar rot and death of the vine.

7.1.2. Epidemiology

Vines of all age groups are susceptible to the disease. Often the inoculum is introduced along with planting material from the nursery to the plantations. The aerial spread of the disease is mainly though rain splashes.

Phytophthora foot rot occurs at random in plantations in the beginning and secondary spread is clustered around previously infected vines. The fungus survives in the form of thickened mycelium and chlamydospores for over 18 months and soil population build up is correlated with soil moisture. For the aerial phase of the disease, there is a positive correlation between rainfall, number of rainy days and relative humidity but negative correlation with temperature and sunshine hours. While the aerial spread is rapid, spread of the soil phase of the disease in the field is slow.

7.1.3. Management

An integrated management strategy involving cultural practices, chemical and biological control and use of resistant variety has been developed for the management of the disease.

Cultural Control : Phytosanitory measures such as removal and destruction of affected vines to reduce the initial inoculum in the field plays a crucial role in disease management. Shade regulation by lopping of branches of support trees during the monsoon season ensures reduction in humidity build up within the canopy of black pepper vines and results in reduction in the severity of aerial infection.

Biological Control : Application of antagonistic micro organisms such as *Trichoderma harzianum* and *Pseudomonas fluorescens* would help in reducing the intensity of the disease. *T. harzianum* is to be applied at the onset of the monsoon during May around the base of the vine @ 50 g /vine (containing 10^8 cfu/g of formulation). A second application of *T. harzianum* has to be done during August-September. *P. fluorescens* @ 50 g/vine (10^8 cfu /g of formulation) may also be applied be along with *T. harzianum*. Addition of organic mulches and oil cakes in the basins improves the texture of the soil and enhances the growth of antagonistic microorganisms.

Chemical Control : Any one of the following chemical control measures can be adopted.

After the receipt of a few monsoon showers (May-June), all the vines are to be drenched at a radius of 45-50 cm with copper oxychloride 0.2% @ 5-10 litres/vine. A foliar spray with Bordeaux mixture 1% is also to be given. Drenching and spraying are to be repeated once again during August-September. A third round of drenching may be given during October if the monsoon is prolonged.

After the receipt of a few monsoon showers, all the vines are to be drenched with potassium phosphonate 0.3% @ 5-10 litres/vine. A foliar spray with potassium phosphonate 0.03% is also to be given. A second drenching and spraying with potassium phosphonate 0.03% is to be repeated during August-September. If the monsoon is prolonged, a third round of drenching may be given during October.

After the receipt of a few monsoon showers, all the vines are to be drenched with metalaxyl mancozeb 0.125% @ 5-10 litres/vine. A foliar spray with metalaxyl mancozeb 0.125% may also be given.

In case biocontrol agents are applied, only aeraial sprays with the chemicals is to be resorted and soil drenching should be avoided.

Resistant Variety : Among several lines

tested from the germplasm collections of Indian Institute of Spices Research, Calicut, one of the lines which was promising has been recommended for release as IISR-Shakthi.

7.2. Stunted disease

Stunted disease caused by viruses is becoming increasingly important in recent years in black pepper growing areas especially at high altitudes because of their systemic nature, widespread occurrence and difficulty in control.

7.2.1. Symptoms

A wide range of symptoms are observed on stunted disease infected vines. The symptoms on leaves include vein clearing, yellow specks, distortion, reduction in size, mottling and mosaic, along with stunting of the whole plant. The infected vines produce short spikes with poor filling leading to yield reduction. In severe cases, the leaves become abnormally narrow and give a sickle shaped appearance. The internodes of vines become abnormally short leading to stunting of plants and the affected branches give a typical witches broom appearance in advanced stages. However, though external symptoms are good criteria for detection of the disease, sometimes, the disease symptoms are difficult to identify visually, especially in early stages. Hence ELISA and PCR based methods which are available are the best methods for the timely detection of CMV and PYMV infections in plants.

7.2.2 Causal viruses and transmission

Two viruses are associated with stunted disease affected vines namely, *Piper yellow mottle virus* PYMV (Badnavirus) and *Cucumber mosaic virus* CMV (Cucumovirus) in India. The major means of spread of the viruses is through use of infected stem cuttings. In general, CMV is known to have a very wide host range infecting several plant species and spread in nature through aphids in a non-persistent manner. On the other hand, badnaviruses are known to have a narrow host range and spread in nature through mealybugs.

7.2.3. Management

Since black pepper is vegetatively propagated, infected planting materials are the major mode of disease spread. Adequate care should also be taken to plant healthy virus-free cuttings especially in new areas where the incidence of the disease is not observed in the field.

Production Of Virus-Free Planting Material : The most viable method to control the disease would be identification and use of virus-free cuttings for planting. Once a good virus-free plant is identified, they must be maintained virus-free under insect-proof conditions. Cuttings or tissue culture raised plants obtained from these virus-free stocks are then grown up on a sufficiently large scale under insect-proof conditions.

Rouging Of Infected Plants : Regular inspection and removal of infected plants and replanting with healthy plants should be resorted to in the field. Other potential weed and crop hosts, which might act as reservoirs for the virus need to be removed. The removed plants may be burnt or buried deep in the soil.

Control Of Vectors : Insect vectors such as aphids and mealybugs on the plant or standards should be controlled with insecticide spray such as dimethoate 0.05%.

Because of the closed placing of seedlings in the nursery, chances of spread of mealybugs are more in the nursery and hence regular monitoring of the nursery for mealybugs is important.

7.3. Spike shedding

Spike shedding is a major problem in high yielding varieties like Panniyur -1 when cultivated at higher elevations. The malady is because of two reasons; absence of bisexual flowers resulting in low fruit-set and/or infection by the fungus *Colletotrichum gloeosporioides*. The incidence is more pronounced when the emergence of spikes is delayed due to delayed monsoon and flowering occurs during June-July. These spikes predominantly produce female flowers instead of bisexual flowers. The symptoms of fungal infection include appearance of small dark coloured spots surrounded by a halo on the leaves. In serious infections, the expansion of lamina is affected resulting in crinkled appearance. Infection on spikes results in spike shedding whereas infection on immature berries leads to formation of brownish split on the seeds due to unequal development.

7.3.1. Management

The disease can be managed by adopting an integrated strategy, including irrigation of black pepper vines 4-5 times at an interval of 5-7 days @ 40-50 litres/plant commencing from the third week of March, followed by shade regulation of support trees to provide minimum 7,500-10,000 lux light under cloudy condition and with the prophylactic spray of Bordeaux mixture 1% or carbendazim 0.2%.

7.4. *Pollu* disease

This disease is caused by *Colletotrichum gloeosporioides* and can be distinguished from the *pollu* (hollow berry) caused by the beetle by the presence of characteristic cracks on the infected berries. The disease appears towards the end of the monsoon. The affected berries show brown sunken patches during early stages and their further development is affected. In later stages, the discolouration gradually increases and the berries show the characteristic cross splitting. Finally, the berries turn back and dry. The fungus also causes angular to irregular brownish lesions with a chlorotic halo on the leaves.

7.4.1. Management

The disease can be controlled by spraying Bordeaux moisture 1%.

7.5. Phyllody disease

This disease is caused by phytoplasma belonging to aster yellows group. The disease is noticed in parts of Wyanad and Kozhikode districts of Kerala. The affected vines exhibit varying stages of malformation of spikes. Some of the floral buds are transformed into narrow leaf like structures. Such malformed spikes show leafy structures instead of floral buds, exhibiting phyllody symptoms. In advanced stages, the leaves become small and chlorotic, and the inter nodes are also shortened. The effected fruiting laterals give a witches broom appearance. Severely affected vines become unproductive. In severely affected vines, the entire spike is converted into small branches which appear chlorotic and the vines decline rapidly. The infected vine becomes unproductive within 2 to 3 years.

7.5.1. Management

The infected vines are to be destroyed to prevent the further spread of the disease.

8.0. INSECT AND NEMATODE PESTS AND THEIR MANAGEMENT

Among the plant parasitic nematodes infesting black pepper, the burrowing nematode and root knot nematode, causing slow decline are important. Among the insect pests, *pollu* beetle, mussel scale and coconut scale, top shoot borer and leaf gall thrips can be considered as major insect pests. Apart from these insects, scale insects, mealy bugs, gall midges and leaf feeding caterpillars also damage the crop in certain areas and could be considered as minor pests.

8.1. Slow decline

Slow decline occurs due to feeder root damage by burrowing nematode *Radopholus similis* and root knot nematode *Meloidogyne incognita* and also the fungal pathogen *P. capsici* either alone or in combination. Surveys conducted in major black pepper areas in Kerala and Karnataka indicated that *M. incognita* and *R. similis* were distributed in over 70% of gardens either alone or together.

8.1.1. Symptoms

The symptoms of the disease include yellowing of leaves, defoliation, die back and loss of vigour and productivity, leading to death of the vine. The diseased vines generally exhibit foliar yellowing from October onwards coinciding with depletion of soil moisture. With onset of south west monsoon during May-June, some of the affected vines recover and put forth fresh foliage. However the symptoms reappear during the subsequent season after the cessation of the monsoon and the vines succumb during the course of 2 to 3 years. The affected vines exhibit varying degrees of root degeneration due to infestation by plant parasitic nematodes. *R. similis* causes elongated dark brown necrotic lesions on roots at points of entry, which coalesce and result in root rotting. *M. incognita* causes elongated thick swellings on thick primary roots and typical galls or knots on secondary and fibrous roots. These galls gradually disintegrate leading to rotting of tissues. Black pepper vines of all ages are susceptible to the nematodes and they are passively distributed through planting material (rooted cuttings). Most of the nurseries harbour nematodes since they provide congenial conditions for their multiplication.

8.1.2. Management

An integrated management strategy is effective for the management of the disease.

Cultural control : Nematode and *P. capsici*-free rooted cuttings raised in fumigated or solarized nursery mixture should be used for planting in the field. Severely affected vines which are beyond recovery should be removed from the field along with the entire root system and destroyed.

Biological control : Bio control agents like *Pochonia chlamydosporia* or *Trichoderma harzianum* can be applied @ 50 g/ vine (containing 10^8 cfu/g of formulation) twice a year (during April-May and September-October).

Chemical control : The planting pits should be treated with phorate 10 G @ 15 g or carbofuran 3G @ 50 g at the time of planting. Phorate 10 G @ 30 g or carbofuran 3 G @ 100 g/vine should be applied during May-June (with onset of south west monsoon) and September–October. Along with phorate the basins should be drenched with either copper oxychloride 0.2% or potassium phosphonate 0.3% or metalaxyl 0.125%. *While applying nematicides, the* soil should be raked lightly in the basin of the vine without causing damage to the root system and the nematicide should be spread uniformly in the basin and covered with soil immediately. Sufficient soil moisture should be ensured at the time of nematicide application.

Resistant variety : In areas severally infested with root knot nematodes, cuttings of the resistant variety Pournami may be planted.

8.2. *Pollu* beetle

The *pollu* beetle (*Longitarsus nigripennis*) is the most destructive insect pest of black pepper and the pest infestation is generally higher in the plains and midlands below 300 m MSL. The pest infestation is generally higher in shaded areas in the plantation. In endemic areas around 30% of the crop is lost due to the pest infestation.

8.2.1. Damage

The adult *pollu* beetle feeds on tender shoots, leaves and spikes of black pepper vines resulting in black patches on tender shoots and spikes and small irregular circular holes on tender leaves. Severely infested leaves and spikes often rot and drop due to invasion of secondary microorganisms. The damage caused by the larva (grub) is more serious and it bores into tender spikes and berries and feeds on the internal contents. The infested spikes develop necrotic patches and the berries turn black and crumble when pressed (the hollow nature of the infested berries is termed as *pollu* in Malayalam).

8.2.2. Bioecology

The adult *pollu* beetle measures about 2.5 mm x 1.5 mm in size, the head and thorax being yellowish brown and the abdomen brown; the elytra (fore wings) is black. The eggs are laid on the rind of tender berries either singly or in groups of 2-3. Sometimes the eggs are also laid on tender shoots and spikes. The eggs are oval and yellow when freshly laid and measure about 0.75 mm in size. The eggs hatch into creamy white grubs in 3-8 days. There are three larval instars lasting for 20-40 days. Fully-grown larvae are creamy yellow and 5.5 mm in length. The pupa is about 3.0 mm x 1.5 mm in size and the pupal period lasts for 6-8 days. Pupation occurs in the soil in earthen cocoons.

The population of adults is seen on black pepper vines throughout the year and is generally higher during September-October. Egg laying occurs during June to October when the berries are tender. The adults are seen in reduced numbers during November to May and they survive by feeding on older leaves. With the onset of pre monsoon showers during May, the adults begin to feed on tender leaves and spikes and resume their breeding activities. No alternate host of the pest has been recorded.

8.2.3. Management

An integrated strategy involving regulation of shade in the plantation by lopping of branches of shade and support trees with the onset of pre monsoon showers and spraying endosulfan 0.05% or quinalphos 0.05% during July and October or spraying endosulfan 0.05% during July followed by 3-4 sprays (at 21 day intervals) of neem-based insecticide such as Neemgold 0.6% during August-October, is effective for controlling the pest infestation. The undersides of leaves are to be sprayed thoroughly where the adults are generally seen.

8.3. Scale insects

Scale insects are major insect pests of black pepper at higher altitudes. Among the various species of scale insects recorded on the crop, mussel scale (*Lepidosaphes piperis*) and coconut scale (*Aspidiotus destructor*) are the most common species and the pest infestation is higher at higher altitudes in Kerala, Karnataka and Tamil Nadu.

8.3.1. Damage

The mussel scale encrusts main stems, lateral branches, mature leaves and berries of black pepper vines resulting in chlorotic patches, yellowing and drying of leaves. Younger vines often succumb to the pest during the course of 1-2 years when the infestation occurs on the main stem. On older vines the infested lateral branches wilt and dry resulting in vacant spaces in the canopy. Infestations of mussel scale are also observed on older cuttings in the nursery especially in the plains. Coconut scales infest mature leaves resulting in chlorotic patches on them and sometimes also infest berries.

8.3.2. Bioecology

Adult females of *L. piperis* are elongated and dark brown measuring 3-4 mm in length. The eggs are white and the I and II larval stages last for 9-12 and 9-10 days, respectively. In males, the prepupal and pupal stages last for 2-3 days each. Adult females of *A. destructor* are circular and light yellow measuring 1.5-2.0 mm in diameter. The eggs are creamy yellow and the I and II larval stages last for 6-7 and 4-5 days, respectively. Males are weak bodied with a pair of wings and do not live long and die after mating. Both the species also reproduce parthenogenetically.

L. piperis is observed in the field throughout the year but its population is higher during February-May with a peak population during April. Summer period is generally favourable for the build up of pest population and the onset of the monsoon results in a drastic decline in their population. *A. destructor* is also observed in the field throughout the year, but its population is higher during the post monsoon and early summer months (September-March) with a peak population during September.

A. destructor is highly polyphagous and has been known to infest more than 20 economically important plants in India. *L. piperis* occasionally infest cassava (*Manihot esculenta*) stems in the field and storage. Various natural enemies such as predatory mites, thrips, mirids, coleopterans and hymenopterous parasitoids have been recorded on *L. piperis* and *A. destructor* among which, *Aphytis* sp. (Aphelinidae), *Pseudoscymnus* sp. and *Chilocorus circumdatus* (Coccinellide) are more common.

8.3.3. Management

Clipping of severely infested braches and spraying dimethoate 0.1% is effective against *L. piperis* when sprayed twice at 21-30 day intervals during January/February. The pest infestation is easier to control at the initial stages of infestation. Infestation of *A. destructor* is generally kept under check by various natural enemies observed in the field. However, spraying dimethoate 0.05% may be resorted to in case the infestation is serious.

8.4. Top shoot borer

The top shoot borer (*Cydia hemidoxa*) is a serious insect pest black of black pepper in younger plantations (1-3 years old) and is widely distributed in the plains and higher altitudes.

8.4.1. Damage

The larvae of top shoot borer infest tender terminal shoots that climb on the standards. The earlier instar larvae scrape and feed on the epidermis of tender terminal shoots and sometimes on tender leaves, whereas the later instar larvae bore into tender shoots and feed on the internal contents resulting in decay and drying of infested shoots. The growth of the vine and also the establishment of newly planted vines are affected due to repeated infestation of tender terminal shoots.

8.4.2. Bioecology

The adults are small moths with crimson red and yellow fore wings and grey hind wings and with a wing span of 10-15 mm. The adults are generally observed under the foliage of black pepper vines. Eggs are yet to be observed in the field. There are five larval instars. Fully-grown larvae are greyish green and measure 12-14 mm in length. The larval period lasts for about 14 days. Pupation generally occurs either within the infested shoot or just outside it. The pupae are elongated and measure about 2 mm in length; the pupal period lasts for 8-10 days.

The pest infestation on tender terminal shoots is observed in the field throughout the year. However, it is higher during the monsoon and post monsoon periods (August-December) when younger vines actively grow and numerous succulent shoots are available on them.

Among the natural enemies recorded on top shoot borer, *Hexamermis* sp. (Mermithidae) and *Apanteles cypris* (Braconidae) are more common during the monsoon period (June-September) and post monsoon period (September-November), respectively.

8.4.3. Management

Spraying endosulfan 0.05% or quinalphos 0.05% twice a year during June and September is effective for the management of the pest.

8.5. Leaf gall thrips

Leaf gall thrips (*Liothrips karnyi*) are serious insect pests of black pepper on younger vines at higher altitudes and also on rooted cuttings in nurseries in the plains, in Kerala, Karnataka and Tamil Nadu.

8.5.1. Damage

Leaf gall thrips infest tender leaves causing the leaf margins to curl downwards and inwards resulting in the formation of marginal, tubular, hypophyllous galls. As the infested leaves grow they become crinkled, malformed and reduced in size and may also turn chlorotic later at the margins. The growth of younger vines and rooted cuttings in the nursery are affected in severe cases of infestation. Serious infestations on older vines affect the formation and development of spikes.

8.5.2. Bioecology

The adults are black with the distal segments of the antenna and legs light lemon yellow, and measure 2.5-3.0 mm in length; the larva the pupae are creamy white. The creamy white eggs are laid within the leaf galls in small clusters and they hatch in 6-8 days. The two larval stages, pre-pupal stage and two pupal stages last for 4-7, 4-7, 2, 2-3 and 2-3 days, respectively.

Leaf gall thrips initially infest tender leaves and remain in them till the leaves become mature. The pest population is higher in the field during monsoon period June-September when numerous tender leaves are produced on the vines.

A few predators have been recorded on leaf gall thrips in the field among which *Montandoniola moraguesi* (Anthocordiae) and *Andothrips flavipes* (Phlaeothripidae) are more common and widely distributed. Both these species are voracious feeders on all the stages of the pest.

8.5.3. Management

Spraying dimethoate 0.05% during emergence of new flushes may be undertaken on younger vines and in nurseries for managing the pest infestation.

8.6. Mealybugs

Mealybugs such as *Planococcus* spp., *Pseudococcus* spp. and *Ferrisia virgata* infest tender shoots and leaves especially on rooted cuttings in the nursery and cause the plants to wilt. The pest infestation can be managed by spraying dimethoate 0.05%. Colonies of root mealybug (*Planococcus* sp.) are also observed at the basal portion of the stem under the soil and on roots causing yellowing, wilting and mortality of vines in the field and cuttings in the nursery especially at higher altitudes. The pest infestation is generally more serious on vines affected with *Phytophthora* and nematodes. The pest infestation can be controlled by drenching chlorpyriphos 0.075% and also by undertaking control measures against *Phytophthora* and nematodes.

8.7. Scale insects

Marsipococcus marsupiale is commonly seen infesting black pepper leaves at higher altitudes though no visible symptom of damage is observed. *Protopulvinaia longivlvata* is observed on mature leaves of older cuttings in the nursery. The pest infestation results in yellowing and wilting of affected plants and the subsequent attack by sooty mould which accelerates the deterioration of the infested plants. The pest infestation can be controlled by spraying dimethoate 0.05%

8.8. Gall midge

Maggots of the gall midge *Cecidomyia malabarensis* develop within tender leaf petioles, leaf veins and shoots of black pepper vines resulting in swelling of infested tissue. The pest infestation is more common in the nursery and also on young vines in the field especially during the monsoon season. The pest infestation can be controlled by spraying dimethoate 0.05%.

8.9. Leaf feeding caterpillars

The semilooper *Synegia* sp. is more common among the few species of leaf feeding caterpillars infesting black pepper. The pest damages tender shoots, leaves and spikes of younger vines especially during the monsoon season. The pest infestation can be controlled by spraying quinalphos 0.05%.

9.0. HARVEST, POST HARVEST PROCESSING AND VALUE ADDITION

There are several factors which affect the quality of processed black pepper products. These include pests and micro-organisms which infest the product from the plantation, foreign matter and impurities from materials used in processing which contaminate the products, micro-organisms and dirt which are introduced through unhygienic practices of people who handle the produce, and loss of quality that results from short-comings in storage practices. Thus, the quality of the product depends on the quality of raw materials, the methods used in processing, the packaging methods and materials and marketing practices. Therefore, to ensure quality of the product, constant care should be maintained from the time of harvesting till the time it reaches the consumer.

9.1. Harvesting

Black pepper takes 7-8 months after flowering to reach full maturity. The crop is harvested during December-January in the 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 off by hand and collected in bags when one or two berries in the spike turn red or yellow. 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. The level of maturity required at harvest for processing into different pepper products is given in table 8.

9.2. Post harvest processing

9.2.1. Threshing

The berries are separated from the spike usually by trampling. This operation is crude, tedious and unhygienic. Chances of extraneous soil particles and filth contaminating the produce are also high. At few places, especially in large plantations mechanical

Table 8. Optimum maturity at harvest for pepper products

Product	Stage of maturity at harvest
Canned pepper	4-5months
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

Source: Natarajan 1981

threshers are used. Mechanical threshers with capacities varying from 50 kg/h to 1200 kg/h are available which can thresh quickly and provide cleaner products are given in table 9.

Table 9. Black pepper threshers developed by various agencies

Thresher	Capacity (kg/h)	Threshing mechanism	Max. efficiency (%)	Damage (%)
Gudalur Thresher	600	Wooden cylinder with aluminium angles	99.5	<0.3
KAU Thresher	50	Metal drum with rubber lining	98.0	<0.5
TNAU Thresher (Improved)	200	Metal drum with wooden rasp bar	99.6	Negligible
Malaysian Thresher	600	Metal drum lined with rubber blades	99.8	Negligible
Indonesian Thresher (Manual)	170-185	Pedal operated metal drum	94.13	3.78
Indonesian Thresher (Power)	425-450	Metal drum	92.21	6.13
Vivega Thresher (Manual)	50	Metal drum with angles	91.5	4.0
Vivega Thresher (Power)	200	Metal drum with angles	96.0	>4.0
Mohta Thresher	1200	Metal drum	Nearly 100	Negligible
Cafex	600	Metal drum	98.0	<0.5

Source: Dhas & Korikanthimath 2003

9.2.2. Blanching

The quality of the black pepper can be improved by a simple treatment of dipping the mature berries taken in a perforated vessel in boiling water for a minute before drying. This processing technique has several advantages:

a. Uniform coloured black pepper is obtained after drying.

b. Microbial load is reduced.

c. Drying is completed in 3-4 days as against 5-6 days required in the traditional practice.

d. Extraneous impurities like dust are removed from the berries.

9.2.3. Drying

Green pepper has moisture content of 60% to 70% at harvest, which should be brought to safer levels of less than 10% by adequate drying. The green colour of matured green 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 the berries eventually turn black. Sun drying is the conventional method followed for drying of black pepper. The despiked berries are dried in the sun for 3-5 days to bring the moisture content below 10%. After drying, if the moisture content is too high, black pepper will be susceptible to fungal attack. Poisonous substances secreted by the fungi render the pepper unfit for human consumption. In order to achieve quality dry product, green pepper berries are spread on clean dry concrete floor / bamboo mats / PVC sheets and dried in the sun for a period of

4 to 6 days. The average dry recovery varies between 33%-37%.

9.2.4. Cleaning and grading

The dried black pepper has extraneous matter like spent spikes, pin heads, stones, soil particles, etc. mixed with it. Cleaning and grading are basic operations that enhance the value of the produce and help to get higher returns. On a small scale, winnowing and hand picking remove most of these impurities; for larger scale, a mechanical unit consists 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. The cleaning and grading units available are given in the table 10.

Using sieves, cleaned black pepper is sifted into different grades based on size. These standards are being implemented rigorously under the mandatory Agmark Grading Scheme for exports from India (table 11). The grades are as follows:

a. Malabar Garbled (MG Grades 1 and 2) Black Pepper

b. Malabar Ungarbled (MUG Grades 1 and 2) Black Pepper

c. Tellicherry Garbled Black Pepper Special Extra Bold (TGSEB)

d. Tellicherry Garbled Extra Bold (TGEB)

e. Tellicherry Garbled (TG)

f. Pin Heads (PH Grade special and Grade1)

g. Garbled Light Pepper (GL Special, GL Grades 1 and 2)

h. Ungarbled Light Pepper (UGL Special, UGL Grades 1and 2)

i. Black Pepper (Non-specified)

9.2.5. Storage

Black pepper is hygroscopic in nature and absorption of moisture from air, notably during rainy season with high humidity may result in mould and insect infestations. Before storage it is to be dried to less than 10% moisture. 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.

Table 10. Cleaner cum graders for black pepper developed by various agencies

Agency	Capacity	Mechanism	Efficiency (%)
KAU	-	Rotary type with three concentric cylindrical sieves	99.6
TNAU	50 kg/h	Inclined belt separator	98.0
CFTRI	100kg/h	Aspirator, destoner, rotary washer, continuous fluidized bed dryer	**100.0**
Export house	Continuous	Pneumatic separators with magnetic gadgets, multiple sieve cum air classifier	100.0

Source: Dhas & Korikanthimath 2003

Table 11. Agmark grade specifications of black pepper

Grade	Trade name	Size, diameter of sieve holes on which retained (mm)	Extraneous matter not exceeding (% w/w)	Light berries not exceeding (%w/w)	Moisture content not exceeding (%w/w)
Tellicherry Garbled Black Pepper					
TGSEB	Special Extra Bold	4.75	0.5	3	11
TGEB	Extra Bold	4.25	0.5	3	11
TG	Tellicherry Garbled	4.25 (50% min) 4.00 (50% max)	0.5	3	11
Garbled Malabar Black Pepper					
MG Grade 1	-	-	0.5	2	11
MG Grade 2	-	-	0.5	5	11
Un-Garbled Malabar Black Pepper					
MUG Grade 1	-	-	2	7	12
MUG Grade 2	-	-	2	10	12
MUG Grade 3 L	-	-	3	15	12
MUG Grade 4 L	-	-	4	20	12

Source: Spices Board, 2001

9.2.6. *Hygiene of environment and personnel during processing*

The premises used to dry and store black pepper should be clean and hygienic and free from dust, cobwebs, undesirable foreign matter like excreta of animals and birds, bits of stone, etc. and should be cleaned daily. The premises should be fenced using nylon or other netting to keep off birds. The storage area should be properly plastered to avoid the entry of rodents and openings in the walls should be covered with metal grills. Persons engaged in threshing, sifting, etc. of black pepper should clean their hands and feet with soap and water before they start their work. Vessels and utensils used in processing and storage should always be kept clean. They should never be allowed to be soiled by dust or other impurities or contaminated by pests. Gutters and other water outlets connected to platforms used for drying black pepper should always be maintained in a clean condition. Only clean bamboo trays should be used for sifting black pepper. These trays should never be smeared with cow dung. Precautions should be taken to see that the clean and sifted black pepper is not re-contaminated by dust and other impurities

9.3. Value-added products

A variety of products which could be made from pepper and are classified as follows :

a. Green pepper based products

b. Black pepper based products

c. White pepper based products

d. Miscellaneous products

9.3.1. Green pepper based products

Canned green pepper

In this process, the de-spiked and cleaned green berries are immersed in water containing 20 ppm residual chlorine for about an hour. The berries are then immersed in hot brine 2% containing citric acid 0.2% exhausted at 80°C, sealed properly and processed in boiling water for 20 minutes. The canned green berries is then cooled immediately in a stream of running cold water. Green berries harvested 1 month before maturity is ideal for the manufacture of canned green pepper.

Green pepper in brine

The manufacturing process consists of de-spiking fresh green pepper berries of uniform size and maturity immediately after harvest followed by cleaning, washing and steeping in brine 20% solution containing citric acid. This is allowed to cure for 3 to 4 weeks. The liquid is drained off and fresh brine 16% solution together with sulphur-di-oxide 100 ppm and citric acid 0.2% are added. The resulting product is stored in containers protected from sunlight.

Bulk-packaged green pepper in brine

Bulk-packaged green pepper spikes and green berries are stored in 10, 20 and 35 litre capacity PVC containers containing brine 16% and acetic acid 1-2%. Alternatively, to give better colour, brine 16% containing citric acid 0.25% and SO_2 100 ppm is used.

Cured green pepper

To overcome the disadvantages of poor texture and weaker flavour of dehydrated green pepper and the higher weight and high packaging cost of canned and bottled green pepper, a new product viz., cured green pepper packed in moist conditions in flexible poly laminated pouches without any covering liquid has been developed. In the process, freshly harvested slightly under mature, tender green berries are cleaned after despiking. The berries are thoroughly cleaned in water, which are then steeped in saturated brine solution containing chemicals for 2-3 months. While curing, the enzymatic action is inhibited and the brown discolouration is prevented. It is then, drained and packed in suitable flexible polyaminated pouches.

Frozen green pepper

Frozen green pepper is considered far superior to green pepper in brine or dehydrated green pepper because it has better flavour, colour, texture and natural appearance. It is packed in poly pouches and hence the cost is much less compared to cans and containers. Though freezing is expensive, it is gaining popularity because of its superiority in every respect.

Freeze dried green pepper

The fresh, tender green pepper (66% moisture) while in frozen state at -30°C to -40°C under high vacuum (5-10 microns) releases most of the moisture. As a result of this, a product with its natural colour, texture and of far superior quality to those of sun dried, solar dried or mechanically dehydrated green pepper is obtained. It is much lighter than frozen green pepper, since its moisture is reduced to 2-4%.

Dehydrated green pepper

Slightly immature green pepper is preferred for producing dehydrated green pepper. The cleaned pepper berries are subjected to blanching in boiling water for 10 minutes till the enzymes responsible for blackening are inactivated and polyphenols washed out of the berries. The pepper thus obtained is immediately subjected to sulphiting in potassium meta-bi-sulphite solution to fix the green colour. The sulphited berries are washed and dried in a cabinet drier at 50°C to get green colour.

Green pepper pickle

Green pepper pickle is popular in many states notably in Kerala, Karnataka, Tamil Nadu, Gujarat and Maharastra.

Mixed green pepper pickle

Green pepper berries are mixed with lime pickles, mango pickles, mixed cauliflower and carrot pickles, brinjal pickles, bitter gourd pickles with or with out green chillies and sliced fresh ginger. They are quite popular but however their preparation is mostly limited to domestic scale.

Green pepper sauce

The product is made from selected green pepper berries, which are first ground pure and then blended with vinegar, salt, sugar and other ingredients. It has natural flavour and is often used as a dip for chips or fries.

Green pepper-flavoured products

Green pepper used in soups, *rasam*, *biriyani*, *rice pulao* and *upma* is very much preferred since its attractive colour makes the product more attractive. The berries give an exotic taste while eating it in conjunction with other products. Green pepper is also used in garnishing of salads and other food.

9.3.2. Black pepper based products

Whole black pepper

In the modern spice processing units, black pepper is first fluidised for the removal of pin heads, husk, light berries and dust. It then passed through magnetic separator for removal of metallic particles and through a destoner for removal of stones. The spiral rejects are removed by passing through spiral separators. It is also passed through brush cleaners to remove the dust on the surface of black pepper. The cleaned black pepper is sieved to required grade. The graded black pepper is then washed, dried and then packed mechanically in suitable packs.

Sterilized black pepper

The cleaned black pepper is subjected to sterilization to ensure high quality, microbial contamination-free, clean and dried product. There are several methods for sterilization including pressure sterilization, ozone sterilization, compressed carbon-di-oxide treatment, irradiation, microwave heating, alcohol vapour treatment, extrusion and steam treatment and fumigation. In continuous steam sterilization method, the spice is subjected to a rapid flow of superheated steam for a predetermined period of time followed by drying, re-humidification and packaging. Microbial levels as well as enzyme activity are considerably reduced to low levels and no significant oil or flavour loss occurs. In countries where sterilization by radiation as well as chemical methods is not permitted, steam sterilization is the best alternative. Chemical sterilization involves the use of chemicals like ethylene oxide.

Effectiveness of sterilization depends on the moisture content of black pepper, concentration of the gas, temperature and time of contact.

Ground black pepper

Ground black pepper is obtained by grinding cleaned black pepper without adding any foreign matter. Grinding is accomplished by employing equipments like hammer mill, pin mill or plate mill. The ground product is further sieved and materials possessing the required size are packed. The overflow is sent back to the grinding zone for further size reduction.

Cryoground black pepper powder

In the conventional grinding of spices, the mill and the product temperature can rise to as high as 90 °C and at high temperatures, there will be considerable loss of volatile oil. Cryogenic grinding overcomes this problem and helps in retaining more volatile oils besides reducing oxidation, improving fineness and posing minimum distortion in the natural composition of powder. The cryo-ground spices disperse more uniformly in spice formulations and the loss of the volatile oil and flavour are very much reduced during the grinding operation. The usual practice during the cryo-grinding is to inject liquid nitrogen into the grinding zone. A temperature controller maintains the desired product temperature by suitably adjusting the nitrogen flow rate. The exhausted gas is re-circulated for pre-cooling of the spice.

Pepper oil

The characteristic aroma of black pepper is due to the presence of volatile oils, which can be recovered by steam distillation or hot water distillation. Industrial process for the recovery of essential oil involves flaking of black pepper using roller mills or grinding into coarse powder and steam distillation in a stainless steel extractor. The steam comes in contact with the ground black pepper particles and vaporizes the oil present in the oil cells and rises up. The oil is recovered using an oil/water separator.

Oleoresin

Oleoresins are concentrated products obtained by extraction of ground black pepper using solvents like hexane, ethanol, acetone, ethylene-di-chloride, ethyl acetate, etc. Black pepper is flaked to a thickness of 1 to 1.5 mm and packed in stainless steel extractors for extraction with the organic solvent. Normally, solid to solvent ratio of 1:3 is employed and an extraction temperature of 55-60°C is maintained.

Solvent-free extraction of essential oils and oleoresins by supercritical fluid extraction has shown promising results. Though many supercritical fluids are available, carbon-di-oxide is the most widely accepted supercritical fluid. The critical temperature and pressure beyond which carbon-di-oxide behaves as super critical fluid are 31.3°C and 73.8 bar pressure, respectively.

Microencapsulated spice flavour

Microencapsulation is the technique by which the flavour material is entrapped in a solid matrix and is ready for release as and when required. Encapsulation is achieved mostly by spray drying. In the production of spray dried spices, the essential oils and/or oleoresins are dispersed in the edible gum solution, generally gum acacia or gelatin, spray dried and then blended with dry base such as salt or dextrose. As water evaporates from the spray dried particles, the gum forms a protective film around each particle of extractive. The protective capsule prevents the spice extractive from evaporating and from being exposed to oxygen.

9.3.3. White pepper based products

White pepper whole

White pepper is the white inner corn obtained after removing the outer skin or pericarp of pepper berries. It is preferred over black pepper in light-coloured preparations such as sauces, cream soups, etc. where dark coloured particles are undesirable. It imparts pungency and a modified natural flavour to food stuff. Varieties like Balankotta and Panniyur - 1 with large sized berries, are ideal for making white pepper. White pepper can be prepared by using any one of the following techniques:

Water steeping technique or retting process: The traditional method of preparation of white pepper is by retting. If running water source is not available, the other alternative is to use fermentation tanks wherein the water is changed every day. The ripe pepper berries are heaped into tanks and water is changed every day for about 7-10 days. The light fractions of pepper like pin heads and light berries which come to the surface are removed. On the 11th day the outer skin is removed by gentle rubbing. The berries are drained from the tank and sun dried. Retting converts only ripe and fully mature berries to white pepper, whereas green berries turn into black eventually after drying. On drying 100 kg of green pepper, approximately 33% of black pepper is obtained. By the retting process the yield of white pepper obtained is 25%.

Steaming or boiling technique: This process involves steaming or boiling mature green berries for 10-15 minutes. The outer skin of the berries gets softened during the steaming process and is removed through a pulping machine. However, the process of boiling gelatinizes the starch and the powder from this method is slightly dull in colour. But the flavour quality and the microbial load are very low.

Chemical method: There are several chemical methods reported for the preparation of white pepper either by treatment with acid or alkali, but no commercially viable technology exists.

Decortication method: Prototypes of pedal and power operated pepper decorticator have been developed at Research Institute for Spices and Medicinal Crops, Indonesia. The decorticating mechanism functions on the principle of pressure and friction. The loss of pepper due to breakage results in reduced yield and hence the white pepper obtained by this method is expensive. Also, the characteristic flavour associated with the traditional product is lacking in the white pepper obtained by decortication process and hence not widely preferred.

Pit method : This is another indigenous method of preparing white pepper by burying the produce in a pit. Semi-ripe (20 to 40% ripe or yellow) and fully ripe (red) berries are put into woven plastic bags and buried at 60 cm below the soil surface. Fully ripe berries are converted into white pepper after 7 days whereas it requires 14 days for converting semi-ripe berries to white. The advantage with this method is that even mature berries get fully converted into white pepper. The percentage of black pepper berries in white pepper is less than 0.2%.

White pepper powder

White pepper powder is processed in the same way as black pepper powder, except that the starting material is white pepper. White pepper powder can also be produced from black pepper by selective grinding followed by sieving. Before pepper is subjected to grinding it is conditioned by adjusting the moisture content. The skin fraction which is a by product of the process can be a feed stock for essential oil or oleoresin extraction.

9.3.4. Miscellaneous products

Curry powder-spice blends

One of the principal values of pepper is its ability to adjust the flavour of the dishes. Such seasonings are also known as 'spice blends', 'spice mixtures' or 'masalas'. Several brands of 'masalas' for different purposes like 'chicken masala', 'fish masala', 'channa masala', 'chat masala' and 'dhal masala', available in markets in India and abroad have pepper as one of the important components.

Pepper-flavoured products

Pepper mayonnaise, pepper cookies and pepper tofu are some of the products prepared from white or black pepper.

Pepper extract

It is a valuable adjunct in the flavouring of sausages, canned meat, soups, table sauces and certain beverages and liquor.

Preservative

Black pepper is valued as an essential preservative for meats and other perishable foods. It is therefore largely used by meat packers and in canning, pickling, baking, confectionery and in the preparation of beverages.

Pepper oil

Pepper oil is used in perfumery and also for manufacturing soaps.

9.4. Pepper byproducts

9.4.1. Light pepper

Light pepper berries lack in starch but are rich in oil, piperine and oleoresin contents. They are being used in the manufacture of oil, oleoresin concentrates, pastes etc. for various meat products.

9.4.2. Pepper hulls

Pepper hulls or shells removed during the preparation of white pepper are sold separately as light to dark pepper powder with very pungent odour. Pepper shells are rich in volatile oil and can be used as a source of pepper oil.

9.4.3. Pepper pin heads

Pepper pin heads are less or least developed berries of the size of pin heads. They are fairly rich in oil and oleoresin but their quality is somewhat inferior. Nevertheless, it is still exported from the country.

9.4.4. Peppersal

The oleoresin obtained from light berries and hulls is used for making peppersal. Peppersal is a spice salt obtained by dispensing or absorbing the above oleoresin from pepper rejections in suitable quantities of refined, pulverized, free flowing common salt.

9.5. Quality

As in the case of other spices, the aroma, flavour and medicinal property of black pepper is attributed to the volatile oils present in black pepper. Pepper oil contains a range of organic compounds, which belong to the group of terpenes and hydrocarbons. The major aroma compounds of black pepper are ß-caryophyllene, sabinene, myrcene, limonene and linalool.

The non-volatile part of black pepper which is extracted using organic solvents is called black pepper oleoresin. The major pungent alkaloid present in black pepper is piperine. In general, black pepper contains about 3-5% volatile oil and 8-16% oleoresin and 2-6% piperine. However, starch, is the predominant constituent ranging from 35% to 40% in black pepper and 53% to 58% in white pepper. Some of the traditional cultivars like Kottanadan and Kumbhakodi are rich in oleoresin and piperine. Some of the new varieties with high quality are Malabar Excel, Sreekara and Subhakara. The important biochemical parameters of high quality black pepper varieties are given in table 12.

Table 12. High quality black pepper varieties

Variety	Essential oil (%)	Oleoresin (%)	Piperine (%)
Kottanadan	4.0	17.0	6.0
Kumbhakodi	4.0	14.0	5.0
Panniyur-I	2.5	9.5	3.0
Sreekara	5.0	13.0	5.0
Subhakara	5.0	13.0	5.0
Malabar Excel	5.4	14.6	3.5

Source: Zachariah 2005

9.5.1. *Physical and microbial contamination*

The physical 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.

Black pepper is exported mainly to developed countries like USA, UK, Germany, European Union, Japan and Canada. In the international market, quality specifications for trade are laid by both importing as well as the producing countries. The quality parameters assessed are extraneous matter, light berries, pin heads, bulk density, insects, excreta and microbiological aspects like presence of *Salmonella, E. coli* and aflatoxin. 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 international trade. Among them, the cleanliness specifications for spices laid down by ASTA, which are also approved by the United States Food and Drug Administration (USFDA) are widely accepted among the consumers.

Black pepper exported to USA should confirm to the cleanliness specification stipulated by ASTA and also the regulations enforced by the USFDA. ASTA cleanliness specifications set limits for criteria such as number of dead insects in the sample analyzed, amount of mammalian excreta, other excreta, percentage of weight of berries with mould and/or insect infestation and the extent of foreign matter present. Black pepper imported into USA failing to meet these cleanliness specifications will be detained and subjected to reconditioning (cleaning to remove the defect). If defects cannot be removed by reconditioning the lot may be destroyed or sent back to the country of its origin. In addition to ASTA cleanliness specifications, black pepper imported to USA has to comply with the Defect Action Level of FDA as and when prescribed. The ASTA and FDA action levels for cleanliness specifications for black pepper are given in tables 13 and 14.

9.5.2. Pesticide Residue

FDA also has surveillance programme to monitor for pesticide residues. The tolerance limits for pesticide residues are established by Environmental Protection Agency (EPA), FDA is responsible for enforcing safe levels of pesticide residues in foods. The tolerance limits for pesticides and aflatoxin exported to USA is given in tables 15 and 16.

Table 13. American spice trade association (ASTA) cleanliness specifications for black and white pepper

Spice	Whole insect count (Count/lb)	Excreta Mammalian (mg/lb)	Excreta other (mg/lb)	Mouldy and/or insect infested (% by wt.)	Extraneous foreign matter (% by wt.)
Black pepper	2	1	3.0	5.0	1.00
White pepper	2	1	1	1	0.50

Source: Spices Board (www.indianspices.com)

Table 14. FDA Defect Action levels for pepper

Pepper	Defect	Action level
Pepper whole	Insect filth and/or mould	Average of 1% or more of berries by weight are insect infested and or mouldly
	Mammalian excreta	Average of 1 mg or more of mammalian excreta per pound
	Foreign matter	Average of 1% or more pickings and sifting by weight.
	Microbial contamination	Presence of *Salmonella/Arizona* not allowed
Ground pepper	Insect filth	475 or more insect fragments per 50 g
	Rodent filth	2 or more rodent hair fragments per 50 g

Source: Spices Board (www.indianspices.com)

Table 15. US pesticide tolerances for pepper

Chemical	Tolerance limit (ppm)
Lindane	1.0
Heptachlor epoxide	0.01
Ethylene oxide	50.0
Aluminium phosphide	0.1
2, 4-D	0.1
Glyphosate	0.1
Acephate	4.0
Captan	25.0
Carbaryl	10.0
Carbofuran	1.0
Chlorpyriphos	1.0
Dicofol	5.0
Dimethoate	2.0
Endosulfan	2.0
Ethion	1.0
Malathion	8.0
Metalaxyl	1.0
Methamidophos	1.0
Methomyl	2.0
Methoxychlor	14.0
Parathion	1.0
Methyl parathion	1.0
Methyl bromide	30.0
Phosphamidon	0.5
Quintozene	0.1
Trifluralin	0.05
Chlordane	0.1
DDT, TDE, DDE	0.1
Dieldrin	0.05

Source: Spices Board (www.indianspices.com)

Table 16. Tolerance limit for aflatoxin for pepper

Aflatoxin	Tolerance level
BI	2 ppb (Maximum)
B I + B2 + G I + G2	4 ppb (Maximum

Source: Spices Board (www.indianspices.com)

9.5.3. European Spice Association (ESA) specifications of quality minima for spices

Like USA, European countries also have very stringent food laws and regulations to ensure that spices are safe, wholesome and produced under sanitary and hygienic conditions. The ESA specifications for spices are given in tables 17 and 18.

10.0. MARKETING AND ECONOMICS

In India, cultivation of black pepper is mainly confined to Kerala, Karnataka and Tamil Nadu, and to a certain extent in Andaman and Nicobar Islands and north-eastern states. Kerala alone contributes about 95% of total production of black pepper. In terms of productivity the all India average is 315 kg/ha while that of Kerala is 323 kg/ha. The crop is a major source of income and employment (> 40 million man days) for rural households.

10.1. Marketing

Marketing of black pepper assumes most important in its trade. Several intermediaries in the country are involved in marketing of black pepper. Farmers dispose of their produce either locally to a village shop, co-operative society or terminal market, the criteria of selection depending on factors like loyalty of financial obligations to a particular trader, distance to terminal market and prevailing market price.

Centres for collecting harvested produce

Table 17. ESA specifications for pepper quality

Subject	ESA specifications
Extraneous matter	1%
Sampling	(For routine sampling) Square root of units/lots to a maximum of 10 samples. (For arbitration purposes) Square root of all containers. e g 1 lot of pepper = 400 bags, therefore, square root = 20 samples.
Foreign matter	Maximum 2%
Ash (% w/w max.) Black pepper White pepper	 7.0 3.5
Acid insoluble ash (% w/w max.) Black pepper White pepper	 1.5 0.3
H_2O (% w/w max.) Black pepper White pepper	 12 12
Packaging	Should be agreed between buyer and seller if made of jute and sisal. However, these materials are not favoured by the industry, as they are a source of product contamination, with loose fibres from the sacking entering the product.
Heavy metals	Shall comply with national/EU legislation*
Pesticides	Shall be utilized in accordance with manufacturers recommendations and good agricultural practice and comply with existing national and /or EU legislation.
Treatments	Use of any EC approved fumigants in accordance with manufacturers' instructions. to be indicated on accompanying documents (Irradiation should not be used unless agreed between buyer and seller).
Microbiology	*Salmonella* - absent in (at least) 25 g. Yeast and moulds - 10^5/g target, 10^6/g absolute maximum *E coli* - 10^2/g target, 10^3/g absolute maximum Other requirements to be agreed between buyer and seller.
Off odours	Shall be free from off odour or taste.
Infestation	Should be free in practical terms from live and/or dead insects, insect fragments and rodent contamination visible to the naked eye (corrected in necessary for abnormal vision).
Aflatoxins	Should be grown, harvested, handled and stored in such a manner as to prevent the occurrence of aflatoxins or minimise the risk of occurrence. If found, levels should comply *with existing national and/or EU legislation (20 ppb**).*
Volatile oil (% w/v max.) Black pepper White pepper	 2.0 1.5
Adulteration	Shall be free from.
Bulk density	To be agreed between buyer and seller.
Species	To be agreed between buyer and seller.
Documents	Should provide details of any treatments the product has undergone, name of product, weight, country of origin, lot identification/batch number, year of harvest.

Source: Spices Board (www.indianspices.com); * Detailed in Table18; ** Detailed in Table16

Table 18. ESA specifications on heavy metal contamination

Constituent	Quantity (Maximum allowed)
Lead	10 ppm
Arsenic	5 ppm
Copper	20 ppm
Zinc	50 ppm

Source: Spices Board (www.indianspices.com)

operate in every town in the spice growing areas. From the collecting centres merchants purchase the produce and after accumulating sufficient stock or when the terminal market price in sufficiently attractive, the commodity is bagged for transport to the terminal markets. The main terminal or wholesale marketing centres for black pepper are Calicut, Telicherry, Kochi and Alleppey. From here, commission agents receive the produce and it is then traded between brokers or dealers and then to the exporters. The exporters grade the finished product according to grade specifications and obtain the grade certificates and finally consign the packed material to the shipping agents according to export order. If the demand of black pepper from foreign countries are less, exporters generally store the produce in their godowns until an export order is received.

The important marketing channels in marketing of spices are:

Producer - village merchant - local trader - wholesaler - commission agent - exporter.

Producer - village merchant - wholesaler - commission agent/wholesaler of consuming market - retailer - consumer.

The first channel is more important regarding export of black pepper is concerned and the interval price is solely dependent on foreign demand. The wide range of disparities in the price received by the producers are due to expenditure incurred in marketing, margin of profit enjoyed by the pre-harvest contractors/intermediaries, deduction on account of high moisture content, incidence of various taxes and other charges, transportation costs, etc.

There are few regulated markets for black pepper in Karnataka, whereas there are no regulated markets for black pepper in Kerala. However, few co-operative marketing societies in Kerala handle black pepper, but they are not effective due to poor financial resources. Apart from these, the Kerala State Cooperative Marketing Federation is also involved in transaction and export of black pepper.

10.2. Price behavior

Price is a deciding factor for export of black pepper. India is in the process of losing its traditional market to East European countries and Russia due to high cost of production. Black pepper price is influenced by external demand from other countries. Vagaries in supply and elements of speculation are the twin problems connected with world price of black pepper. Generally the price of black pepper in the market is depressed during January-February mainly due to fresh arrivals in the market and registers an increase from July-August. The price of black pepper varies from market to market depending on marketing activities. The production decision of farmers is influenced by the price they received at the farm. The annual average price of black pepper for the past 10 years is shown in table 19.

Table 19. Annual average price of black pepper (MG1) at Cochin

Year	Price (Rs/Quintal)
1993-94	3,769
1994-95	6,281
1995-96	7,708
1996-97	8,375
1997-98	17,343
1998-99	20,603
1999-00	21,502
2000-01	17,424
2001-02	8,039
2002-03	8,832
2003-04	7,411

Source: Spices Board, 2004

10.3. Export

Black pepper is exported to USA, USSR and East European countries from India. Indian black pepper is famous for its superior intrinsic quality but that identity is being lost due to repacking of bulk imports with or without value addition and marketed under popular brand names. In India, domestic demand for value-added products are less and hence the entire production is exported. Export of black pepper and value-added products during the past five years are shown in table 20.

A majority of black pepper is exported as black pepper whole followed by black pepper in powder form. Over the last 25 years black pepper exports have recorded an annual growth rate of 5%. Over the last few years Vietnam has overtaken traditional black pepper producing countries such as India and Indonesia in export. Pepper oil is exported to German Federal Republic (GFR), Netherlands, Singapore, UK, and USA. The important countries to which oleoresin is exported are Belgium, Canada, French, Japan, UK and USA.

Table 20. Individual item-wise export of pepper from India (Qty=tonnes; Value=Rs. Lakhs)

Item	1998-99		1999-2000		2000-01		2001-02		2002-03	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Black pepper	30,869	58,659	39,458	83,281	18,475	32,140	18,400	15,444	15,641	12,843
Pepper pin heads	1282	1056	863	631	642	458	265	88	608	264
Pepper powder	846	1304	1032	1711	1556	3041	26,237	29,126	338	2381
White pepper	133	411	119	380	82.26	209	186	390	219	273
Dehydrated green pepper	204	807	303	1281	264	929	326	670	771	1272
Freeze dried green pepper	10	113	32	311	61	619	12	110	44	344
Pepper in brine	1762	1127	1014	932	748	684	1050	752	942	509
Total	35,109	63,479	42,823	88,528	21,830	38,081	22,877	20,366	2160	17,887

Source: Spices Board, 2004

10.4. Economics of cultivation

The economics of cultivation of black *pepper is presented in the table 21 .*

Table 21. Cost of cultivation of black pepper

Item	Price / Unit (Rs.)	Year 1	Year 2	Year 3	Establishment cost (1-3yrs)		Maintenance cost (4-20yrs)	
					Qty	Value (Rs.)	Qty	Value (Rs)
Labour (man days)	110.00	148	81	83	306	33,660	162	17,820
Planting material (nos.)	6.00	2000	0	0	2000	12,000	0	0
Standard (nos.)	10.00	1000	0	0	1000	10,000	0	0
FYM (kg)	3.00	500	500	500	1500	4500	500	1500
Fertilizer:								
Urea (kg)	4.90	70	145	220	435	2132	220	1078
Rock phosphate (kg)	2.85	48	95	144	287	818	144	410
MOP (kg)	4.66	90	60	280	430	2004	280	1305
Plant protection:								
For drenching (litre)	0.46	2500	5000	10,000	17,500	8050	10,000	4600
For spraying (litre)	0.55	0	1000	1000	2000	1100	2000	1100
Need based						750		750
Tying material (value)	1100	0				1100		1200
Mulch (kg)	2.00	0	500	1000	1500	3000		1500
Interest on working capital @11%		699	1511	2966		5176		3439
Total						84,290		34,702
Amortized value of estimated cost @ 11 %								10,620
Total cost of cultivation								45,323
Cost of cultivation Rs/kg								30
Gross return	70.00							105,000
Net benefit (Rs.)								59,677
Benefit : Cost ratio								2.32

Recommended package of practice is combined with actual survey information to work out the present cost; Assumed yield (dry) 1.5 kg; Number of vines per ha = 1000 nos.

Source: IISR Annual Report, 2004-05

countries. There are number of challenges facing black pepper farmers in India today. Though technological advance has been effective, adoption rate by farmers is low and hence the yields are also low. Though

10.5. Prospects

Global availability of black pepper has increased substantially during the last few decades. However, the availability of sizable stocks and the increasing production trends in many countries are pushing down the price of black pepper in all producing

there is a worldwide trend for spicy or hot food, chillies with many varieties having varying levels of pungency, is competing with black pepper in making food preparations hot. The price of chillies is cheaper and imports of chillies into USA are higher than imports of black pepper. However, the production of value-added products have helped to provide new value to black pepper by creating new uses, both in food and non-food applications. Promotion of new and emerging markets, development of new products, and increasing the consumption in producing countries would help in increasing the market price of black pepper.

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Improved varieties of Black pepper

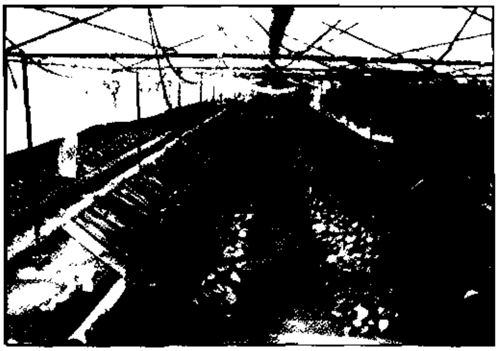
Panniyur -

Panniyur - 2

Sreekara

Girimunda

Propagation of Black pepper



Rapid multiplication method

Serpentine method

Pests and diseases of Black pepper

Pepper plant affected by Scale insects

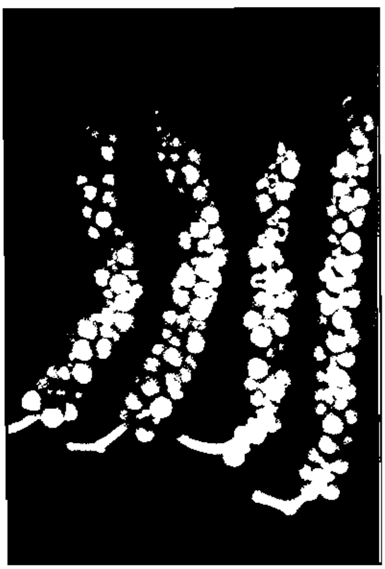
Tender shoot damaged by Top shoot Border

Phytophthora Foot rot disease

Stunted disease

Mosaic on leaves

Slow decline



Pollu beetle infestation

Marginal gall forming thrips infestation

CARDAMOM

M.N.Venugopal, S.J.Ankegowda, D.Prasath

1.0. INTRODUCTION

The cardamom of commerce, the dried capsule of *Elettaria cardamomum* Maton. belongs to the family Zingiberaceae under natural order Scitaminae. It is a perennial plant indigenous to South India, occurring in the moist evergreen and deciduous forests of Kerala, Karnataka and Tamil Nadu.

Cardamom is one of the oldest spices originated from India as early as 5000 years ago in mountains of South-Western parts of the peninsula. Cardamom found a place in Queen Sheba's gift box to King Solomon. The sweet aroma has been praised in Indian literature by Kalidas and others. Indian cardamom occupies a unique position in the world market, for its high quality. Till early eighties, India was a pioneer both in area and production of cardamom. Of late, Guatemala has emerged as a keen competitor in the international market. Cardamom is cultivated for its dried capsules, which are used as flavouring agent in food, confectionary, beverages, cosmetics and medicines in Ayurvedic system. It finds an important place in the dishes prepared by Indians, Japanese, Germans and Swedish. Use of cardamom for confectionary preparations in Scandinavia is well known. It is an essential ingredient in 'Gahwa' of Arabs. 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. The aroma and medicinal values of cardamom are due to the volatile oil present in seed and husk. The cardamom oil is of high economic value since it is used in flavouring beverages, cosmetics *etc*.

1.1. *Area and production*

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. Presently India's production is 11,415 mt(2004 - 2005). where as during the same period Guatemala, produced 23,000 mt.

The total area under cardamom in India is estimated to be 73,725 ha during 2004 - 2005. It is mainly cultivated in the three southern states of Kerala, Karnataka and Tamil Nadu each of which nearly contributes to 56, 37 and 7 per cent of total area respectively. State wise area, production and yield details reported during 2003-2004 are furnished in table1.

Table 1. Area, Production and Yield of Cardamom in India

State	Area (ha)	Yielding area (ha)	Production (mt)	Yield (kg./ha)
Kerala	41332	30991	8875	286
Karnataka	20510	20509	1740	85
Tamil nadu	5017	3721	965	259
Total	66859	55221	11580	210

Cardamom cultivation in India is concentrated mostly in those regions, which form the natural habitat of spices except for a small area in North Kanara and adjoining southern districts in Karnataka and Wynad district in Kerala where it is grown as a subsidiary crop in arecanut gardens. It is also not uncommon to see its performance as a mixed crop with coffee in suitable pockets. The important areas of cultivation are Uttar Kannada, Shimoga, Hassan and Chickmagalur, hills of Kodagu (Coorg) district in Karnataka; Northern and Southern foot hills of Nilgiris, Madurai, Salem and Tirunelveli, Aanamalai and parts of Coimbatore districts of Tamil Nadu and Nelliampathy, Wynad, Idukki etc in Kerala state.

Cardamom export from India was 2345mt in 1980-81, which attained a peak of 3272mt (1985-86).The export sharply declined to 180mt in 1989-90 and the recent export figure was 690mt (2003-04). The unit domestic price for cardamom progressively increased from Rs.126/kg. (1987-88) to Rs.395/kg (1992-93) and further to Rs.650/kg (1999-2000) and subsequently decreased to Rs.220/kg (2005-06).

India has a very large domestic market for cardamom, consuming more than 7000 mt/year. Apart for household consumption, cardamom is utilized in the industrial sector including biscuits, cardamom falvoured tea and milk, as a component in a variety of herbal medicines, panmasala, food mixes etc. The industrial consumption of cardamom in India is estimated to be around 2500mt/year and the demand in hotel, bakery and fast food sector is around 1250 mt/year.

2.0. BOTANY AND IMPROVEMENT

2.1. Botany

It is a herbaceous perennial (2-5 m in height) having underground rhizomes with aerial pseudostems made of leaf sheaths. The leaves are long, most pubescent/puberelent and lanceolate in shape. Inflorescence is a long panicle with racemose clusters arising from the underground stem, but comes up above the soil. The growth habit of the panicles and the shape as well as the size of the capsules vary in different cultivated varieties/types of cardamoms.

2.1.1. Floral biology

Flowers are bisexual, zygomorphic and open in succession from base towards apex in racemes. Bracts linear, oblong and persistent, sepals 3, petals 3, unequal, lip longer than corolla tube shortly exerted, white sheathed with violet carpels 3, style 1, ovary-trilocular, axile placentation, ovules-numerous in each carpel. Fruit is a trilocular, fragrant capsule round to oblong in shape containing 10-18 seeds. Structure of cardamom flower is pre-disposed for insect pollination as indicated by the prominent labellum, stigma positioning above anthers, and the presence of nectar glands.

Generally 2 to 4 panicles emerge from the swollen base of tillers. Flower initiation takes place in March-April. It takes 25-35 days from initiation to full bloom and 110-140 days from bloom to maturity. Flowering is spread over a period of 6 - 7 months from April to continue up to October in India. Capsules start maturing in August-September and continue further up to December-January. Maximum number of flowers open during early hours (3.30 AM) and continues till 7.30 AM of the day followed by the anther dehiscence (7.30 to 8.30 AM). Flowers wither on the same day. The pollen grains are round and mostly found in single and measure 87.6μ on an average. Though apparently 85.2 per cent of the pollen grains appear fertile, germination tests showed that the maximum of 70.1 per cent germination in artificial media containing 20 per cent sucrose and 1 per cent agar solution. Studies on the viability of the pollen grains indicated that only 6.5 per cent of pollen grains remained viable after 2 hours of storage, but after 6-8 hours of storage, the percentage of viability was practically zero. Pollen morphology of the three varieties of cardamom, showed that all the three varieties of cardamom are round in shape and appeared as a creamy powder. The stigma remains receptive from 4 AM on the day of the flower opening depending on the environment conditions. Receptivity of stigma was highest between 8 AM and 12 noon giving about 72 per cent fruit set. Thereafter, the stigma receptivity decreases gradually resulting in the minimum fruit set of 24 per cent at 4 PM.

2.1.2. *Pollination behaviour*

Though cardamom has bisexual flowers and is self-compatible, cross-pollination is the rule, since self-pollination is hindered in the flowers due to the slight protrusion of the stigma above the stamens. Cardamom flowers remain in bloom for 15-18 hours and stigma receptivity and pollen viability were reported to be maximum during morning hours.

2.2. Improvement

2.2.1. *Types/cultivars of cardamom*

Elettaria is a small genus with 3-4 species in East and South-East Asia. The cultivars are grouped as 'Malabar' (prostrate panicles), 'Mysore' (erect panicles) and 'Vazhukka' (semi erect panicles), based on the adaptability, nature of the panicle, shape and size of fruits, which are presented in table 2.

2.2.2. *Varieties*

A large number of varieties have been released by various research institutions. Prominent among them are given in table 3.

Table 2. Characteristics of three eco types of cardamom

Characters	Malabar	Mysore	Vazhukka
Adaptability	Lower altitudes 600-900 m MSL	Higher altitudes 900-1200 m MSL	Wide range
Areas of cultivation	Karnataka	Kerala and parts of Tamil Nadu	Kerala
Plant growth	Medium	Robust	Robust
Panicles	Prostrate	Erect	Semi erect
Capsules	Round or oblong	Bold, elongated	Round to oblong (Intermediate)
Leaf petiole	Short	Long	Long
Bearing nature	Early	Late	Late
Flowering span	Short	Long	Long
Capsule colour at maturity	Pale/golden/ Yellow	Green	Green

Table 3. List of Improved varieties of cardamom and their characteristics

S.N.	Slection/ Variety	Cultivar	Area of adaptability	Important features	Yield status (Kg/ha)
Indian Institute of Spices Research, Cardamom Research Centre, Kodagu, Karnataka - 571 201					
1	IISR Kodagu Suvasini	Malabar	All cardamom growing tracts of Karnataka and Wynad of Kerala.	Suitable for intensive cultivation.	745 (average) 1156 (intensive cultivation)
2	IISR Avinash	Malabar	Suited for hotspots of rhizome rot and leaf blight prone areas. Suitable for Kodagu, Hassan, Chikmagalur and North Waynad.	Rhizome rot resistant Dark green capsules.	848 (protective Irrigation)
3	**IISR Vijetha**	**Malabar**	Suitable for *katte* prone areas. Adapted to moderate rainfall and Moderate to high shade areas.	**Katte resistant.**	643
Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala - 685 553					
4	ICRI 1	Malabar	South Idukki of Kerala.	Early maturing. dark green bold capsules.	656
5	ICRI 2	Mysore	Vandanmedu and Nelliyampathy of Kerala and Aanamalai, Meghamalai of Tamil Nadu.	Tolerant to azhukal disease.	766
6	**ICRI 3**	**Malabar**	Cardamom growing tracts of Karnataka.	Tolerant to rhizome rot.	790
7	ICRI 4	Malabar	Adapted to Lower Pulney hills of Tamil Nadu.	Suitable for low rain fall areas (1500 mm).	961

S.N.	Slection/ Variety	Cultivar	Area of adaptability	Important features	Yield status (Kg/ha)
Kerala Agricultural University, Cardamom Research Centre, Pampadumpara, Idukki - 685 556					
8	PV 1	Malabar	All cardamom growing tracts.	Elongated capsules	500
Kerala and parts of Tamil Nadu.					
9	PV 2	Vazhukka	Cardamom Hill reserves of Idukki.	Green bold capsules	982
University of Agricultural Sciences, RRS, Mudigere, Karnataka - 577 132					
10	Mudigere 1	Malabar	Traditional cardamom growing malanad areas of Karnataka.	Tolerant to shoot borer and thrips	1000
11	Mudigere 2	Malabar	Cardamom growing tracts of Karnataka	—	476 (rainfed)
Farmer's selections					
12	Njallani Gold/ Green Gold	Vazhukka	Suitable to Kerala and Karnataka tracts.	Performs well under intensive cultivation	1000 (average management)
13	Vander cardamom	Vazhukka	Suitable for Kerala tracts.	Extra bold, deep green capsules	—
Other promising land races from Idukki, Kerala					
14	Panikulangara No.1				
15	Palakuzhi selection				
16	Valley green bold				

3.0. SOIL AND CLIMATE

3.1. Soil

The natural habitat of cardamom is the evergreen forests of Western Ghats. It grows well in forest loamy soils. These soils are generally acidic in nature with pH from 4.2 to 6.8. Analytical data of cardamom growing tracts indicate that they are high in organic matter and nitrogen, low to medium in available phosphorous and medium to high in available potassium.

3.2. Climate

3.2.1. Altitude

The optimum altitude for growing cardamom is from 600 to 1500 above MSL. Cardamom cultivation in India is restricted to the Western Ghats regions. The Malabar type, the traditional cardamom of Karnataka, posses the capacity to be productive at lower elevations of 500-700 MSL. The other cardamom types, Mysore and Vazhukka are not productive below 700m elevation. At lower elevation, vegetative growth is satisfactory with lower yield. In Guatemala, cardamom is grown at varying altitudes, ranging from 90 to 1200m above MSL. Cardamom is highly sensitive to elevation and the wrong choice of cultivar or wrong location can severely affect the growth and productivity.

3.2.2. Temperature

In India, optimum growth and development is observed in the warm and humid conditions at a temperature range of 10-35°C. The upper temperature limit will normally be around 31-35°C. In the eastern side of the Western Ghats a combination of desiccating winds passing from the hinter lands of east and low humidity leads to desiccation and drying of plants. In such areas, protective irrigation would be essential for retention of humid conditions for setting of capsules. It is noticed that rate of spread of 'katte' disease will be more during summer than in rainy season. Cold conditions result in low setting of capsules. Thus extremes of temperature and wide diurnal variations are not conducive for healthy growth of cardamom plants.

Cardamom is very sensitive to temperature fluctuations. There has been a drastic reduction in tree cover due to deforestation, felling and excessive opening of canopy during the last decade and this could be the reason for the increase in minimum temperature. Land use pattern of the hills has also changed to a great extent. More light demanding crops like coffee, black pepper, arecanut etc were being cultivated in place of cardamom, which further reduced the canopy cover.

3.2.3. Rainfall

Cardamom is grown in South India under rainfall conditions ranging from 1500 to 5750 mm. Nearly 75 to 78 per cent 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 dependable. Hence, these crops suffer both from excessive moisture and moisture stress. Dry spells in these tracts usually occur during December-May.

In Guatemala, rainfall conditions are more favorable than in India. Here rainfall varies from 2000 to 5000 mm per annum in cardamom growing belts, distributed evenly throughout the year, though two peaks of high rainfall occur. Because of the absence of heat and drought stress, cardamom yields are much higher in Guatemala, registering a national average of 300 kg/ha. Similar situation occurs in Papua New Guinea also, leading to very high yields.

In India, prolonged drought in the first 6 months during 1983, when rain was most needed for cardamom plantations, brought about devastating effect leading to significant crop loss especially in exposed and partially shaded areas of Idukki district of Kerala. India's cardamom production came down to the lowest level of 1600 mt, there indicating 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. In India, 75-80 per cent of total area under cardamom is rain fed and due to variations and erratic rainfall, the average yield of cardamom is as low as 149kg/ha.

Even though all the characters of rainfall were positively correlated with the production of cardamom, a significant correlation was observed only between total number of rainy days and yield. During 1998-99, there was no rain continuously for 93 days in summer. Hence the production was only 20 per cent of the average production. An annual rainfall of 2000 mm with uniform distribution is considered ideal for cardamom.

4.0. NURSERY MANAGEMENT

Cardamom can be propagated by seeds and by vegetative means. Seedling population is variable because cardamom is a cross pollinated crop. Hence, vegetative propagation is normally adopted for multiplication of elite clones. Vegetative propagation can be either through rhizome bits (suckers) or by micro propagation (tissue culture). In order to raise a cardamom plantation, seedlings or suckers of high yielding varieties are to be used. The different steps involved in raising the nursery are given below.

4.1. Primary nursery

4.1.1. Site selection

Select nursery sites on gentle sloppy area and preferably near to a perennial water source. Clean the area from all existing vegetation, stumps, roots, stones etc. In the cleared area, beds can be prepared with one-meter width, 20 cm height and required length. Jungle top soil can be spread to a thickness of 2 to 3 cm on the beds.

4.1.2 Mother plant selection

Seeds should be collected from high yielding vigorous plants with well-formed compact panicles and well-ripened capsules free from infestation of pest and diseases. Number of flowering branches formed on the panicles, percentage of fruit set and number of seeds per panicle should be given due consideration while selecting the mother plants for seed collection.

Apart from these desirable attributes, the mother plant should have more number of tillers (shoots) per plant, leaves with dark green colour and high percentage of fruit set. One kg fruits contain 900-1000 capsule with 10-15 seeds per capsule. On an average 1kg of seed capsules are required to get about 3000-5000 seedlings. To plant one acre nursery half kg seed capsules are required

Seeds are collected from fully ripe capsules preferably from second to third round of harvest in September and are then either washed in water and sown immediately or mixed with wood ash and shade dried for 2 to 9 days. Immediate sowing results in higher and uniform germination . After picking seed capsules, extract the seeds, immerse them in water to separate immature seeds and thoroughly wash them in water to remove mucilaginous coating on seeds. After draining out water, seeds should be mixed with wood ash and surface dried in shade.

Storage of seeds results in loss of viability and delay in germination. Germination will get reduced if there is a delay in sowing after storing the seeds for longer periods, especially stored in airtight containers.

Cardamom seeds sown immediately after harvest in September germinate uniformly, early and satisfactorily and seedlings are ready for transplanting at the end of 8-10 months. The ideal sowing season has been reported to be November- January for Kerala and Tamil Nadu and September for Karnataka.

4.1.3. Pre sowing treatments of seeds

Cardamom seeds posses a hard seed coat that delays its germination. Acid scarification with 25 % nitric acid or sulphuric acid for 10 minutes enables uniform and early germination. The procedure for acid scarification is as follows:

Take freshly dehusked seeds and remove the sugary mucilaginous covering from the seeds by rubbing and repeated washing in water. Prepare in plastic bucket. The seeds to be treated are wrapped in nylon mosquito net and loosely tied. Immerse the seeds tied in nylon bags in the acid for 10 minutes. Remove the seeds and wash repeatedly in water to remove acid traces.

4.1.4. Sowing

Seeds are sown in lines usually not more than one cm deep. Rows are spread at 10 cm apart and seeds are sown 1-2cm apart within the row. Deep sowing of seeds should be avoided for better and quicker germination. Seed rate is 30 to 50 g per 6x1m size bed. After sowing, beds are covered with a thin layer of sand then with mulch material such as pothagrass or paddy straw. Water the beds to sufficient moisture conditions. Germination will commence in about 20-25 days after sowing and may continue for a month or two. The mulch materials are removed soon after the commencement of germination. The young seedlings are to be protected against exposure to sun and rain by providing shade over seed beds.

4.1.5. Mulching of beds

Mulching of seed beds enhances germination. The beds covered with paddy straw recorded highest germination. Mulching with dry leaves of rose wood, goose berry leaves and wild fern also helps in higher uniform germination.

4.2. Secondary nursery

There are two methods of raising seedlings in secondary nursery. They are bed and polybag nurseries.

4.2.1. Bed nursery

Prepare beds as in primary nursery. A layer of compost may be spread on the bed and mixed with soil. Seedlings of four to five leaf stage from the primary nursery beds can be transplanted in the secondary nursery at a distance of 20 x 20cm. In Karnataka, where seeds are sown during August-September, transplanting can be done in

November-January. In Kerala and Tamil Nadu states, seedlings from primary beds are transplanted to secondary nursery beds at a spacing of 20 x 20 cm during June-July. Rate of mortality was higher when transplanting was done in second leaf stage. It can be minimized by transplanting at four-five leaf stage.

On average, 120g nitrogen, 20 g phosphorus and 300 g potash, 50 g Magnesium and 75g calcium are removed from a bed planted with seedlings. To promote uniform growth, 250g mixture made of nine parts of NPK 17:17:17 and eight parts of zinc sulphate dissolved in 10 litre of water may be sprayed once in 15-20 days starting one month after transplanting. Regional Research Station, Mudigere, recommends NPK mixture at the rate of 160g per bed one month after planting. This is to be increased by 160g every month until a maximum 960g per bed is reached. The proportion of NPK is one part urea, two parts superphosphate and one part muriate of potash. Indian Institute of Spices Research, Appangala, observed that application of 45g N, 30g P_2O_5 and 60g K_2O per bed of 2.5m x 1m size in three equal splits at an interval of 45 days would result in better growth and higher number of tillers. First dose of fertilizer may be applied 30 days after transplanting in the secondary nursery.

Hand weeding has to be done once in 20-25 days and earthing up of seedlings carried out during each fertilizer application.

It would be ideal to shift nursery site once in 2-3 years to avoid buildup of soil borne pests and pathogens. In the area where such shifting is not possible due to non-availability of alternate site, leaving a part of the area fallow after deep digging/ plouging for a year would help in reducing inoculum buildup in the nursery site during the succeeding years. Fallowing in alternate year is safest approach to avoid problems of nutrients depletion and diseases in the affected nursery sites.

By following cultural practices regularly, seedlings would be ready for transplanting by 8 to10 months of sowing.

4.2.2. Poly bag nursery

Polythene bags of 20x20 cm size and thickness of 100 gauge with 3 to 4 holes at the bottom can be used for this purpose. Fill the bags with potting mixture in the ratio of 3:1:1 Jungle top soil, cowdung and sand. The bags may be arranged in rows of convenient length and breadth for easy management. Seedlings at four to five leaf stage can be transplanted into each bag (one seedling per bag). Adequate space in between the bags may be provided for better tillering. The advantages of raising seedling in poly bags are

a) Seedlings of uniform growth and tillering can be obtained

b) Nursery period can be reduced to five to six months after transplanting the seedlings as against 10 to 12 months in the secondary nursery with beds

c) Better establishment and growth of seedlings in the main field.

Cardamom plants from secondary nursery or poly bags can be transplanted to the main field during last week of May after receipt of pre-monsoon showers or the first week of June soon after commencement of south west monsoon.

Cardamom is naturally cross pollinated crop, hence seedling populations will be highly heterogeneous, and the average yield from such populations will be low compared to clonally propagated planting materials.

4.3. Vegetative propagation

Suckers from elite clones can be used for establishing plantations for high productivity. Plants raised from suckers come to bearing earlier than seedlings. Suckers should not be used in areas where katte and other virus diseases (such as Kokkekandu and Niligiri necrosis) are common. Vegetative propagation can be adopted both by using tillers (suckers) and by tissue culture plants.

4.3.1. Rapid Clonal Propagation

High yielding varieties/selections are generally multiplied in isolated clonal nurseries. Virus free high yielding plants are selected and sub cloned for further multiplication. For rapid multiplication, timely agro techniques has to be implemented

i. High yielding plants free from pest and diseases, with desirable characters as mentioned in section 4.1.1are selected and uprooted for clonal multiplication leaving the mother clump in its original place to induce subsequent suckers for further use.

ii. The minimum planting unit consists of one grown up sucker (rhizome) and a growing young shoot.

iii. Trenches having width and depth of 45 cm and convenient length have to be opened filled with jungle soil, compost and topsoil.

iv. The rhizomes (planting unit) are placed at a spacing of 1.8 m x 0.6 m in trenches, thus accommodating 9259 plants per hectare of clonal nursery area.

v. Pandal protection, regular watering (once in a week during November to May) and fertilizers @ 48:48:96 g. NPK per plant in two splits have to be applied.

vi. On an average 32-42 suckers will be produced after 12 months of planting per one planting unit. Taking the barely minimum of 50% of these suckers/ clump one can get 16-21 planting units (one grown up sucker along with a growing young shoot *i.e.* sucker) from one mother-planting unit after 12 months.

vii. In an area of 1-hectare clonal nursery 1,48,144 to 1,94,439 planting units can be produced after 12 months.

viii. Clones thus produced should be free from virus, rhizome rot and root knot nematodes.

5.0 PLANTING AND AFTER CARE

5.1. Preparation of land

Before taking up the planting, field should be made ready. For planting in a new area, ground should be cleared and if it is replanting area, old plants should be removed. Shade regulation, terracing and preparation of pits should be done during summer months.

5.1.1. Shade requirements

Cardamom is very sensitive to moisture stress, light stress and performs comparatively better in cool, shady environment. The shade canopy provides suitable environment by maintaining humidity and evaporation at suitable level. Shade requirements vary from place to place depending on the lay out of land, soil type, rainfall pattern, crop combination etc. In Guatemala, which receives well-distributed rainfall and has cool climate round the year, cardamom is grown practically in open areas with either no shade or having only very sparse shade. Light is a major factor contributing to higher productivity in that country. Gaps in the shade canopy have always lead 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.

Even though cardamom does not tolerate direct sunlight, too much shade affects metabolic activities of plants and they fail to grow well and yield. Hence, removal of excess shade is also essential so as to allow sufficient penetration. Shade has to be regulated based on the lay out of land, moisture content etc. so as to get about 50 per cent filtered sunlight for proper growth and flowering.

5.1.2. Shade regulation

Shade regulation is one of the important practices in cardamom plantations. It should be attended to during summer (March-April) in the new planting areas and during May-June after the receipt of summer showers in the existing plantations. 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 per cent 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 and borders should be provided with more shade than North eastern slopes.

Normally all kinds of trees that are found in forests are maintained as shade trees. Trees belonging to 32 families of Angiosperms constitute the major tree flora in cardamom hills of Kerala, Karnataka and Tamil Nadu. An ideal shade tree in cardamom plantation should have the following characteristics.

i. Wide canopy so that number of shade trees in an unit area is minimum.

iii. They should be of medium size having evergreen nature retaining their foliage through out the year

iv. The trees should have small leaves and a well spread branching system

v. Root system should be deep to avoid competition for surface feeding

vi. Trees should be fast growing to provide necessary immediate shade

vii. They must have heartwood to resist wind

It is desirable to maintain a mixed population of medium sized shade trees, that facilitate shade regulation and to maintain more or less optimum conditions throughout the year. Common shade trees in plantations are Balangi (*Artocarpus fraxinifolius* Wt), Nili (*Bisochofia javanica* Blum), Jack (*Artocarpus heterophyllus* Lamk), Red cedar (*Cedrella toona* Roxb), Karimaram (*Diospyros ebenum* Koenig), Karna (*Vernonia monocis* C.B. Darke), Nandi (*Lagerstroemia lanceolata*) and Spanish cherry (*Mimusops elangi*). *Maesopsis eminii*, an introduction from Africa, is a very good shade tree.

Cardamom is generally cultivated in forest area. The initial work involves clearing the under growth and thinning out overhead canopy in order to get one umbrella canopy to get filtered shade. If land is sloppy, it is advisable to start cleaning from the top and work down wards. The shade will have to be regulated in such a way as to allow sunlight to filter through tree canopy almost uniformly. The bushes/shrubs and undergrowth are cleared and heaped in a rows or piles to decay. Where slopes are steep, it is advisable to utilize such debris to check soil movement. Contour terraces may be formed in places where land is too steep. In arecanut gardens, deep trenches and pits are dug among palms and filled up with fresh soil brought from neighboring forest. In marshy areas, adequate provision should be made to drain out excess water by providing main and lateral drains depending on natural gradient of land.

5.1.3. Spacing

Cardamom even though a perennial rhizomatous crop, behaves like a biannual. The tiliers produced will bear fruits and dies with in two years. Therefore spacing should be decided based on variety and duration of crop in the field. Mysore and Vazhukka types which are tall with big rhizome characters need wider spacing and Malabar types are comparatively smaller plants and need closer spacing.

In high production technology demonstration plots, cardamom seedlings planted at 2x1m in hill slopes along the contour and 2.1x2.1m in flat lands, gentle slopes and valley bottoms, yielded over 500kg/ha in just 2 years of planting. In trials at Appangala (Karnataka, India), cardamom seedlings were planted at 2500, 3333, 5000, 6666, or 10,000 plants/ha (2x2, 2x1.5, 2x1, 2x0.75, 2x0.5 m respectively) and supplied with NPK fertilizers at 50:25:100; 100:50:200 or 150:75:300 kg /ha. During the early stages of plant growth, plant height increased as both fertilizer rate and plant density increased. The number of leaves and panicles increased with fertilizer application but decreased with plant density Optimum fertilizer rate and plant density for cardamom cultivation were 150:75:300 kg NPK/ha and 5000 plants/ha, respectively. The trench method of planting (60 cm x 30 cm) and a spacing of 2 x 1 m resulted in the best growth and yield (543.9 kg/ha). In spacing trial conducted at Yercad, Tamil Nadu, it was found that closely spaced (1x1 and 1.5x1.5m) plants recorded better yield per unit area than plants at wider spacing of 2.5x2.5m and 2x2m. In general, for Mysore and Vazhukka cultivars, plant to plant distance of 3x3m or 2.4x2.4m is ideal when planted in high rainfall or irrigated areas. A spacing of 1.8 x1.8 m or 2x2m for malabar types is suitable in Karnataka.

In sloppy lands, contour terraces need to be made in advance and pits taken along contour at 2x 1m spacing along contour. Based on slope, terraces are made 2-3meter between contours.

5.1.4. Method of planting

The trench method of planting (60 x 30 cm) and a spacing of 2 x 1 m gives best growth, yield and greater moisture retention under trench system than pit system of planting. In some places, seedlings are planted in holes just scooped out at the time of planting. In other areas, considerable care is taken in the preparation of planting pits and they are filled with surface soil mixed with leaf mould, compost or cattle manure. In Karnataka pits are smaller (45cm^3), in Kerala, for planting Var. Mysore and Vazhukka, usually pits of 90 x 90 x 45 or 90 cm are used. For Malabar, 45 x 45 x 45 cm pits are generally opened during April-May after pre-monsoon showers. Pits are filled with mixture of topsoil and compost or well rotten farmyard manure and 40g of rock phosphate.

5.1.5. Planting season

Planting season is decided based on topography and rainfall pattern. Normally planting is done in June-July. In areas experiencing heavy south-west monsoon, planting is either completed before July or is taken up in August-September, so as to avoid very heavy rains of July. Early planting gives better establishment and growth than late plantings. In low laying areas (such as valleys) planting should be done only after heavy rains by July. In Mudigere area of Karnataka, better establishment and growth resulted when seedlings were planted in August. Cardamom suckers are planted from June to August on the surface or 15-20 cm deep below the surface. Mortality is least with surface planting and when rainfall is relatively less heavy during the week after planting. Suckers planted in August survive best, with a mean mortality of 25 per cent and those planted on the surface have the lowest mortality rate.

5.1.6. Planting

Ten or 18 months old cardamom seedlings are planted in centre of pits by taking small portion of filled soil and adding 15g carbofuran and rock phosphate (40g) in the centre of pit . Soil is then replaced taking care that the roots are distributed in their normal position and well pressed around the base of the clump. Planting need to be done just above ground level so that rooting can be avoided in heavy rains. Seedlings are normally planted in a pit at acute angle for promoting shoot production. For 18 months old seedlings, light root pruning need to be taken up. In case of planting suckers, suckers may be placed in pit in slanting position and the base of rhizome may be covered with soil. After planting, cross staking need to given immediately after planting to avoid damage by wind and mulch the plant base to avoid evapo transpiration and damage due to heavy rain.

After transplanting, care should be taken to offset the transplanting shock and to save the seedlings from heavy rains. The newly planted area should be inspected regularly and gaps may be filled immediately, if the climate is favourable.

5.2. After care

5.2.1. Mulching

Fallen leaves of the shade trees are utilized for mulching. Sufficient mulch should be applied during November-December to reduce the ill effect of drought, which prevails for nearly 4-5 months in summer. Exposing the panicle over the mulch is beneficial for bee pollination.

Demulching is also equally important during May - June after the pre monsoon showers for facilitating honey bee movement to obtain better pollination and capsule setting and also for providing better aeration and minimizing incidence of clump rot or rhizome rot. The practice of uncovering the panicles shortly after the commencement of flowering improves fruit set in cardamom. The average number of capsules per panicle is 27.4 and 2.1 in case of exposed and covered panicles respectively in Malabar type. In Mysore and Vazhukka types also, fallen mulch on panicles should be removed to facilitate better pollination and to avoid deformity of capsules during development stages.

5.2.2. *Weeding*

Cardamom is a surface feeder, therefore, in the first year of planting, frequent weeding is necessary to avoid root competition between young cardamom seedlings and weeds. Depending upon the intensity of weeds, two to three rounds of weeding are necessary in a year. The first round of weeding is to be carried in May-June, the second in August-September and third in December –January and weeds can be used as mulch. In sloppy lands, only slashing of weeds is to be carried out to prevent soil erosion.

Herbicides can also be used for controlling weeds in the cardamom estates. These herbicides should not be used under organic farming. Spraying of paraquat or glyphosate may be done only in the interspaces between rows leaving 60cm around the plant base. On an average 625ml of paraquat in 500 litre of water is sufficient for one round of application per hectare. Care should be taken to avoid spray drift to any part of cardamom plant. Spraying may be taken up both in pre and post monsoon periods.

5.2.3. *Trashing*

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

5.2.4. *Earthing up*

Due to erosion of soil, top soil covering at the plant base is washed away and the rhizome and roots are exposed. Then the roots will starts drying after North-east monsoon. Earthing up of the plant base and root zone with top soil is recommended during October-December. While doing this operation, care should be taken to ensure that only top soil is used and it 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 in cardamom plantations are forking, digging and raking/loosening of soil around the root zone.

5.2.5. *Drainage*

In valleys and high rainfall areas with medium slopes, suitable drains (45 cm depth and 30 cm width) have to be provided while planting in between two rows of cardamom. These drains have to be cleaned regularly to avoid stagnation of water during rainy season. This will also avoid rhizome and root rot to considerable extent.

5.3. Replanting of cardamom

The tillers, which produced yield, dry and decay within in two years and this leads to production of new tillers from the rhizomes. Cardamom yield declines after 8-10 years based on soil fertility status and management. In order to maintain higher productivity, replanting once in 8-10 years is ideal or replanting may be decided once yield levels reduces below the economic level.

5.4. 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 receipt of a major proportion of 75 per cent rainfall 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' x 1.5' dimension trenches by filling with farm yard manure, jungle soil and top soil is found to conserve more soil moisture and supplement the plants even during dry spells. In area having slope of more than 7 percent, bench terracing of about 5-6 feet width has to be adopted for taking up cardamom planting. The clearing of shade trees before taking up planting and keeping shade trash and weeds in between the rows across the slope will help as a barrier to check soil erosion and to prevent run off losses 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.

5.4.1. Water requirements and irrigation management

Cardamom is generally grown as a rain fed crop and cardamom tracts of India experience a dry spell of about 5-6 months. Increased denudation of forests, deterioration in forest ecology and erratic trends of rainfall lead to aridity effects, adversely affecting cardamom production. Even if there is no reduction in total rainfall, failure of pre-monsoon and post-monsoon showers affects the crop adversely. During monsoon, post monsoon and winter months even if 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 from January and continue to produce flowers from May onwards. Failure of post-monsoon rains and subsequent stress situation leads to flower and fruit drop and under severe conditions drying up of portion of panicles. Therefore, irrigation is necessary, almost from January to May.

5.4.2. Methods of irrigation

Among the various methods of irrigation viz., overhead irrigation or sprinkler irrigation, drip irrigation or mini sprinkler irrigation are suited in cardamom plantations.

Sprinkler irrigation

The sprinkler method of irrigation is a mechanical process in which water is lifted from its source by means of a pumping system and conveyed under pressure through pipelines to specially designed delivery points called sprinkler nozzles in the form of spray distributed in a wide circle over the crop below, wetting both crop and soil in the manner of a shower of rain. Since cardamom is grown on hill slopes with undulating topography, sprinkler irrigation can provide uniform water supply. Field can be irrigated without excessive loss of 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 overhead sprinkling. Frequent light sprinkling can be done on soils of poor water-holding capacity. Irrigation equivalent to a rainfall of 25mm, every 10 days or 40 mm once in 15 days would be quite sufficient for cardamom crop.

Drip irrigation

There is no necessity of flooding the soil with water for maintaining a healthy plant in the field. The minimum quantity of water required by a plant would be the sum total of the amount of water transpired from the plant, lost by evaporation from the soil in the root zone and the minimum quantity of water required for washing out the unwanted salts from the root zone. If we can supply this required quantity of water to the plant, then we can make maximum use of the water available. This is the basic principle behind the development of drip irrigation. Most of our cardamom areas are on sloppy tracts 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 through sprinkler method will be too high, 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 yieldof the crop and controlled weed growth. Disadvantages of drip irrigation are clogging of outlets, unsuitability for closely spaced crops and damage caused by ants and rodents etc. Drip irrigation with 8 litres per plant daily from January 15th onwards recorded significantly higher yield followed by sprinkler irrigation once in 12 days. Initial cost of drip irrigation equipments is considered to be its limitation for large-scale adoption.

Mini sprinkler irrigation

Many farmers who have taken up intensive cultivation of cardamom with high yielding clones are irrigating cardamom by mini sprinkler irrigations. In this system, similar to drip irrigation, small pipelines are provided in middle of the rows. In general mini sprinkler heads are fixed at height of one and half to two feet and water is sprinkled around five feet radius for an hour daily. They have a discharge rate of 40-50 litre per hour. Compared to conventional sprinkler irrigation, this method is more water saving.. The main disadvantage is that the water sprinkle cannot wet the foliage

5.4.3. Time and frequency of irrigation

Since the roots of cardamom are shallow, moisture at the root zone does not last long. Hence it is essential to irrigate the crop during January to May. It is recommended that, regular irrigation may be commenced from second week of February and the irrigation requirement is equal to one acre inch (25mm once in 10 days). Protective irrigation need to given after 25-30 days of rain.

5.4.4. *Water harvesting*

Since the cardamom is grown in undulating terrain, with heavy rain and having steep slopes, many small and big streams are passing through the land. It is necessary to construct number of small ponds in order to store the water where the rain falls at convenient locations. The water collected in these farm ponds can be utilized for irrigation during dry spells or when the gap between two rains is more. The percolation or seepage loss can be prevented by giving a lining with soil cement, polythene sheet etc. When the ponds are located at the higher elevation, the water can be used for irrigation by gravitational flow. There is a need to provide additional drainage channels to remove the excess water during the heavy rains. But at the same time, to prevent excessive soil erosion and water loss small check dams or obstruction by stones may be provided in these drainages. During rainy season the water should be drained quickly and during other seasons, the water should 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 during the next dry season which can be used for giving supplemental irrigation during dry months.

5.5. Guide lines for organic cultivation practices for cardamom

5.5.1. *Selection of site*

Moderate rainfall areas (2000 to 2500mm rainfall/annum) with filtered natural shade should be selected for growing cardamom. Conversion period of minimum three years and isolation of 25 m wide space should be provided. If organically produced planting materials are used and if at least two years have elapsed without use of any inorganic inputs in the field prior to planting, the yield from such a crop shall be considered as organic. In case of cultivation in virgin lands and farms wherein no chemical inputs have been applied in the past, the conversion period can be relaxed. In the case of wild cardamom plants available in the forest, the entire produce can be considered as organic.

5.5.2. *Sources of planting material*

Initially the seeds can be collected from any elite plantation even if they are not grown organically. However, the methods followed for raising seedlings should conform to the organic standards. If rhizomes are to be used as planting material, the plantation should have been following organic methods of production at lease one year prior to collection. Tissue culture plantlets should not be used as planting materials in order to keep integrity with the natural methods of propagation. Acid treatment of seeds should be avoided, treatment of seeds with Trichoderma culture (50 ml spore suspension for 100 g of seed) is desirable as a prophylactic measure for managing nursery rot diseases. At the time of preparation of beds, incorporation of VAM multiplied in recommended organic medium may be done. For raising polybag seedlings (Preferably bio-degradable polybags), potting mixture may be prepared by using a mixture of soil rich in organic matter, well rotten cowdung or vermicompost and sand in 3:1:1 ratio.. VAM and Trichoderma can also be added (250g of mass multiplied media mixed with 25kg of well rotten cow dung) to the mixture. If growth of the seedlings is not adequate, spraying vermiwash once in a month is desirable (20ml per plant). The diseases in the nurseries may be managed by regular surveillance and adopting phytosanitary measures. Restricted application of Bordeaux mixture 1% may be done to control rot disease at the initial stage itself. Changing the nursery site is recommended to ward off pests and diseases and for vigorous growth of seedlings.

5.5.3. Preparation of land for planting

In sloppy areas, adequate soil and water conservation measures are necessary while preparing the land for planting. Planting in trenches across the slopes in low rainfall areas, diagonal planting and mulching the soil will help in soil and water conservation.

5.5.4. Cultural practices

Clean weeding is to be limited to the plant bases (50cm) and the inter rows are to be maintained by slash weeding. The weeded materials should be used for mulching. Trashed materials and fallen leaves may also used for mulching. Trashing the dry leaves and leaf sheaths as well as removal of yielded old suckers along with rhizomes may be carried out once in a year about a month after completion of final harvest, which can be used, for composting. Trashing thrice a year and cleaning the plant bases during monsoon months help in better pollination, elimination of breeding sites of thrips and aphids and reduce dampness at plant base which will reduce pest infestation and rhizome rot. The inter rows should not be dug at any cost. Water which is not contaminated with insecticides, fungicides, other chemicals and fertilizer leachates should only be used for irrigation under organic system of cultivation. This implies that the watersheds for irrigation source should also be maintained following organic methods of production. In areas where adequate soil conservation measures and mulching have been practiced, there will not be any necessity for earthing up.

To facilitate penetration of sufficient light, restricted lopping of shade tree branches may be done. However, even under such situations no tree top shall be cut. In areas which are overexposed, planting of shade trees is an essential operation and while doing so, maximum bio-diversity suited to the local situation may be considered. Trees having desirable characters such as defoliation during rainy season, self pruning habit, flowering during summer and medicinal value may be considered. If such trees belong to leguminous species they are preferred. Restricted loppings and leaf litter may be used for green leaf manuring or composting. Preservation of bee fauna is an integral part of organic cultivation. Integration of apiculture will not only ensure bio diversity, but also help in increasing the production through assured pollination.

5.5.5. Manuring

Application of organic manures such as neem cake @ 1kg or poultry manure/farmyard manure/compost/vermicompost @ 2kg per plant may be done once in a year during May-June. Application of Mussorie rock phosphate or bone meal may be done, if found necessary, based on soil analysis.

5.5.6. Plant protection

Diseases

The major soil borne fungal diseases affecting cardamom are azhukal (*phytophthora medii*) and clump rot (*Pythium vexans, Rhizoctonia solani* and *Fusarium* sp.). Incorporation of *Trichoderma* multiplied in suitable organic medium in the plant base(50 to 100gm/plant) or (1kg of compost seeded with *Trichoderma*/plant) prior to the onset of monsoon season (May) is a effective prophylactic method to manage clump rot disease. Use of Bordeaux mixture 1% when found necessary may be resorted to control rhizome rot and azhukal. For managing viral disease of cardamom, healthy clones/seedilings, removal of partly dried leaf sheaths and infected plants right from the planting stage are most effective methods. Spraying of insecticides to control aphid vector should be avoided as it results in hyper activity of vector and higher spread of disease. Infected plants should be removed promptly and destroyed or dumped in exposed isolated place.

Pests

Removal of dropping dry leaves, dry leaf sheath, old panicles and other dry plant parts is an important sanitation method recommended for reducing the pest population. Mechanical collection and destruction of egg masses of pests, larvae of hairy caterpillar (Eupterote sp) and beetles or foot grub (*Basilepta fuvlicorne*) are other approaches in reducing the pest damage. As soon as bore holes of stem borer (*Conogethes punctiferalis*) are noticed, injection of *Bacillus thurigensis* preparation into the bore hole (0.5ml in 10 ml water) will kill the larva so that subsequent resurgence can be reduced. Wherever organic methods of cultivation are adopted, out break of white flies (*Dialeurodes cardamomi*) is seldom observed. However in the event of such outbreak, collection of adults using yellow sticky trap and control of nymphs by spraying neem oil with soft soap made out of minimum caustic soda (500ml neem and 500g soft soap in 100 l water) is to be followed, In areas prone for nematodes (*Meloidogine* sp.), application of crushed neem seed can be adopted. Application of fish oil rosin soap may be done for managing thrips (*Sciothrips cardamomi*). Malabar varieties are found to be tolerant to thrips to a certain extent. Regular surveillance is absolutely essential for timely detection and adoption of remedial measures against the pests affecting cardamom.

5.5.7. Harvest and post harvest operations

After harvesting, the freshly harvested capsules need to be cleaned from dirt. Curing of cardamom capsules is done by reducing the moisture from 80% to 8-12% at an optimum temperature by retaining green colour to the maximum extent. Cardamom can be cured by two methods.

Sun drying : Cardamom is directly dried under the sunlight. Sun drying generally requires 5-6 days. It is not dependable during rainy season. This practice is followed only in some parts of Karnataka. By this method, it is not possible to obtain good green colour.

Conventional curing: This is the most commonly adopted method for curing cardamom. It requires a structure fitted with furnace, flue pipes, chimney, ventilators etc. It is a masonry structure consisting of two apartments, a curing room and a furnace room. Curing room is a tall one provided with ceiling at the roof and fitted with wire gauge on the beams at the middle of the room parallel to the ground floor, making the room in to two compartments. Flue pipes having a radius of about 25cm made with galvanised iron sheets are provided in the ground floor from one end to the other from the furnace to chimney pipe to expel the smoke through the roof. Racks holding rectangular trays are also fitted to the side walls for accommodating larger quantities of cardamom.

Capsules are spread in a single layer on the racks and trays. After spreading, the curing room is closed and heating is done by burning fire wood in the furnace as the heat produced is conducted. Only fallen trees and lopped branches should be used as fuel. The smoke passes through the pipes bringing the room temperature to 45 to 50°C. This temperature is maintained for 3 to 4 hours. At this stage, capsules sweat and give off moisture. Ventilators are then opened for sudden cooling and sweeping out vapour from the drying capsules. Ventilators are closed after vapour has escaped completely and temperature is maintained at 40°C for about 24 to 30 hours. Temperature is raised again to 45°C for one hour. The whole process of curing takes about 28 to 36 hours. In general, quality of capsules cured by this method is very good. Community curing is less costly and less polluting.

5.6. Cardamom based cropping system

In inter-cropping systems, plants compete for light, water, soil and space. Competition will occur when the immediate supply of a single necessary factor falls below the combined demands of the plants. In some perennial crops, the leaf canopies of the components of crop combinations occupy a differential vertical layer with tallest components having foliage requiring or tolerating shade and/or high humidity. Better utilization of environmental resources is the prime objective of these planting systems. In mixed cropping, even if all other conditions are favorable for growth of mixed crops, light is the limiting factor since light penetration of plant stand is reduced through interception and absorption by the taller canopy. In this situation, shade loving species, which require low light intensities, are likely to perform better under high-density multispecies cropping system. Physiological and economic analysis of various cardamom plantations adopting mixed cropping systems in Kerala and Karnataka indicated that the inclusion of black pepper (*Piper nigrum*) or coffee (*Arabica coffee*) and arecanut (*Areca catechu*) are highly remunerative giving higher cost benefit ratio.

In roubsta coffee, cardamom can be introduced without removing robusta coffee plants by trimming only the alternate side branches so as to make room for single hedge planting of cardamom. In arabica coffee and cardamom mixed cropping system, cardamom can be introduced by removing alternated rows of arabica coffee. In arecanut plantations situated at high elevations (Uttara Kannada district of

Karnataka), cardamom can be introduced between arecanut row at a spacing of 2.7 x 1.2 m. In established coconut plantations (7.5 x 7.5 m), cardamom can be introduced at a spacing of 1.5 x 1.5 m. Trees spices like nutmeg, clove and garcinia can be grown as shade trees in cardamom plantations.

5.7. Growth regulators

Application of ethrel on cardamom seedlings results in increased sucker production but lesser biomass. Plants treated with 250ppm ethrel in June and again in August which are planted in May produced more number of suckers after 16 months under low light intensity (2.4-9.6 klux) under coconut palms. Application of maleic hydrazide (MH) (250ppm), daminozide (500 ppm), chloromequate (250ppm) and ethepon (100 ppm) significantly enhanced tiller production and other vegetative characters when applied on 7-month-old seedlings. Spraying vipul, ergostin, folic acid and simazine (low concentration) at 3-4 leaf stage increased number of suckers, leaf area and biomass of cardamom seedlings.

Large numbers of cardamom fruits are shed during the process of their development. Over 80 per cent of flower and capsule drop was noticed in all cardamom types and varieties. Capsule set ranged from 15.79 to 20.29 per cent with a mean of 18.26 per cent. Various reasons are attributed to this low fruit set including climatic factors such as temperature, wind, humidity, and other factors such as improper fertilization, injuries, competition for resources, soil nutrient status, pest and diseases etc and physiological factors

Growth regulators are known to enhance fruit setting in many crop species. Studies on hormonal relationship and growth regulator application effect on flowering, fruits setting and capsule shedding in cardamom indicated that auxin activity was high in fruits 36 hours after pollination. The activity at this period was 315µg/g and it dropped to 80µg/g within one month after fruit set. The fall in auxin activity resulted in the formation of an abscission zone resulting in the shedding of immature capsules. Application of 40 ppm NAA or 4 ppm 2,4-D decreased the incidence of capsule shedding and increased the capsule yield.

5.8. Bio fertilizers

Roots of cardamom plants growing in experimental plots with three fertilizer levels were examined before and after southwest monsoon. Three species of Vesicular Arbuscular Mycorrhizal (VAM) fungi were recorded (*Glomus macrocarpum*, *G. fasciculatum* and *Gigaspora coralloidea)*. Percent colonization in roots varied from 40-100 per cent in pre monsoon samples and 63-94 per cent in post monsoon samples. Degree of infection varied from 4.5 to 76.0 in pre monsoon and 30-0 to 70.0 in post monsoon samples. The increasing doses of fertilizer tended to decrease the intensity and incidence of the VAM population in soil and roots.

5.9. Pollination management

In cardamom, pollination is effected by the activity of bees. Two species namely *Apis cerena indica* F. (Indian hive bee) and *Apis dorsata* F. (Rock bee) constitute more than 95 percent of all the flower visitors and are the true pollinating agents. The active foraging of bees is seen in the morning hours of the day which help in increasing the fruit set of cardamom. Honeybees visit cardamom flowers during flowering season for collecting nectar and pollen and they do help in attaining over 90 per cent pollination.

The mean number of flowers which open per day per plant is 34.5. The optimum bee visit for pollination is 3 to 5. In general, bee activity starts by around 7.30 AM and continues till 6.30 in the evening, the peak is between 11.00 AM to 1.00 PM. On a clear day, a flower is visited as many as 120 times, on a cloudy day 57 times and a rainy day 20 times on an average.

The number of honeybee colonies required for effective pollination of cardamom is a minimum of four colonies (about 5000 foragers per colony) per hactare (3000 plants). It is reported that maintenance of bee hives in cardamom plantations will lead to 9 to 13 percent increased yield .Mulching during flowering period hindering bee pollination resulted in 33 to 44 per cent reduction in fruit set. Bee pollination resulted in better quality capsules of uniform size and shape. Insecticide spraying during morning hours (maximum foraging activity of bees) should be avoided to get good fruit set. Insecticides that are safer to bees (eg. Phosalone) may be used.

Promoting use of bee keeping for pollination of cash crops will benefit both the bee keeper through harvest of honey as well as the farmer through higher crop productivity as a result of pollination by bees. This will help ensure food security and enhance the livelihoods of both the farmers and bee keepers.

6.0 MANURING

6.1. Fertilizer requirements

Cardamom is being grown in the rich fertile soils of forest eco-system. Due to the high status of N and K in native cardamom growing soils, a maintenance dose of 30:60:30 kg N, P_2O_5 and K_2O/ha is recommended for healthy and vigorous growth of plants. A fertilizer dose of 75:75:150 kg N, P_2O_5 and K_2O /ha was recommended under rain fed situation for normal crop of 100 kg dry capsules/ha. If the yield is more, the fertilizer doses are to be increased proportionately. Additional fertilizer dose of 0.65kg N, P_2O_5 and 1.3 kg K_2O is to be applied for increase in yield of every 2.5 kg dry capsules over normal yield. The fertilizer schedule recommended region wise is furnished in table 4.

Table 4. Fertilizer schedule for cardamom

Region	Soil application	Soil-cum-foliar application	Time of application	
			Soil	Foliar
Kerala and Karnataka	NPK 75:75:150 kg/ha	NPK 37.5:37.5:75 kg/ha	May-June	September
		Urea (2.5%)	August-September	November
		Single super phosphate (0.75%)		January
		Muriate of potash (1.0%)		
Tamil Nadu	NPK 40:80:40 kg/ha	NPK 20:40:20 kg/ha	May-June	September
		Urea (3.0%)	August-September	November
		Single super phosphate (1.0%)		January
		Muriate of potash (2.0%)		

Note: Instead of straight fertilizers, 2 per cent each of di-ammonium phosphate and muriate of potash can also be used.

It is necessary to give one-third of the recommended dose (NPK 75:75:150 kg/ha) during the first year of plant growth both under rain fed and irrigated conditions. During the second year of plant growth, the dose may be increased to one-half of the recommended dose (NPK 75:75:150 kg/ha and 125:125:250 kg NPK/ha for rain fed and irrigated conditions respectively). Fertilizers at full dose may be applied from third year of plant growth onwards.

6.2. Micro nutrients

Micronutrient survey conducted showed that Zinc deficiency is widespread in cardamom soils and boron deficiency is observed in certain areas. Application of Zinc to the foliage is found to enhance not only cardamom growth and yield but also the quality of the produce. Hence it is recommended that Zinc may be applied as a foliar spray as Zinc sulsphate @ 250gm/100 litres of water during April/May and September/ October. Approximately 1.5 kg Zinc sulphate will be needed for one application per hectare. Zinc should be applied alone and not mixed with any insecticide/fungicide/ fertilizer.

Soil application of Boron in the form of commercial grade Borax at the rate of 7.5 kg/ha is recommended in Boron deficient areas. It may be applied in 2 doses along with NPK fertilizers.

6.3. Organic inputs

One of the factor for low productivity in cardamom is inadequate application of manures either in the organic or inorganic form. To meet the nutrient requirements of cardamom, it is necessary to integrate both organic and inorganic fertilizers to obtain higher yields and also to maintain soil health and fertility. Organic manures are considered essential for improving physical characteristics of soil, apart from their nutritional values, and they are indispensable for cardamom irrespective of whether fertilizers are applied or not. Application of organic manures such as compost or farm yard manure 5kg/plant may be made once in year in May-June along with rock phosphate and murate of potash. Application of 3 - 4 t of well rotten cattle or sheep manure apart from 30 kg each of N, P_2O_5 and 40 kgs K_2O/acre greatly enhanced the yield in cardamom. Integrated nutrient management with 25% organic manure +75% inorganic fertilizers and 50% organic manure +50% inorganic fertilizers also recorded yields at par with 75 % organic manure +25 % inorganic fertilizers.

6.4. Method and time of application

Nearly 70 per cent of cardamom roots were confined to shallow depth of 5-40 cm and 30-50 cm radius. Therefore for the maximum efficiency of applied fertilizers, it would be necessary to apply them at a radius within 50 cm. Being a surface feeder, deep placement of fertilizers is not advisable. Before application of fertilizers, demulch the plant base, coil the panicle and apply the fertilizer followed by farm yard manure and mix with soil by forking. After mulching, panicles may then be released and spread on the ground for Malabar types to facilitate honeybee movement for better pollination

Growth of cardamom plant is influenced by seasonal factors, 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 per cent of flower production was recorded between May and August. Hence for efficient utilization of fertilizers, time of application is very important. Applications of fertilizers in May and later in September are found to be ideal under rain fed conditions. How ever, under irrigated conditions, as tiller initiation and panicle initiation are continuous processes, application in more splits is beneficial.

As cardamom is grown under shade trees, complete utilization of applied fertilizers by the crop may not take place because of root interference. Hence for yielding cardamom plants, soil as well as foliar application will be an effective method. Soil application of fertilizers in two rounds during May-June and August-September and subsequent applications through foliage during September, November and January is more advantageous compared to soil application alone.

7.0. DISEASES OF CARDAMOM AND THEIR MANAGEMENT

7.1. Fungal and bacterial diseases

Major fungal diseases causing considerable crop loss are 'azhukal' (capsule rot), rhizome rot (clump rot), seedling rot (damping off), leaf blight, leaf blotch and nursery leaf spots.

7.1.1. *'Azhukal' or capsule rot*

'Azhukal' is a serious problem and a major constraint in the successful cultivation of cardamom in Kerala where almost 69 per cent of the crop is grown. The disease is locally known as 'azhukal' which means rotting.

History and distribution

'Azhukal' disease was first reported from Idukki district of Kerala. Since then, it is frequently observed in Idukki and Wynad districts of Kerala and in isolated pockets of Aanamalai hills in Tamil Nadu. A crop loss of 30 per cent has been estimated. However, during years of heavy and continuous rainfall, as high as 40 per cent crop loss has been reported. It is caused by *Phytophthora nicotianae* var. *nicotianae*. . Recent studies revealed that *P.meadii* Mc Rae of A2 mating type is the pathogenic fungus responsible for 'azhukal' disease.

Symptoms

The disease appears during South West monsoon season in the form of water soaked lesions on tender leaves and capsules, which later form dead areas surrounded by yellow halo and the leaves rot and shred along the veins. In advanced stages, the infection spreads to panicles and tillers and in extreme cases the rhizomes also rot and the entire plant perishes. Immature capsules rot and fall off emitting a foul smell. Mature capsules when infected become shrivelled on drying. Symptoms of rotting appear simultaneously on capsules and tender leaves or first on capsules followed by foliage rotting. Plants of all ages are infected; however under field conditions; disease incidence is noticed mainly on bearing plants.

Spread of disease

High incidence of the disease is seen

during months of heavy and continuous rainfall and high relative humidity especially during July-August. The soil population levels of *Phytophthora* will be at its peak during this period followed by high incidence of 'azhukal'. Thick shade and close spacing together with favourable climatic conditions predispose the plants to infection. *Phytophthora* survives in soil in the form of hyphae and sporangia for 4 to 6 weeks.As chlamydospores, it can survive as long as 48 weeks in moist soils.

Disease management

Early detection of the disease and timely plant protection measures are important in managing the disease. The spraying of fungicides such as 1 % Bordeaux mixture and copper oxy chloride is recommended to control the disease.

Since the occurrence and spread of 'azhukal' disease is directly correlated to weather conditions, an integrated disease management strategy involving plant sanitation, chemical and biological methods are more suitable. Plant sanitation including removal and destruction of diseased plant parts and regulation of shade in plantations are to be carried out before the onset of monsoon. The first round of prophylactic fungicidal application should be done before the onset of monsoon, usually in May. Since water stagnation aggravates disease, better drainage in the plantation should be assured. Plant sanitation coupled with timely application of Bordeaux mixture (1%) two to three times per year effectively controls the disease.

Biological control of *P.meadii* infections using antagonistic fungi such as *Trichoderma* spp. and *Laetisaria* sp. has been found effective in managing 'azhukal' disease.

7.1.2. Rhizome rot

Rhizome rot is one of the earliest noticed fungal diseases occurring in Kerala and Karnataka, and is also called as clump rot disease.

Symptoms and damage

The disease appears as yellowing of foliage, followed by drooping of leaves; collar region becomes brittle which breaks off at slight disturbance. As the disease advances, rotting starts at collar region and extends to the rhizomes and roots and the affected tillers later fall off. Rhizome rot and shoot lodging are severe during monsoon season. In nurseries, the disease is known as damping off. The seedlings die and collapse in masses. In secondary nurseries of 6-18 month old seedlings, the symptoms are similar to those in mature plants. In nurseries, the disease incidence varies from 10 to 60 per cent.

Causal organisms

Soil borne pathogenic fungi, *Pythium vexans* and *Rhizoctonia solani* are the causal organisms of rhizome rot disease both in seedlings and bearing plants.

Disease management

For control of damping off of nursery seedlings, application of fungicide mancozeb is effective.

Antagonistic *Trichoderma* spp. are also effective in controlling the diseases in nursery and plantations. In nurseries the mass multiplied bio agents have to be incorporated as (i) coating on seeds (ii) incorporation to seed beds or planting furrows during sowing, after emergence and tillering stages.

7.1.3. Leaf blight

In recent years ,leaf blight caused by foliar infections by *Phytophthora meadii* and *Colletotrichum gloeosporides* is gaining importance. The disease appears during mid-monsoon, becomes severe during late monsoon periods (October-November) and declines by March. The symptoms develop as brownish spots and patches on the leaf lamina, often extend to large continuous areas and finally these portions or the entire affected leaves shred and dry. The disease is found only in certain localities. It has been observed that intermittent rain and continued mist formation in plantations favours the incidence and spread of the disease. The disease can be controlled by one or two rounds of Bordeaux mixture spray (1%).

7.1.4. Leaf blotch

This is comparatively less important disease and it is caused by *Phaeodactylium alpiniae*. During wet season, lesions develop at the tip or near the leaf midribs which turn necrotic brown. The mycelium and conidial masses of the fungus are visible as thick grey coloured mats or powdery coatings on the underside of the blotched area. During dry weather, infection is restricted to smaller lesions. In such cases the mycelium is not visible and the spread of the disease is also restricted. Fungicides such as Bordeaux misture (1%), copper oxychloride (0.2%) or mancozeb (0.3%) as foliar spray are effective for the control of the disease.

7.1.5. Leaf spots

Occurrence of various types of leaf spots caused by a variety of fungal pathogens is only a minor problem in cardamom plantations.

Sphaceloma leaf spot

Small scattered spherical blotches leading to large patches appear on the leaves during monsoon and it is caused by *Sphaceloma cardamomi*.

Cercospora leaf spot

It is seen both in nurseries and plantations. The symptoms appear on the foliage as rectangular or linear lesions which are muddy red in colour running along and bound by the veins, 0.5 to 2 mm wide and of varying lengths. The upper side of the lesions is dark brown in colour with less defined margin. A number of such spots are formed on the leaves. The disease is caused by *Cercospora zingiberi* which produces conidiophores in clusters with few conidia which are linear and 3-6 septate.

Leaf spots caused by *Cercospora elettariae* occur rarely on cardamom leaves. *Phaeotrichoconis* leaf spot appears on young and old leaves both under dry and wet conditions as papery white irregular areas with brown margins. During dry weather, the central portions dry and break off.

Leaf blight caused by *Alternaria* sp. is observed rarely in young seedlings. It appears in the form of desiccated areas on the foliage which later show symptoms of wilting. It can be controlled through the use of fungicides such as mancozeb (0.3%).

7.1.6. Leaf rust

The disease appears after monsoon rains during October to May. The symptoms appear as small pin head white pustules on leaves which later become rusty brown in appearance. Many such pustules formed in clusters are surrounded by a broad yellow halo. It is caused by *Phakospora elettariae*.

In recent years widespread incidence of leaf rust has been observed in lower Pulney areas of Tamil Nadu.

7.1.7. Chenthal or leaf blight

The disease was locally known as 'chenthal'. The symptoms of the disease appear as elongated water soaked lesions on the abaxial surface of young leaves. In advanced stages, the lesions become brown to dark brown with a pale yellow halo. The leaves wither resulting in wilting of pseudostems. The disease affected gardens present a burnt appearance. Flowers produced after disease incidençe fail to form capsules.

Though *Corynebacterium* was reported earlier, detailed investigations carried out in later years showed that *Colletotrichum gloeosporioides* is the pathogen responsible for the disease.

Several *Colletotrichum* leaf spots leading to blight similar to the so called 'chenthal' is a common occurrence in cardamom plantations which are exposed to direct sunlight. The disease is aggravated during summer season. Providing adequate shade in the plantation and mulching the plants to conserve soil moisture etc.ensure disease control to a certain extent. Spraying of mancozeb (0.3%) or Bordeaux mixture (1%) was found to limit the further spread of infection.

7.1.8. Minor diseases on capsules

In addition to foliar diseases, a number of fungi cause various minor diseases on capsules. *Fusarium* capsule rot caused by *F.moniliforme, Rhizoctonia* solani and anthracnose or brown spot cuased by *C.gloeosporioides* are also reported to occur in recent years. Trashing followed by spraying helps to control these diseases.

7.1.9. Stem lodging

A new disease producing lesions on the pseudostems leading to dry rotting and lodging of tillers was recently observed in several cardamom areas particularly in lower Pulneys. The pathogen was identified as *Fusarium oxysporum*. The disease occurs during the post monsoon periods.

7.1.10. Nursery leaf spot

This is a most important nursery disease and it is caused by *Phyllosticta elettariae* Disease symptoms develop on the leaves of young seedlings as whitish round spots which later turn papery white with a hole in the center. The disease is more severe and widespread in nurseries in Karnataka. In severe cases, rotting of leaves is also observed followed by reduced tillering. Spraying with Difolatan (0.2%) or Bordeaux mixture (1%) is effective in managing *Phyllosticta* leaf spots.

7.2. Viral diseases of cardamom

Crop losses caused by widespread occurrence of cardamom mosaic virus (*'Katte'*) has been considered as one of the major production constraints to cardamom in India. Occurrence of cardamom necrosis virus (Nilgiri necrosis virus) and cardamom vein clearing disease (*Kokke kandu*) in some endemic zones is also a matter of concern to Indian cardamom industry.

7.2.1. Mosaic or 'Katte' disease (Cdmv)

Mosaic disease is locally known as 'katte' meaning a disorder and is also known as marble disease in Annamalais.

Distribution

Earliest reference of 'katte' dates back to 1900. In South India, 'katte' is widely distributed in all the cardamom growing tracts with incidence ranging from 0.01 to 99.0 per cent. In India, a survey conducted during 1992 has revealed the presence of katte disease in many gardens in Kerala with an incidence ranging from 0.01 to 99.9 per cent. Cardamom grown in Gautemala remained free of virus disease until the 1970s. In 1975 a disease with virus like symptoms was observed in some parts of Gautemala and within 5 years the disease spread to all the nearby plantations of the southern pacific cost region, which produces 60 per cent of cardamom in Gautemala. Recent survey conducted for 'katte' and 'kokke kandu' has revealed the prevalence of 'katte' in most of the plantations surveyed in cardamom areas.

Crop loss

The loss in yield due to the disease depends upon the stage of crop at the time of infection and duration that the plants have been infected. If the plants are infected in the seedling stage or early prebearing stage the loss will be almost total. Infection on bearing stage results in gradual decline in the productivity. Crop loss of 10-60 per cent, 26-91 per cent and 82-92 per cent was reported in cardamom raised as a mixed crop with areca nut during first, second and third years of production respectively. Similarly in monocrop situations, the infection on bearing plants reduced the yield to 38 per cent during the same year of infection, 62 per cent in the second year of infection and 68.7 per cent in the third year of infection. Total decline of plants occurs after 3-5 years of infection.

Symptoms

The first visible symptom appears on the youngest leaf of the affected tiller as slender chlorotic flecks measuring 2-5 mm in length. Later these flecks develop into pale green discontinuous stripes. These stripes run parallel to the vein from the midrib to leaf margin. All subsequently emerging new leaves show characteristic mosaic symptoms with stripes of green tissue almost evenly distributed over the entire lamina. Often mosaic type of mottling is seen on the leaf sheaths and young pseudo stems. Variation in the field symptoms were seen in different cardamom growing tracts of South India on inoculation of different virus isolates on common host. Plants of all stages are susceptible to virus infection and the infection is systemic in nature and gradually spreads to all the tillers in the plant. In the advanced stages, the affected plants produce shorter and slender tillers with few shorter panicles and degenerate gradually.

Transmission

The virus is not transmitted through seed, soil, root to root contact and through manual operations. The only method of the dissemination of the virus is by means of banana aphid (*Pentalonia nigronervosa* Coq.) and also through infected rhizomes. The first experimental transmission of 'katte' virus in India was obtained with banana aphid.

Spread of the disease

Infected clones and apparently healthy clones, seedlings raised in the vicinity of infected plantations, volunteers collected from severely infected plantations and few infected Zingiberaceous hosts (*Amomum* sp.) form the initial sources of virus infection. In a contiguous area, infected plants are the reservoirs of virus sources.

Pattern of disease spread

Primary spread: In plantations, the primary spread occurs at random due to activity of viruliferous alate forms of the vector. Under field conditions, the plantations which are located 4-600 m from concentrated virus sources, the percentage of primary infection varied from 0.07 to 5.19. The frequency of random spread directly depends upon access and nearness to virus sources.

Secondary spread: After the primary spread, the secondary spread of disease is mainly internal and the rate of spread is very low. Centrifugal spread was found around primary centres due to the activity of the apterate adults. In plantations, the disease is concentrated within 40 m radius with occasional random spread up to 90 m distance. The gradient of infection is steep within 40 m from initial foci and it flattens thereafter. In Guatemala and areca based cardamom crop in some parts of South India, the rate of disease spread is very fast and natural infection may reach 83 per cent within 6 months of planting.

Disease incubation period: In the field, the disease incubation period varies from 20 to 114 days during different months and its expression is directly influenced by the growth of the plants. Usually the young seedlings at 3-4 leaves stage express the symptoms within 15-20 days of inoculation, whereas grown up plants show symptoms within 30-40 days during active growing period and 90-120 days during winter months. Senile leaf sheaths, which are natural breeding site of the vector are poor inoculum sources but the young actively growing parts serve as better sources of inoculum.

Host range of the virus

Several plants belonging to the family Zingiberaceae viz., *Amomum connecarpum, A. involucraltum, A. subulatum, Alpinia neutans, A. mutica, Curcuma neilgherrensis, Zingiber cernuum* and arrow root (*Maranta arundinacea)* were found infected in lab inoculation tests.

Causal organism

The evidence for the viral nature of the disease was first established in 1945 with the successful transmission of virus through the banana aphid *P. nigronervosa*. Studies in Gautemala and India have evidently shown the association of flexuous rod shaped virus particles measuring 650 nm in length and 10-12 nm in diameter. The purified preparations of six strains also revealed homogenous flexuous particles. Presence of inclusion bodies was also reported from leaf tissues of mosaic-infected plants. Based on the morphology of virus particles and presence of characteristic pinwheel shaped inclusion bodies, it was suggested to include mosaic in 'poty virus'. In Gautemala, mosaic affected cardamom leaves revealed pinwheel type inclusion bodies which is a common feature in other poty viruses. Leaf dip extracts showed particles of 660 nm length and those of purified preparation showed 700-720 nm long particles. Recent studies confirmed that Maclura virus, which comes under poty viridae, causes the cardamom mosaic virus in India.

7.2.2. *Cardamom vein clearing disease or Kokke Kandu (Cdvcv)*

This disease is a new threat to cardamom in some endemic pockets in all the main cardamom growing districts of Karnataka state in India. Surveys conducted in 1991-93 indicated the prevalence of 'kokke kandu' ranging from 0.1 - 79.99 percent in plantations and nurseries. Because of its characteristic symptom "hook like tiller", in Karnataka state,India it is locally called as "Kokke Kandu".

Importance

All the 5 cardamom growing districts/ areas viz., Kodagu, Hassan, Chickmagalur, Shimoga and North Canara revealed the presence of the disease. In 381 plantations surveyed, wide spread incidence of 'katte' and 'kokke kandu' and mixed infections were seen in 375 plantations with incidence ranging from 0.1 to 82 per cent. A survey in 39 nurseries in hotspots also revealed the incidence of' kokke kandu 'right in nurseries raised in vicinity of infected plantations..

Crop loss

The affected plants decline rapidly. Yield reduction is to the extent of 62-84 per cent in the first year of peak crop. Under mixed crop conditions with arecanut as main crop, yield losses varied from 68-94 per cent in the plants with different stages of infection. The affected plants decline very rapidly and become stunted and perish within 1-2 years of infection. Thousands of ha area in Hongadahalla zone in Hassan district and arecanut based mixed crop in North Canara district in Karnataka have become uneconomical due to mixed infection of 'katte' and "Kokke Kandu" diseases.

Symptoms

The first symptomic leaf reveals characteristic continuous or discontinuous intraveinal clearing, stunting, rosetting, loosening of leaf sheath, shredding of leaves and clear mottling on pseudo stem. Clear light green patches with three shallow grooves are seen on the immature capsules. Cracking of fruits and partial sterility of seeds are other associated symptoms. In summer, the newly infected plants reveal only faint discontinuous vein clearing symptoms. However, mottling on pseudo stem is clear in summer months also. Plants of all stages right from seedlings to bearing stage show these symptoms.

Transmission

Kokke kandu is not transmitted through seed, soil, mechanical contact, leaves, roots and farm implements. The disease is transmitted through cardamom aphid, *Pentalonia nigronervosa* f. *caladii* in a semi-persistent manner. Single viruliferous aphid can transmit virus and plants of all stages with incubation period ranging from 22-128 days are susceptible to infection.

Causal organism

The exact etiology of associated organism(s) is not yet established.

Disease spread

Primary spread: Like mosaic, the initial spread occurs randomly in distant blocks due to the activity of incoming alate viruliferous vectors. Random spread was reported in new plantations located up to 2000 m away from the infected plantations. The frequency of primary spread is directly dependant on the distance from centres of infection.

Secondary spread: Within the infected plantations, both centrifugal and random spread are noticed. The alate forms of the aphid are responsible for random spread and apterate forms for the centrifugal spread. In the infected plantation, the rate of spread varied from 1.3 to 8.5 per cent per unit per year. The disease spread depends on the distance and level of incidence in the foci of infection. Gradient is steep near concentrated sources of virus inoculum and it is shallow in the next 100 m.

7.2.3. Cardamom necrosis disease (Nilgiri necrosis disease)

This disease was first noticed in severe form in Nilgiris, Tamil Nadu, hence the name Nilgiri Necrosis Virus (NNV). Recent survey conducted revealed the existence of the disease in new pockets in Kerala, Tamil Nadu and few spots in Karnataka. These are located in Nilgiris, Anamalais, Cardamom hills and Biligeri Rangana hills.

Importance

Random survey in South India revealed the low incidence of 0.1 to 1 per cent. Only in an isolated case, incidence up to 13 per cent was recorded in Valparai, Tamil Nadu. Recent random survey in South India revealed that the disease is prevalent in some of the cardamom growing regions of Tamil Nadu with an incidence ranging from 7.7 to 80 per cent. In Lower Pulneys out of 24 plantations surveyed only one plantation in Thadiankudisai reveled 76 per cent incidence. In Valparai 7.7 to 15.07 per cent incidence was recorded. Highest incidence of 80 per cent was recorded in Conoor of Nilgiris. In Kerala, some estates in Munnar and Thondimalai areas of Idukki, an incidence of 4.6 and 1.46 per cent was recorded respectively. Unlike 'katte' the infected plants decline very rapidly and become stunted and unproductive.

Symptoms

The symptoms are seen on young leaves as whitish to yellowish continuous or broken streaks proceeding from the midrib to the leaf margins. In advanced stages of infection, these streaks turn reddish brown. Often leaf shredding is noticed along these streaks. The leaves are reduced in size with distorted margins. Early infected plants produce few panicles and capsules but in advanced stages of infection, tillers are highly stunted and fail to bear panicles and capsules. All the three types of cardamom cultivars are susceptible to the disease.

Crop loss

Plants in the early infection stage recorded less reduction in the yield when compared to the plants in advanced stage of infection. One-year study carried out in diseased plantation revealed a 55 per cent reduction in yield in early-infected plants and 99.8 per cent reduction in late infected plants.

Transmission

The disease is not found to be transmitted by seed, soil, sap and mechanical means. It is transmitted through planting of infected rhizomes. No insect transmission of the disease from infected to healthy were recorded so far.

Causal organism

Association of flexuous particles of 570-700 nm and 10-12 nm breadth size was seen in the dip preparations of NNV infected leaf tissue and it belongs to "Carla" virus group.

Spread of disease

The infected rhizomes/seedlings raised from diseased nurseries are the primary sources of inoculum. Plotting of new infections at regular intervals in a diseased plantation revealed that the spread of the disease is mainly internal and new infection occurs in a centrifugal fashion from the source of inoculum. Most of the infections occurred within 10-15 m radius from the source of inoculum and the number of new infections decreased as the distance increased. The pattern of spread is similar to that of 'katte' disease of small cardamom. The rate of spread of the disease is rather low , being 3.3 per cent for the period of one year. Occurrence of few outbreaks around the infection foci is an indication that the disease can be successfully managed by periodical rouging of infected plants.

7.2.4. Infectious variegation virus

This disease was first noticed in Vandiperiyar area in Kerala in a severe form. Further it was also noticed in Coorg, Hassan and North Canara districts in Karnataka. A disease incidence of 15 per cent was recorded in Vandiperiyar zones. Infected plants show typical variegated symptoms on leaf with characteristic slender to broad radiating stripes of light and dark green colours on the lamina. Distortion of leaves, tillers and stunting are other associated common symptoms. The infected plants become unproductive within the same year of infection. Only 2 per cent transmission was obtained through the aphid *P. nigronervosa* f. *caladii*. Rouging resulted in near elimination of disease in the test plantations in Birunani (Kodagu, Karnataka) and Manjushree (Nilgiris, Tamil Nadu).

7.3. Integrated management of viral diseases of cardamom

7.3.1. Production and use of virus-free planting material

Seedlings: Because of many infrastructure constraints like suitable nursery site, water resources, accessibility, availability of labour force and security, seedlings are raised repeatedly in the same nursery site more commonly in the area adjacent to plantations which invariably are infected. Seedlings require 10-18 months to attain planting stage. The prolonged exposure to virus access through viruliferous aphids in the vicinity of concentrated virus sources results in the infection in nursery stage itself. Further, secondary spread in nursery through aphids results in the spread of virus to many plants. As high as 28 per cent 'katte' and 73.33 per cent 'kokke kandu' was reported in the nursery stage itself. Since 'katte', 'kokke kandu' and Nilgiri necrosis are not seed transmitted and lack of long distance movement by the vactor beyond 2000 m, raising nursery in isolated places is necessary to produce healthy seedlings. For 'katte', isolation of more than 200 m from virus sources is adequate and for 'kokke kandu', isolation of more than 2000 m is necessary.

Clones: Apparently healthy high yielding plants are normally subcloned and planted for gap filling and raising plantation. As the infected plants take 23 -168 days to express 'mosaic' symptoms and 22-128 days to express vein-clearing symptoms, it is not advisable to use clones from severely infected gardens. Like nurseries, clonal nurseries also have to be raised in isolated sites. In micro propagation, starting material has to be checked for virus free status.

Avoidance of volunteers: Volunteers which sprout from remnants of infected materials are the potential primary sources of spread. Self-sown seedlings in the infected plantations are exposed to virus access for 2-8 months. As high as 28 per cent infection was recorded in the nurseries raised from volunteers. Removal of infected volunteers in replanted area and total avoidance of volunteers for nursery activity in hot spots are most important requisites for producing virus free planting material.

Movement of planting material: In India, surveys conducted in 1981 and in 1994 shown that within the infected zone/plantation there are many disease free pockets. Further, 'kokke kandu' is confined to few endemic pockets only. In Guatemala also large area is free from mosaic infection. Creating awareness for preventing the movement of planting material across locations have to be followed to check introduction/reintroduction of viruses.

7.3.2. Vector management

Chemical control

Because of non-persistent nature of mosaic and semi persistent nature of 'kokke kandu' chemical control measures are not that effective to reduce secondary spread. The insecticides at recommended concentrations do not kill the aphids rapidly enough to prevent probing. Further, persistence of aphid vector throughout the year makes vector control measurers almost impracticable. Thirty four insecticides were evaluated to determine their effect on transmission and acquisition of katte virus under laboratory conditions. Transmission results showed that none of the insecticides tested were effective on acquisition and transmission of the virus even on the day of insecticide application. Being non-persistent, mosaic can be transmitted within short periods of probing and feeding. Mere probing is sufficient for transmission of virus. This may be the reason for ineffectiveness of insecticides in checking secondary spread. The cardamom aphid *P. nigronervosa f. caladii* is photophobic and it is found in colonies of 30-50 comprising nymphs, alate and apterate adults. These colonies are found in between the pseudo stems and loose leaf sheaths especially of old, partly dried or damaged parts. Occasionally the colonies are found on the leaf spindles, young suckers and panicles. Because of their concealed placement in the older parts, the possibilities of direct access to contact insecticides and indirect contact to systemic insecticides are less. As a result of insecticide treatment, the disturbance of vector colonies and the consequent hyperactivity, probing and intermittent migration in search of suitable hosts may be responsible for ineffectiveness of some chemical like Phorate(granules), Carbofuran (granules) and Phosphamidon.

Non-chemical methods

Removal of breeding sites: The photophobic vector breeds in the senile, concealed parts of the host. Periodical removal of old parts of the rhizomatous crop is effective in reducing the aphid population and the spread of mosaic. Other plants like *Colocasia* sp., and *Caladium* are the other natural hosts of cardamom aphid which are naturally found in the swampy areas of cardamom plantations. Removal of the breeding sites and other hosts are necessary to check reinfestation of aphid.

Use of biopesticides: Extracts of many botanicals *were found to be effective in reducing the breeding of aphid vector. Neem* products significantly reduced the settlement of the aphids on the cardamom leaves even at 0.1 per cent concentration and lethal to aphids at higher concentrations. Aqueous extracts of *Acorus calamus* L.(dried rhizome), *Annona squamosa* L. (seeds) and *Lawsonia inermis* L. (Leaves) reduced the settling percentage of aphids. Vapours of *A. calamus* are highly toxic to aphids and cause total mortality. Essential oil of turmeric (*Curcuma longa* L.) was also found to possess repellant property against the aphid.

7.3.3. Removal of virus sources

In management of plant viruses, phytosanitation involves the detection and elimination of virus sources present within and outside the crop. Efficiency of phytosanitaion in management of viral diseases of cardamom is centered on prompt inspection, detection and elimination of virus sources. Attempts to control katte disease spread began as soon as researchers recognized the role of virus and such control has been mainly based on sanitation or removal of virus source. Rouging is effective in minimising the spread and enhancing economic life of the plantation. How ever, the disease intensity and distribution of disease within the plantation are the prime factors which need careful scrutiny to adopt rouging. It is more appropriate to adopt rouging as an effective means of containing disease spread if the disease is less than 10 per cent. Generally in the plantations, the disease is seen concentrated in patches with random spread in few spots. In concentrated spots, survey to detect fresh infection and rouging may be undertaken at shorter intervals to minimise the chances *of secondary spread. This may be continued for 3-4* months *till* the new outbreaks are *reduced and* thereafter survey intervals can be increased . Through sustained timely efforts, new infections can be reduced to 2-3 per cent per annum although it is impossible to eradicate the disease in a plantation because of predominance of small holdings and multiple chances of reintroduction. In contiguous cardamom holdings, isolated attempts are not adequate to contain the disease economically. In such areas, community approach through total removal of all the plants followed by replanting and surveillance are shown to be more feasible. In varied field situations like (i). new plantation in isolated place, (ii). new plantation in hot spot, (iii). plantation with unidirectional virus source, (iv). plantation with multi directional virus source, (v). plantation located between two infected plantations and (vi). plantation in continuous belt, different approaches involving total removal and replanting, selective rouging and gap filling, phased replanting etc can be shown effective in reducing secondary spread.

In 'katte' and 'kokke kandu' infected area, there is independent and also mixed infection of both viruses. In such areas comprehensive efforts involving use of healthy seedlings, periodical survey through trained disease surveillance gang, prompt removal and destruction of infected plants are reported to be effective in containing both viral diseases.

Integration of several methods like (i). Strategies to produce healthy seedlings in isolated place , (ii). Efforts to reduce vector population, (iii). Use of virus resistant lines and (iv). Removal of foci of infection are required to manage virus diseases in the field. Establishment of plant disease clinics in potential cardamom zones also helps to create awareness and train planting community to manage viral diseases. In India, an attempt was made to contain mosaic through 'katte clinic' programme. There was encouraging response from the growers to this and in a period of 8 months 60 plantations extending to 393 ha area distributed in 30 villages in Coorg district were covered. In India, the erstwhile Government of Bombay tried to eradicate the katte disease in North Canara district by providing technical assistance at Government cost. Similarly Spices Board also took up katte eradication programme in contiguous blocks by giving technical and financial assistance for rouging. These programmes have created awareness about identification and management techniques to contain spread of viral diseases.

8.0. INSECT AND NEMATODE PESTS AND MANAGEMENT

Pest infestation in varying degrees at various stages of crop is an important factor which contributes to the high cost of cultivation and low yield in cardamom. As many 60 insect and non-insect pests attack cardamom, but only 5 or 6 are the major problems. The most important pests are Thrips, shoot and capsule borers, root grubs, hairy caterpillar and shoot fly. Knowledge on most damaging pests and pest complex is necessary to plan pest management measures.

8.1. Major pests

8.1.1.Cardamom thrips (Sciothrips cardamomi Ramk.*)*

The cardamom thrips is the most destructive pest of cardamom and was first described from Anamalai hills and later from other cardamom growing areas.

The adults and larvae lacerate and feed on leaves, shoots, inflorescences and capsules. When panicles are infested, it results in shedding of flowers and immature capsules. The feeding activity on tender capsules results in the formation of corky, scab-like encrustations on them. These later become malformed and shriveled with slits on the outer skin; the seeds within them are poorly developed and lack the usual aroma. The extent of damage may be as high as 80 per cent in certain areas. The thrips breed within unopened leaf spindles, leaf sheaths, flower bracts and flower tubes.

The adults are grayish brown and measure 1.25-1.50 mm in length. Reproduction is by sexual and parthenogenetic means. The egg period lasts for 9-12 days. There are two larval, a prepupal and pupal stages. The life cycle from egg to adult is completed in 3-4 weeks. The population of thrips is generally high during summer months and declines with the onset of rains. The Mysore and Vazhukka types of cardamom are highly susceptible to thrips infestation. The pest infestation was also higher with closer spacing.

A number of alternate hosts were recorded in the field. These include *Panicum longipes, Hedychium flavescens, H.coronarium, Amomum carnaecarpum, A. involucratum, A.subulatum,* *A.microstephanum, Afromomum melegueata, Remusatia vivipara, Colocasia antiquorum, Zingiber sp., Curcuma pseudomontana, Costus speciosus, Crinum sp., Globba ophioglossa* and *Alpinia galanga*.

8.1.2. Shoot and capsule borer (Conogethes punctiferalis Guen.)

The shoot and capsule borer is a serious pest in nurseries and main fields in Kerala, Karnataka and Tamil Nadu. The larvae bore into pseudo stems and feed on the internal contents leading to formation of 'dead heart' symptoms. The larvae also bore into the panicles resulting in drying up of the same and into the capsules feeding on the seeds.

The adult is a small moth with a wing span of about 24 mm; the wings are orange yellow with small black spots. The earlier instars of larvae bore into panicles, flower buds and capsules and the late instar larvae bore into pseudo stems. Studies on the life cycle of the pest conducted at Idukki (Kerala) indicated that the total period from egg to adult took 41-57 days during summer (March-May) and 84-123 days during winter (November-February). The pest infestation was generally observed throughout the year but was higher during January, March, June, August and October.

The shoot borer is highly polyphagous. Its other hosts include guava, mango, peaches, pomegranate, jack, ginger, turmeric, avocado, mulberry, loquat, pear, sorghum, cocoa, castor, tamarind, amaranthus, soapnut, hollyhocks, *Caesalpinia bonducella, Anona cherimelia, Zingiberaceous* hosts like *Curcuma aromatica, C. amada, Alpinia* sp., *Amomum* sp.and *Aframomum melegueta*. The other *Zingiberaceous* hosts recorded include *Amomum subulatum, A.microstephanum, Hedychium coronarium, H.flavescens* and *Alpinia galanga*.

8.1. 3. Root grub (Basilepta fulvicorne Jacoby)

Root grubs are major pests of cardamom in nurseries and main fields and widely distributed in Kerala, Karnataka and Tamil Nadu. In Karnataka, the pest is generally serious in primary and secondary nurseries. The grubs feed and damage roots and portions of rhizomes; some times the entire root system is eaten away. The infested plants turn yellow and are stunted; severely infested plants die.

The adults are shiny metallic blue, green or brown beetles measuring 4-6 x 2-4 mm. Males are smaller than females. The adults are polyphagous feeding on a number of plants that are present around cardamom plantations. The peak periods of adult emergence at Idukki (Kerala) was during April and September. The females lay eggs in soil around the base of clumps and fully grown grubs are pale white, stout and 'C' shaped, and measure about 1 cm in length. At Idukki, the egg, larval and pupal stages lasted for 13-19, 45-60 and 10-17 days, respectively. At Mudigere (Karnataka) the egg, larval and pupal stages lasted for 10-15, 78-80 and 20-25 days, respectively.

8.2. Minor pests

*8.2.1.*Capsule borers

The lycaenid borer *Jamides* sp. is some times serious in Karnataka and the caterpillars bore into and feed on flowers and capsules. The affected capsules become empty, decay and drop off. The pest is generally serious during the monsoon and hence control of the pest with insecticides is difficult. Spraying with quinalphos or methyl parathion (0.05% each) during early blooming period helps in reducing the pest damage *J.alecto* was also reported from Mudigere (Karnataka).

Adults and larvae of *Thamurgides cardamomi* bore into capsules and feed on the mucilage. The incidence of the pest is high during the monsoon, particularly in densely shaded areas. Regulation of shade and spraying with quinalphos or methyl parathion (0.05% each) during the crop period is recommended for the control of the pest.

Adults of *Onthophagus* sp. and *O. coorgensis* also bore into flowers and young capsules, while the larvae feed on roots. When young capsules are attacked, they decay and drop off. The symptoms of damage are similar to that of *T. cardamomi*. Regulation of shade and spraying with quinalphos or methyl parathion (0.05% each) is effective against the pest.

Tribolium castaneum (Hbst.) is a serious pest on stored cardamom. Storage of capsules in disinfected alkathene lined jute bags is recommended to control the pest infestation.

8.2.2. Root and rhizome borers

The larvae of *Hilarographa caminodes* Meyr. bore into roots making tunnels filled with frass. The roots die due to the pest infestation and the entire clump dries if the infestation is severe. The caterpillars of the moth remain inactive without feeding during summer months. Destruction of infested plants and drenching with chloropyriphos (0.03%) is recommended for the control of the pest.

The grubs of *Prodioctes sp.* tunnel into rhizomes and sometimes into pseudo stems also. The pest infestation is generally serious in the secondary nursery. The grub phase is prolonged and lasts for about 3 months. Destruction of infested rhizomes, drenching chloropyriphos 0.03% and use of healthy rhizomes collected from non-infested areas are recommended for the control of the pest.

Maggots of *Hallomyia cardamomi* Nayar were recorded to bore into exposed roots causing extensive galling. Larvae of *Mimela xanthorrhina* Hope, *Holotrichia serrata* and *Anomala* sp. were also reported to damage roots and rhizomes of cardamom.

8.2.3. Sap feeders

Infestation by *Dialeurodes cardamomi* Favid & Subr. is more serious in Kerala and Tamil Nadu. The adults and nymphs are seen in colonies on the lower leaf surface and they suck the sap. Severe infestation results in yellowing of leaves and the plants lose their vigour. The pest infestation is more severe during summer. A fungus, *Aschersonia placenta* was found to infect over 95 per cent of the pupae during an outbreak of pest in Kerala. Spraying ethion (0.1%) or acephate (0.07%) and neem oil (5%) is effective in controlling the pest.

Colonies of *Pentalonia nigronervosa* f. *caladii* van der Goot are seen within leaf sheaths of older pseudo stems. The adults and nymphs suck the plant sap. Though the damage caused by them is not very serious, they act as vectors of mosaic or 'katte' disease of cardamom. Reproduction is by viviparous and parthenogenetic means. The life cycle is completed in 10-15 days with four nymphal instars. The pest population was high during January-February in the field. The aphid was also found breeding on *Colocasia* sp., *Alocasia* sp. and *Caladium* sp.

The other sap feeders recorded on cardamom include *Planococcus citri*, *Saissetia nigra*, *S.coffeae* Walk. *Bothrogonia* sp., *Eosocarta nilgiriensis* Dist., *Aphrophora nuwarana* Dist., *Cosmoscartaz thoracica* Dist., *Diaspis* sp., *Mytilaspis* sp., *Tettigoniella ferruginea*, *Riptortus pedestris* F., *Stephanitis typica* Dist. and *Ischnodemus vochus* Tol.

8.2.4. *Foliage feeders*

The grass hoppers *Orthacris* sp. and *Aularches miliaris* L., the leaf beetles *Lema* sp., *L.admiralis*, *L.coromandeliana* and *L.subirdes* and thrips *Panchaetothrips indicus* Bagn. and *Leewania maculans* Pr. damage cardamom leaves. The leaf feeding caterpillars recorded on cardamom include *Acanthopsyche bipar* Walk., *Homona* sp., *Attacus atlas* L., *Plesionuera alysos* M., *Notocrypta feisthamelii* B., *Polythilpta maoralis* Led., *Eumelia rosalia* Cram., *Anisodes denticulatus* Hamps., *Thalassodes* sp. and *Arcilasia plagiata* M.

8.2.5. *Hairy caterpillars*

Hairy caterpillars appear sporadically in large numbers and cause severe damage to cardamom by defoliating the plants. Eight species of hairy caterpillars are associated with cardamom. These include *Eupterote canarica* Moore, *E. cardamomi* Renga, *E. fabia* Cram., *E.testacea* Walk., *Lenodera vittata* Walk., *Euproctis lutifacia* Hamp. *Alphaea biguttata* Walk. and *Pericallia ricini* Fab. Among them, *E.cardamomi*, *E.canarica* and *L.vittata* . The caterpillars are gregarious in habit and they congregate on trunks of shade trees during day time. The females lay large number of eggs and the larval period is also extended.

8.2.6. *Shoot fly*

The larvae of *Formosina flavipes* Mall. feed on the growing shoot of young cardamom plants resulting in formation of dead hearts. The pest incidence is generally severe during the months of October-November and March-April and young plants in new plantations with inadequate shade are seriously affected. For controlling the pest, early planting, removal and destruction of maggots and spraying with dimethoate, quinalphos or methyl parathion (0.05% each) or application of carbofuran 3 G (20-25 kg/ha) are to be followed systematically. Sufficient shade should also be provided in the plantation to reduce the infestation

8.3. Integrated pest management in cardamom

8.3.1. Pest management in nurseries

In nursery stage seedlings are affected by cut worm, shoot borer, root grub, leaf thrips and root knot nematode. Infestation by root grubs and leaf thrips poses more problems in two season nurseries. To manage whole pest complex, the following measures are to be followed at various stages of nursery.

Cultural practices

i. Raise nurseries away from main plantations to reduce possibilities of infestation and reinfestation.

ii. Provide sufficient organic fertilizers to encourage better vegetative growth.

iii. Shift nurseries sites regularly to overcome soil borne pest infestation like root knot nematode and root grubs.

iv. Catch and kill the beetles of root grubs through insect nets in 2 season nurseries.

v. Collect the cut worms hiding in the mulch in the affected spot and destroy.

Chemical control

i. Spray with quinolphos (0.05%), Fenthion (0.075%) or Dimethoate (0.05%). Give insecticidal spray at monthly interval from the rapid tillering stage onwards.

ii. In the old nursery sites, exposed sandy loam areas and two season nurseries root knot nematode assumes serious proportion. Apply one round of Furadan or phorate at 30-40 g/sq metre in one season nursery at rapidly tillering stage and apply two rounds of granular insecticides to two season nurseries at 3 monthly interval.

iii. Application of granular insecticides at 3 monthly intervals is essential to protect underground and sub-aerial parts in clonal nurseries.

8.3.2. Prebearing stage

Shoot fly, root grubs and root knot nematode are the main pests in the prebearing stage which lasts for 18-30 months. Response of plants, tillering, vegetative vigour and uptake of nutritional inputs depend on the health of the root system. The maiden peak harvest totally depends on the proper management of these three main insect pests. To manage these pests, following measures can be adopted.

i. Apply granular insecticides during initial establishment and tillering stage @ 20-40 gm per plant.

ii. Catch root grub beetles through insect nets and destroy.

iii. Trace the maggots and larvae of shoot borer from the small tillers showing dead heart symptoms and destroy.

iv. Spray with insecticide quinolphos (0.05%) or Fenthion (0.075%) or Dimethoate (0.05%) during early monsoon and late monsoon periods.

8.3.3. Bearing stage

Thrips, shoot and capsule borers, root grubs, root knot nematodes and occasionally defoliators are the main pests during the bearing period. To manage the complex pest problems, integration of cultural methods and chemical methods is essential. It is always advisable to apply insecticides during afternoon hours and during flowering period. Select only those insecticides which are less toxic to honey bees. Apply insecticides only after trashing to reduce quantity of insecticides, to provide better coverage and to increase efficiency. Heavy (more than 60 mm) over lapping rain is detrimental to most of the pests. In periods of successive over lapping rains, insecticide application may be deferred.

Cultural practices

i. Undertake earthing up, up to the collar region immediately after last rain to protect active exposed feeder roots.

ii. Undertake trashing thrice a year during early monsoon, mid-monsoon and late monsoon periods to remove pest breeding sites.

iii. Provide adequate mulch to protect feeder zone.

iv. Remove the weeds and other herbaceous cover which act as hosts for many potential pests.

v. Collect the adult beetles of root grubs during the peak periods of emergence i.e. April-May and September-October using hand nets and kill them. The beetles, which are brightly coloured in metallic shades, could be easily spotted during day time. Being weak fliers, they could be easily caught using sweep nets. In the same way the adult moths of shoot and capsule borer which are found resting on the lower surface of cardamom leaves can be collected by net and killed.

vi. Cardamom tillers harbouring the larvae and pupae of shoot and capsule borers as indicated by the presence of fresh excreta should be cut and destroyed. This will greatly reduce the emergence of the subsequent generation

vii. The hairy caterpillars are gregarious in habit and they congregate on the trunk of shade trees during day time. These congregations should be traced, collected and killed mechanically.

viii. The adults of hairy caterpillars can be lured and captivated by operating light traps at night. These can be collected later and killed.

Chemical control

A holistic schedule as given in table 5 may be followed to manage shoot & panicle borer, capsule borer, thrips, defoliator and sapling feeders.

Table 5. Spray Schedule for Pest Management

Spray	Stage of crop	Insecticide	Concentration	Qualtity/100 litres of water
1.	Panicle elongation	Quinolphos/ Fenthion	0.05% a.i. 0.05% a.i.	200 ml. 60 ml.
2.	Stray flowering (30-40 days after 1st spray)	Quinolphos or Chlorpyriphos or Phosalone	0.025% a.i. 0.04% a.i. 0.07% a.i.	100 ml. 200 ml. 200 ml.
3.	Flowering stage	Phosalone	0.07% a.i.	200 ml.
4.	Fruit development & stray flowering	Chlorpyriphos	0.06% a.i.	300 ml.
5.	Fruit development, ripening & production of new tillers (for erect/ semi erect types)	-do-	-do-	-do-
6.	-do-	-do-	-do-	-do-

* A gap of 30-40 days may be given between the sprays

* Since highest bee activity is seen in morning hours, spraying may be undertaken in the afternoon hours.

* Spraying after trashing increases efficiency and reduces the quantity of pesticide solution.

8.4. Management of nematode pests

Plant parasitic nematodes cause considerable damage to feeder roots of cardamom. The most important nematodes infesting cardamom are the root knot nematodes *Meloidogyne incognita* and *M .javanica* occurring in nurseries and plantations.

8.4.1. Symptoms:

Mature plants on heavy infestation show stunting, yellowing, reduced tillering, premature drying of leaf tips and margins, reduced leaf size, delay in flowering, immature capsule drop and reduction in yield. Root knots are found in young seedlings only and excessive branching is common both in seedling and bearing stages. Severe nematode infestation is responsible for pre-emergence failure in primary seed beds and reduced production of standard seedlings in secondary nursery, poor establishment of nematode infested seedlings in main field, yield reduction in bearing stages and increased incidence of root and rhizome diseases.

8.4.2. Spread

Root knot nematode spreads mainly through infested planting material. Many weeds and shade trees like *Erythrina indica* and *E.lithosperma* are hosts of nematode and they help in build up of population. Exposed areas and sandy soils favour higher multiplication of nematodes.

8.4.3. Losses

Nematode infestation leads to reduced yield to the extent of 32-47%.

8.4.4. Management

Management in nurseries

Disinfecting nursery beds through biocides like Ethylene dibromide, formalin or methyl bromide under polythene cover for 3-7 days or application of granular insecticides like phorate 10 G @ 30-40 g/sq m or Furadan 3G @ 40-50 g/sq.m. help in reducing nematode population.

Management in plantation

An integrated package involving planting of nematode free seedlings, provision of mulch in particularly in exposed areas, application of organic manures, application of neem oil cake twice a year @ 250-1000 g depending on the clump size and spot application of granular insecticides like Furadan 3G/phorate 10 G 15-50 gm, depending on the size of the plant twice a year in May/June and September helps to reduce nematode population. Application of nematicide immediately after harvest keeping the minimum 12-15 days inter harvesting gap reduces possible residue in the processed capsules. Alternating with first nematicide application in pre-monsoon period followed by neem oil cake application in mid monsoon period is the safest approach to reduce residue problem in the fruits.

9.0. POST HARVEST PROCESSING AND VALUE ADDITION

Cardamom plants start bearing two years after planting of suckers/seedlings. Panicles appear from the base of plants from January onwards and the peak period of flowering is from April to December, which may extend further. Generally flowering is high during June to August period. Fruits mature in about 120 days after flowering. Fruits are trilocular capsules containing 15-20 seeds. On maturity, seed turn black in colour. The Indian cardamom is known for its rich colour, flavour and aroma. The aromatic seeds inside the fruit pod form the spice.

9.1. Time and stage of harvesting

Due to prolonged flowering period, cardamom capsules ripen successively at 10 - 15 days intervals over an extended period of 8 months (from August to March). Generally harvesting is carried out at an interval of 15-30 days and completed in 8-9 rounds. Fruits (capsules) that are fully mature and still retaining dark green colour of rind (peel) and black coloured seeds are picked by experienced workers. Harvesting done at ripe stage will lead to loss of green colour and also will result in splitting of capsules during curing.

Percentage recovery of dry capsules will be 29% from ripe capsules, 34% from physiologically mature and 14% from immature stage. Hence it is ideal to pick cardamom at physiologically mature stage (rind green colour and seeds inside the capsules black in colour).

Two types of pickings are adopted - light picking and hard picking. In light picking, only mature capsules are harvested. In hard-picking semi-mature crop is also removed which reduces the curing percentage, but increases the efficiency in this labour intensive crop. In this method, more green coloured capsules are obtained after curing and it also reduces the chance of fruit drop and rodents damage in the field.

9.2. Retention of green colour

Colour and size of processed cardamom is an important factor in the consumer market. The Arabian (Middle East) markets prefer green coloured cardamom. The traditionally recognized highest quality cardamom is 'Alleppey Green' which is still regarded as the best. This traditional 'Alleppey Green' comes from the high ranges of Idukki district where the predominant varieties grown are Vazhukka and Mysore types.

Different chemical treatments have been tried to retain green colour of harvested capsules, which fetches premium price in the market. Soaking green (wet) capsules immediately after harvesting in anti oxidants like 2% sodium carbonate solution for 10min fixes green colour during subsequent drying and storage. Immature capsules retain greater intensity of green colour.

9.3. Curing and drying

On maturity, the dark green capsules are harvested and cured within 24 to 36 hours

Table 6. Mean dry recovery and essential oil content at different stages of harvest

Genotypes	Dry recovery (%)			Seed weight (%)			Oil yield (%)		
	FR	PM	IM	FR	PM	IM	FR	PM	IM
IISR Avinash	20.5	17.5	16.5	72.8	68.7	68.0	5.4	6.3	6.8
Vander Cardamom	22.7	19.4	17.7	73.1	72.5	72.5	6.2	6.7	7.0
Green Gold	23.7	17.9	17.6	73.2	69.5	66.4	6.2	7.1	7.3
APG 250 (Compound panicle)	23.2	19.8	18.5	72.3	70.5	70.6	5.0	7.1	6.9
APG 416 (Vazhukka)	24.4	19.8	18.5	74.3	71.5	65.9	5.8	7.7	8.7

(FR - fully ripened, PM - physiologically matured, IM - immature) in order to avoid deterioration in quality. The cardamom curing may be defined as the process in which the moisture content of freshly harvested cardamom capsules is reduced from 70-80% to 11-12% at an optimum temperature of 45-55°C so as to retain its green colour and volatile oil to a maximum extent.

The widely adopted system is a slow, passive process stretching up to 24-30 hours with an initial temperature around 45°C. The entire curing time can be divided into four stages as follows:

Stage	Time lag
I	3 to 4 hours
II	6 hours
III	9 hours
IV	9 to final curing

Maturity of capsules and curing temperature influence the colour and quality of processed cardamom. During the process of drying, if temperature exceeds the threshold levels, capsules tend to develop brownish streaks as a result of heat injury. Increase in drying temperature also results in loss of oil from seeds. Maintaining the temperature at 40-45°C in all 4 stages of drying helps in good retention of green colour. Drying at a temperature of 55°C and 60°C significantly increases the percentage of yellow and splitting of capsules. Gradual increase of drying temperature to 50 °C - 60 °C in the last two hours of curing enables easy removal of flower remnants during polishing.

Maximum loss of chlorophyll occurs in the initial 6 hours of curing. Lesser temperature has to be maintained in the initial stages for extraction of moisture when evaporation is from the surface layers of capsules.

Drying of cardamom is normally adopted using firewood, fuel, electricity or sunlight. There are two type of drying in cardamom

1. Natural (Sun drying)
2. Artificial drying

9.3.1. Natural (Sun drying)

In this method, the harvested capsules are directly dried under sun for a period of five to six days or more depending on the availability of sun light. From this method, it is not possible to obtain green colour. Frequent turning of capsules leads to their splitting. Further if the weather is cloudy and rainy, drying is not possible and quality of the harvested capsules may deteriorate. This type of dried capsules is not preferred for export. This method is most common in some parts of Karnataka.

9.3.2. Artificial drying

Flue pipe dryer

It is one of the best methods of drying by which high quality green cardamom can be obtained and where drying is carried out in specially designed driers/curing houses. These curing houses are masonry structures, which are fabricated to meet the requirements. The dryer walls are made of bricks or stones and tiled roof with wooden ceiling. A furnace is situated on one side of the chamber. Burning firewood produces heat. A pipe made of zinc or iron sheet starting from the 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 either side of the wall ensure uniform spreading of heat. Inside the room trays are piled one over the other with spacing of 20-22.5 cm between the trays. The fire in the furnace has to be regulated so as to maintain the temperature of 45-55°C. Under these conditions, it is possible to obtain high quality green cardamom in about 24-30 hours. A drying chamber of dimension 4.5m length and breadth is sufficient for a plantation producing 2 tonnes of fresh cardamom. The firewood requirement for drying one kg fresh cardamom will be three-four kg. Since the construction cost of the dryer is very high, the small and marginal growers find it difficult to own driers. Large quantity of firewood for burning and requirement of space are other major disadvantages.

Melccard dryer

This is a fire wood operated dryer being used at Bodinayakanur region (Tamil Nadu). It consists of a fully insulated (fire bricks with mud coating) oven kept 3m 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 drier and is finally exhausted through two chimneys. The surface of the smoke tank and flue pipes transfer heat to the dryer. A central opening at the ceiling (with an exhaust fan) of the dryer ensures conservation of heat . 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 (with wheels) 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 pipes. Dried capsules are rubbed by hand or with coir mat or wire mesh and winnowed to remove other plant residues and foreign matter. They are then sorted out according to size and colour.

Electrical dryer

There are different types of electrical dryers available in the plantations. The normal electric dryer is of 90 x 84cm size inside of which contains 24 aluminium trays of 81cm length and 40cm breadth , piled one over the other with a gap of 2 cm between trays. Green capsules after harvesting are to be uniformly spread in the trays Uniform distribution of heat is ensured by means of fans. This way, 50kg of capsules can be dried in 10-12 hours. It is possible to obtain good green coloured cardamom by maintaining the temperature between 45 and 50°C.

We cannot use this method when regular power supply is not assured in carda mom growing tracts which are remote. The cost of electricity is also very high. Further the splitting rate of capsules is also high compared to the conventional system.

Bin dryer

The bin drier is designed by University of Agricultural Sciences, Bangalore, Karnataka; Drying unit consists mainly of a blower with motor, electrical heating unit and drying chamber. The blower is of backward curve vane type coupled to 373 KW motor, with 2820 revolutions per min. Volume of air driven through the dryer can be adjusted from 1.5 -8 cm^3/sec. The dryer is made of mild steel, asbestos sheet and wood. Aluminium or steel trays of the size 0.4 x 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 the trays. Hot air passing through the pipes increases the temperature ranging from 30°C to 80°C. Good quality cardamom can be produced by drying capsules at 55°C by maintaining the volume of air at 3.7m3/sec. The relative humidity ranges from 65 to 92 per cent during drying. The cost of drying by this method is around Rs.0.66/kg compared to Rs.1/kg in the conventional method.

Solar cardamom dryer

Direct type solar dryer developed by the Central Plantation Crops Research Institute (CPCRI), Kasaragod for copra drying can also be used for cardamom. The drier has an area of 1m^2 drying surface made of painted wire mesh tray (black colour) placed over corrugated GI sheet (black colour) inclined at 12.5°. Aluminium foil reflectors of 1.5 m^2 are provided from three sides of the dryer. Load density of materials can be 3 times more than that used in open drying system. Complete drying of cardamom could be achieved within 3 days using this dryer in comparison to 5 days in open sun.

Mechanical cardamom dryer

This is developed by the Regional Research Laboratory, Trivandrum and it consists of a centrifugal blower, electric furnace, arrangements for uniform hot air flow and a drying chamber. It can be used for drying cardamom at a load of 120kg fresh cardamom/batch. It takes 22 hours for complete drying at a temperature of 50°C. The final product is found to possess superior green colour, flavour and appearance.

Kerosene stove dryer

During 1995-96, Jose Ananda Bhavan of Kerala attempted to dry cardamom using Nutan Kerosene stoves with fair degree of success. This was evaluated by the Indian Cardamom Research Institute, Myladampara for its efficiency and economics and found handy for small quantity of drying. The drying cost workout be Rs.1.8 -2.00/kg wet cardamom. For drying 50 kg ,a small room of 2.4 x 2.4 x 3 m (l x b x h) with four kerosene Nutan stoves is required. However availability of Kerosene and risks in handlings are the limitations.

Liquefied petroleum gas (LPG)

Indian Cardamom Research Institute, Idukki for the first time in collaboration with Caltex Spic India Ltd initiated studies since 1998 to use LP Gas as an alternate source of fuel for drying cardamom. The system was standardized for small quantity of 50-100 kg capacity. The construction cost of the cabinet with trays works out to be Rs.10,000 . Infra red radiant burner was used for heating with the fuel source as LP gas. The drying cost works out to be Rs.2.5 -3.00/kg wet. The drying time is 10-12 hours. The drying is clean and retension of green colour is good. Half a dozen planters of Karnataka have installed this drying method with high rate of success and less drying cost. At present, use of LPG in existing traditional curing houses using canteen type burners namely T-22, T-35, T-50 and T-78 with minimum modification and investment is going on with fair amount of success at ICRI. The advantage of this drier is that growers can use either LP gas or fire wood depending upon the situation.

Diesel dryer

Bin type of dryer of capacity 100-300 kg is in use in some plantations. The hot air at 45-55oC are blown from the bottom into the bin containing 100-300 kg green cardamom in a bin. The cardamom will be float in the hot air. It is started with electricity or generator. Later heat is generated by diesel engine. Temperature will be raised once in two hours. It takes 22 hours to dry cardamom. Cardamom keeps good green colour after drying.

9.4. Bleaching of cardamom

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

9.4.1. Bleaching of freshly harvested capsules

Fresh capsules are soaked for 1 hour in 20% Potassium Metabisulphite solution containing 1% Hydrogen Peroxide solution which will degrade the chlorophyll. Drying of these capsules will give "golden Yellow coloured" bleached cardamom.

9.4.2. Bleaching of dry capsules

Sulphur bleaching

This process involves fumigation using Sulphur with alternate periods of soaking and drying. Capsules are soaked in 2% bleaching powder (920 g/l of water) for 1 hour and spread on wooden trays which are arranged inside airtight chambers. Sulphur Dioxide produced by burning Sulphur (15 g/kg of capsules) is made to pass over the trays. The process of soaking and drying is repeated 3-4 times depending on the intensity of white colour required.

Potassium Metabisulphite bleaching

In this method capsules are treated with 2% Potassium Metabisulphite containing 1% Hydro chloric acid for 30 minutes. Further they are transferred to 4% Hydrogen Peroxide solution for 6 hours.

Hydrogen Peroxide bleaching

Hydrogen peroxide at low concentration (4-6%) and pH 4 can bleach capsules in 6-8 hours of soaking. These capsules are then dried to moisture content of 10-12%. Bleached capsules contain sulphur which protects cardamom from pests. Some reports say that this type of bleaching leads to loss of volatile oil.

9.5. Moisture content

Moisture levels in cardamom samples of market ranges from 7 to 20% depending on regions and mode of curing. It is found that 10% moisture is ideal for the retention of green colour. Well-dried capsules produce a typical sound on shaking.

9.6. Packing

Cardamom is a high value spice and all care should be given for efficient packing. The cured capsules are graded using sieves of 8, 7.5, 7 and 6mm which are manually operated. After grading cardamom need to stored over a period of time, in double lined polythene bags. Storage rooms should be free from insect damage. Studies have shown that cardamom dried and maintained at or below 10% moisture retains original parrot green colour and avoids mould growth. It is advisable to make use of dried cardamom capsules preferably within 12 months of harvesting.

9.7. Other value added products of cardamom

9.7.1. *Cardamom seeds*

Cardamom seeds are obtained by decorticating capsules. Decortication is achieved by using a flourmill or plate mill which is also called as disc mill. Normally the ratio of seeds to husk in matured capsules is 70:30.

9.7.2. *Cardamom powder*

Cardamom in its powder form gives the maximum flavour to the food products. But the disadvantage is that powdered form loses aroma and quality by rapid loss of volatiles. Hence the powder needs more protection on storage than whole capsules or seeds.

9.7.3. *Cardamom oil*

Cardamom oil is obtained by distillation of powdered seeds of cardamom. Steam distillation is the common method employed for the production of oil. The quality of oil depends on the variety, rate and time of distillation. The important trade varieties are Alleppey green, Coorg green and Saklesphpur bleached. Yield of volatile oil from the seeds of these three varieties reported is 10.8 per cent, 9.0 per cent and 8.0 per cent respectively External appearance, size or bleached colour need not be the parameters to be considered while selecting cardamom for distillation. The high-grade cardamom is not used for distillation, since it fetches a better price as whole cardamom in the trade. Lower grades, which do not fetch higher value with defective appearance, but still good from the flavour point of view, are ideally suited for distillation. The husk is almost devoid of any volatile oil. The flavour of cardamom is mainly due to 1,8 cineole, terpinyl acetate, linalyl *acetate and linalool.*

9.7.4. *Cardamom oleoresin*

Oleoresin is made of two components, viz., the volatile oil and resin. Volatile oil represents the aroma while the resin is made up of non-volatile matter like, colour, fat, pungent constituents, waxes etc. The total flavour of a spice is obtained only after blending the oil and resin. Volatile oil is obtained by steam or hydro-distillation while the resin is obtained by solvent extraction. The demand for cardamom oleoresin is only small unlike other spice oleoresins. Cardamom oil itself accounts for almost all the aroma and flavour of the capsules.

10.0. ECONOMICS AND MARKETING

10.1. Cost of cultivation

Productivity and cost of cultivation plays crucial role in deciding the competitiveness of product in the global market. Compared to India, the cost of production in Guatemala is much lower. This is mainly due to high productivity and low wages. The present estimated cost in India ranges from Rs. 150 to 250 per Kg of dry cardamom and it depends upon area, variety, cultivation system and cropping system followed. The wages component in total cost of production make the Indian cardamom costly, which accounts up to 60 per cent during the establishment stage and more than 40 per cent in the subsequent years.

Interest on borrowed capital, depreciation value and hidden cost are other important factors deciding the cost of cultivation of cardamom and it vary from region to region because of difference in wage rates, systems of cultivation and access to transportation.

Table 7. Cost of cultivation for 1 hectare @ Rs. 90 per day of wage

Particulars	I Year	II Year	III Year	
Cleaning site	3600.00	--	--	
Shade regulation	3500.00	1500.00	2000.00	
Marking lines	900.00	--	--	
Marking Roads/Foot paths	1000.00	500.00	--	
Taking drain	2000.00	--	--	
Taking and filling pits	7000.00	800.00	--	
Planting materials	1100.00	500.00	350.00	
Planting/staking/mulching	2500.00	350.00	250.00	
FYM	5700.00	6250.00	6250.00	
Neem cake/vermicompost	7700.00	7700.00	7700.00	
Fertilizers	1500.00	2500.00	4100.00	
Manuring	2250.00	3500.00	4000.00	
Weeding	5000.00	6000.00	5000.00	
Trashing	--	--	3500.00	
Plant protection chemicals	2500.00	3500.00	4500.00	
Plant protection operation	2800.00	3450.00	5250.00	
Digging	3500.00	4750.00	3700.00	
Irrigation	4500.00	5100.00	5500.00	
Maintaining drainage & foot paths	--	600.00	750.00	
Harvesting & Processing	--	6500.00	15550.00	Net profit at the end of third year
Total cost of cultivation	**57050.00**	**53500.00**	**68400.00**	
Yield per hectare (kg)	-	**250.00**	**700.00**	
@Rs.150/kg		37500	112500	92950
@Rs.250/kg		62500	187500	196500
@Rs.350/kg		87500	262500	281600

Source: Spice Statistics, Spices Board.2004

10.2. Grades of cardamom

Mostly grades available in the market are based on physical parameters such as colour, size, weight per specific volume, freedom from microbial, insect and filth contaminations. The grade specifications, as per the norms of Indian Standards Institution are given in table 10.

10.3. Marketing

Cardamom trade in India is affected through regulated market. Different players such as exporters, clearers and auctioneers are involved in the marketing. The entry of these actors and their functions are

Table 8. Economics of cardamom in mixed cropping systems (Kerala)

Cropping system	Plant density (ha^{-1})	Yield (kg/ha)	Expenditure (Rs.)	Price ($Rs.kg^{-1}$)	Average annual income (Rs.)	Cost Benefit Ratio
Cardamom +	1000	200	35000	300	140000	1:4
Black pepper	750	1600		50		
Cardamom +	1000	250	45000	300	182000	1:3:5
Arecanut +	750	1600		5		
Black pepper	750	1765		50		
Cardamom +	1000	150	45000	300	160000	1:3:5
Arecanut +	500	1500		5		
Black pepper +	500	1700		50		
Coconut	75	7500(nuts)		3(nut^{-1})		
Cardamom +	750	125	40000	300	85000	1:2
Rubber +	500	1000		40		
Arecanut	500	1500		5		
Cardamom +	1000	100	25000	200	50000	1:2
Banana	750	750(bunches)		40($bunch^{-1}$)		

Table 9. Economics of cardamom in mixed cropping systems (Karnataka)

Cropping system	Plant density (ha^{-1})	Yield (Kg/ha^{-1})	Expenditure (Rs.)	Price($Rs.Kg^{-1}$)	Average annual income (Rs.)	Cost Benefit Ratio
Arecanut +	1400	6000	36000	10	120000	1:3.5
Cardamom	2500	300		200		
Cardamom +	2000	196	33000	200	101200	1:5
Arecanut +	1400	5000		10		
Black pepper	750	300		40		
Cardamom +	1500	100	21500	200	112300	1:5
Arecanut +	1000	6030		10		
Black pepper +	750	300		40		
Coffee	1000	500		40		
Cardamom +	2000	750	33650	200	110000	1:3 5
Coffee +	1000	300		40		
Black pepper	750	500		40		

regulated through the Cardamom (licensing and marketing) rules 1987 which also provide norms for streamlining the system of marketing. As per the norms, various

Table 10. Specifications for Indian cardamom (based on physical characters)

Grade	Description	Size (mm)	Weight (g/l)min	Colour	General characteristics
AG Alleppey Green					
AGB	Extra Bold	7	435	Green	
AGS	Superior	5	385		Kiln dried, 3 cornered
AGS 1	Shipment	4	320-350	Light green	and with ribbed
AGL	Light	3.5	260		appearance
CG Coorg Green					
CGEB	Extra Bold	8	450	Golden to light	
CGB	Bold	7.5	435	green	
CG-1	Superior	6.5	415	Light green	Round ribbed or
CG-2	Mota. Green	6	385	Green	smooth skin
CG-3	Shipment	5.5	350	Cream	
CG-4	Light	3.5	280	Brown	
Bleached					
BL-1		8.5	340	Pale	Fully developed round/3
BL-2		7	340	Creamy	cornered ribbed or
BL-3		5	300	Dull white	smooth skin

Source: Indian standards Institution, New Delhi-1

certificates and licenses viz. cardamom export *licenses, cardamom auctioneer li*censes, certificates of registration for exporters are issued by the Spices Board under the Ministry of Commerce, GOI.

A salient feature of market structure is the existence of an efficient auction system, which ensures fair prices to the growers who are willing to take the produce to the auction centres. At present, there are 11 auction centres in India. The licensed auctioneers conduct weekly auctions during the harvest season in production tracts or assembly centres on particular days as approved by the Spices Board. In spite of this type of regulated trade, only 70 per cent of the production in the country flows through the auction centres and the remaining flows from producers to dealers out side the auction system. The reasons for this are the non existence of auction centers in places that are remote closer to *the producing centres and norms of auction* being not suited to lots of smaller sizes.

10.4. Price structure

Cardamom is a moderately storable export commodity. The domestic price formation in cardamom is based upon season to season *intelligent* speculation by farmers/ producers on production; such speculations being made depending on the length of summer, severity of droughts, pre monsoon showers and quantum of rainfall during June-July. If the anticipated production is much lower than the normal, a much higher price is set for the particular season and vice versa if anticipated production is higher. At the same time, the export prices are set based on the speculations made through out the harvesting seasons by the dealers on quality aspects. The trends in cardamom

Table 11. Export of cardamom from India

Year	Quantity (mt)	Value (Rs. Lakhs)	Unit Value (Rs/Kg)
1970-71	1,705	1121.60	65.78
1971-72	2,147	803.07	37.40
1972-73	1,384	684.65	49.47
1973-74	1,813	1155.28	63.72
1974-75	1,626	1332.32	81.94
1975-76	1,941	1938.37	99.86
1976-77	893	1403.14	157.13
1977-78	2,763	4843.63	175.30
1978-79	2,876	5835.36	202.90
1979-80	2,636	4855.81	184.21
1980-81	2,345	3475.39	148.20
1981-82	2,325	3019.69	129.88
1982-83	1,032	1636.90	158.61
1983-84	258	544.23	210.94
1984-85	2,383	6480.53	271.95
1985-86	3,272	5345.99	163.39
1986-87	1,447	1849.53	127.82
1987-88	270	340.03	125.94
1988-89	787	1037.36	131.81
1989-90	173	314.11	181.57
1990-91	400	1086.61	271.65
1991-92	544	1557.41	286.29
1992-93	190	75.57	395.04
1993-94	387	1454.83	375.93
1994-95	257	762.61	296.74
1995-96	527	1266.78	246.10
1996-97	226	869.67	384.81
1997-98	370	1266.78	342.37
1998-99	476	2525.27	530.52
1999-00	676	3270.72	483.83
2000-01	1545	8468.02	548.09
2001-02	1031	6167.80	598.23
2002-03	682	4707.42	690.24
2003-04	690	3301.00	478.41

Source: Spice Statistics, Spices Board.2004

prices over the years shows that there is a cyclical fluctuation in prices; prices remain stable or tend to increase during a certain period and followed by a sharp fall. They remain low for the next few years and then start rising and continue to increase or remain stable for another period. The process of decline and increase repeats itself. The period of this cycle is worked out to be 11 years, As regards to the overall trend, the prices have been increasing from 1950's, the increase being 10 fold in 30 years till the middle of 1980's.

10.5. Exports

Even though historically cardamom in

India was an export oriented crop, recent trends show drastic decline in exports with the domestic market absorbing the bulk of the produce. Till the end of 1960's, India was monopolizing the export market. Ever since then Guatemala stepped up its production and captured India's traditional markets. The details of export figures from the country till the year 2000 are furnished in table 11.

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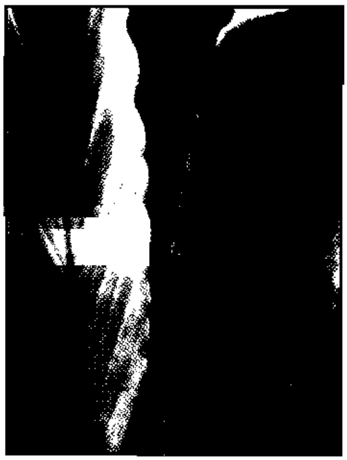

'Kokke kand' disease

Rhizom rot

Thrips and borer

GINGER

A. Kumar, B. Sasikumar, V. Srinivasan, T. John Zachariah, P. Rajeev

1.0. INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is a herbaceous perennial, but cultivated as an annual. The crop is originated as a native of tropical South-East Asia from where it was introduced into the West Indies, African countries and other tropical belt of the world. Ginger is the underground stem (rhizome) of a perennial herb, which is used as a spice. The knobby rhizome is harvested between 6 and 12 months after planting. It is then prepared for market by either scalding, to produce black ginger, or by scraping and washing to produce white ginger. It is sold in the fresh condition or, more frequently, in a peeled and split dried form. Ginger is utilized widely as a spice, for pickles, candies and as a medicinal herb. This compilation is all about aspects related to ginger production including pest and disease management, post harvest technology and value addition in ginger

1.1. Area and production

The Indian production of ginger during the year 2002-03 was estimated at 3.07 lakh tonnes from an area of 85.93 thousand ha. Ginger production is mainly distributed over India, China, Nigeria, Indonesia, Bangladesh, Thailand, Philippines, Hawaii, Jamaica etc. The countries importing the biggest amounts are the United Kingdom, United States and Saudi Arabia. Nigeria ranks first with respect to area under ginger covering about 56.23 percent of world total area followed by India (23.60%), China (4.47%), Indonesia (3.37%) and Bangladesh (2.32%). India ranks first with respect to ginger production contributing about 32.75 percent of total world's ginger production followed by China (21.41%), Nigeria (12.54%) and Bangladesh (10.80%). World average ginger productivity is 2419 kg/ha. It is also grown in countries such as Japan, Mauritius, South Africa, Indonesia, Malaysia, Philippines and West Indies. In India, states of Kerala, Karnataka, Sikkim, Himachal Pradesh, Meghalaya, Assam and other Northeastern states cultivate this crop very extensively. Indian ginger has high esteem in the global market because of its characteristic lemon like flavour. India is the largest producer of dry ginger in the world and it contributes 33 percent of the world production accounting for a foreign exchange earning to the tune of around Rs.30 crores per annum. India as a largest producer of ginger has capabilities to cater to the requirements of the consuming countries in terms of quantity and quality matching to international standards. The crop exhibited an annual growth rate of 4.6 per cent in area, 7.4 per cent in production and 2.7 per cent in productivity. Though grown all over India, the finest quality ginger comes from Kerala endowed as it is with a congenial climate and a rich earthy soil. However, four states viz. Kerala, Meghalaya, Arunachal Pradesh and Orissa together contribute over 60 per cent to the country's total production. The state wise area and production details in India is furnished in table 1.

Table 1. Area & production of ginger in India

States	Area ('000 ha)	Prodn. ('000 mt)
Andhra Pradesh	2.03	3.31
Andmans & Nicobar	0.40	1.28
Arunachal Pradesh	4.45	32.33
Bihar	0.49	0.73
Chhattisgarh	1.38	1.10
Gujarat	1.15	19.41
Haryana	-	-
Himachal Pradesh	-	-
Jammu & Kashmir	0.04	0.05
Karnataka	9.76	12.85
Kerala	9.00	32.41
Madhya Pradesh	5.19	5.33
Maharashtra	1.30	1.25
Manipur	2.14	3.53
Meghalaya	7.92	45.65
Mizoram	5.10	31.14
Nagaland	2.01	13.33
Orissa	15.34	29.49
Rajasthan	0.18	0.64
Sikkim	4.95	23.61
Tamil Nadu	0.42	6.67
Tripura	1.36	5.45
Uttar Pradesh	0.67	1.58
Uttaranchal	1.27	16.02
West Bengal	9.38	20.21
Total	**85.93**	**307.37**

Source : Spices Statistics, Spices Board 2004

1.2. Composition and uses

The average chemical composition of some of the traditional ginger cultivars are listed in table 2. Ginger is used in dry as well as fresh (raw) form. The dry ginger is the basic material for ginger powder, which is major ingredient in all the curry powders. Ginger powder is used in confectionary, pharmaceutical preparations, nutriceuticals, canning industry etc. Oil extracted from ginger is used for flavoring liquors, soft drinks, culinary products etc. Oleoresin extracted from the powder is used as a substitute in catering industry as it imparts total flavor of the spice.

In fully matured ginger, fibre content varies from 3-8%. Fibre separates at the last phase of maturity. Rainfall, soil texture and other agro-climatic factors also influence crude fibre content. It is estimated by acid and alkali digestion of the ginger powder and whatever remains is considered as fibre.

Dry ginger is the form in which ginger can be stored after drying. Dry recovery varies from 18-25% depending on location and climatic factors. Dry ginger is used for preparing ginger powder, extracting ginger oil, ginger oleoresin etc. Dry ginger on distillation yield about 1.5 to 2.5% volatile oil (15 to 25 ml per kg dry ginger). It contributes aroma to oil. The main constituent in the oil is zingiberene. Technology is now available to extract oil from fresh ginger.

Dry ginger powder on treating with organic solvents like acetone, alcohol, ethyl acetate etc. yield a viscous mass that attribute the total taste and smell of the spice. The major non-volatile principle in oleoresin is gingerol. Technology is now available to extract oleoresin from fresh ginger. Oleoresin content varies from 4 to 10% (40 to 100 gm per kg). Generally, climatic conditions of north east region helps in recovery of high oleoresin and oil as the prevailing low temperature reduces synthesis of starch, which lead to more recovery of oleoresin per kilogram of rhizome.

Table 2. Composition of some ginger cultivars in India

Variety	Mean yield green (mt/ha)	Oil	Fibre	Protein	Lipid	Oleoresin
				(%)		
Bajpai	18.7	1.7	5.5	6.5	6.3	5.8
Jorhat	15.4	2.0	5.7	8.0	6.8	5.7
Karakal	17.8	2.0	6.4	7.2	7.4	6.4
Nadia	11.8	1.0	5.3	5.8	7.2	4.4
Narasapattom	15.5	1.6	6.4	6.2	8.1	5.2
Riode Janeiro	20.1	1.7	6.7	9.4	11.2	9.8
Thingpui	13.8	1.4	8.1	7.4	7.3	6.2
Thinladium	13.3	1.7	6.7	7.8	6.6	4.5
Wynad local	23.1	1.9	7.2	4.3	5.7	7.3

2.0. BOTANY AND IMPROVEMENT

2.1. Ginger varieties

Ginger in India has rich cultivar diversity and several cultivars of ginger are grown in different ginger growing areas in India and they are generally named after the localities where they are grown. At present, there are about 50 such popular cultivars the names of which are provided in table 3. Some of the prominent indigenous cultivars are Maran, Kuruppampadi, Ernad, Wayanad, Himachal and Nadia. Exotic cultivars such as Rio-de-Janeiro and Jamica have also become very popular among cultivators.

Since seed set is absent in ginger, clonal selection has been the most successful method for breeding improved varieties of ginger with high yield and quality. The breeding work is mainly carried out in Indian Institute of Spices Research, Kerala, High Altitude Research Station, Pottangi under the Orissa University of Agriculture and Technology and Y.S. Parmar College of Forestry and Horticulture, Solan, Himachal

Table 3. Popular cultivars in major ginger growing states in India

State	Culture Name
Assam	Nadia, Chekerella
Himachal Pradesh	Himachal, Rio de Janeiro
Karnataka	Himachal, Jorhat, Wyanad local
Kerala	Rio de Janeiro, Burdwan, Jamaica, Nadia, Maran, Bajpai, Narasapattam, Kuruppampadi, Thingpui, Assam, China, Ernadan, Mananthavady
Maharashtra	Mahim, Poona, Wayanad
Meghalaya	Tura, Thingpui, Nadia
Mizoram	Thingpui, Thinglaidum, Thingria
Nagaland	Thinglaidum, Nadia, Khasi local
Sikkim	Bhainsey, Gurubathan
Tamil Nadu	Maran, Thodupuzha, Himachal, Rio de Janeiro
Tripura	Nadia
West Bengal	Gurubathan, Nadia

Pradesh.The improved varieties of ginger released and their salient features are given in table 4.

humus. Compact clay soils characterized by water logging or coarse sands with poor water holding capacity, gravelly soils or soils with hard pan are not suitable. Deep slopes

Table 4. Characters of improved varieties of ginger

Variety name *	Pedigree	Mean yield (mt/ha)	Dry recovery (%)	Oil content (%)	Oleoresin (%)	Crude fibre (%)	Mean days to maturity
Suprabha	Selection from Kunduli local	16.6	20.5	1.9	8.9	4.4	230
Suruchi	Induced mutant of Rudrapur local	11.6	23.5	2.0	10.0	3.8	220
Suravi	Selection from germplasm	17.5	23.0	2.1	10.2	4.0	225
IISR Varada	Do	22.6	19.5	1.7	6.7	3.3	200
IISR Mahima	Do	23.2	23.0	1.7	4.5	3.3	200
IISR Rejatha	Do	22.4	19.0	2.4	6.2	4.0	200

* The first three varieties are released from High Altitude Research Station, Pottangi, Orissa and last three from Indian Institute of Spices Research, Calicut, Kerala

3.0. SOIL AND CLIMATE

3.1. Soil

Ginger can be grown on a wide variety of soils such as sandy loams, clay loams, alluvial and lateritic soils. However, it is mainly grown in red and laterite soils of Kerala, Karnataka, Orissa, West Bengal, Maharashtra and Northeastern states. Well-drained soil with atleast 30 cm depth, loose and friable is preferable for cultivation as the rhizomes and roots proliferate in the top 25 cm. By adopting cultural practices such as bedding and surface mulching, shallow soil can be utilized. Alluvial soils and drained paddy fields or well-drained marshy areas can also be utilized for ginger cultivation. Deep soils with rich organic matter content and nutrient availability are more suitable for cultivation. However, it performs well on medium loams having enough quantity of

in hilly areas are not advisable for ginger cultivation as it leads to soil erosion during heavy rainfall. Soil hardiness less than 15.7 mm is optimum. The yield decrease with increases in soil clay content and decrease in pH. The optimum soil pH preferred for ginger is 6.0 – 6.5. Maximum rhizome yield can be achieved in sandy loam soil having minimum bulk density (1.20 g/cc), moderately acidity (pH 5.7), high organic matter and available potassium. The soil should be relatively free of root knot nematodes and soil-borne pathogens causing rhizome rot and bacterial wilt.

3.2. Climate

Ginger requires a tropical or subtropical climate, being a shade loving plant. It comes up well up to an altitude of 1500 m above MSL, the optimum being 300-900 m. The base temperature requirement is 13 °C with an optimum range of 19-28 °C. The optimum soil temperature of 25-26°C is preferable for germination of rhizomes and 27.5°C for growth and development. In Kerala, the crop is being cultivated in the temperature range of 28-35°C. Warm sunny days are preferred but extremely high temperature causes sunburn and low temperature induces dormancy. The crop requires short or long day length for its growth and development. With the increase in day length from 10 to 16 h, vegetative growth enhances and while the day length decreases from 16 to 10 h rhizome swelling is promoted. Good sunshine, heavy rainfall and high relative humidity are necessary for getting good yield. A well-distributed rainfall of 1500-3000 mm over a span of 8-10 months produces good crop. The crop is sensitive to water logging, frost and salinity. Ginger requires partial shade for better rhizome yield. Frost is injurious to foliage and rhizomes of ginger. Hence, in areas where frost is common as that of hill regions of North/North eastern India, harvesting is done before the frost.

4.0. NURSERY MANAGEMENT

4.1. Seed storage

Ginger is propagated vegetatively by portions of rhizomes known as seed rhizomes and among inputs, seed material alone accounts for about 40% of total cost of production. In order to obtain good germination, proper storage of early season seed rhizomes is essential. The seed rhizomes should be stored appropriately so that rotting, shriveling, dehydration and sprouting can be avoided until the next season. Ginger can be stored in pits (1 x 1 x 1 m size), inner walls lined with stones/bricks. The bottom is filled with 10 cm thick dry sand. Disease free and apparently healthy rhizomes are selected after harvest, cleaned and treated with mancozeb or carbendazim (0.3%) and malathion (0.05%) for 30 minutes and then shade dried. Wherever bacterial wilt is a problem, the seeds should be treated with streptocycline 200 ppm. Treated rhizomes are placed in pits leaving 10-15 cm space on the top, covered with wooden plank to have space for aeration and plastered with cow dung. Covering the seed material with a layer of *Glycosmix pentaphylla* leaves is also beneficial . Zero energy cool chamber (ZECC), is found ideal for storing fresh ginger. The loss in weight of rhizomes was only 23% after storing for 4 months in this chamber, while the ginger stored in open conditions was shrunken in 4 months. The stored rhizomes must be examined at monthly intervals and the rotten ones are removed to keep the pathogen inoculum level low. Rhizome treatment with the above recommended chemicals before planting is also advised.

4.2. Seed size and rate

Seed rhizome weight and the size used for planting vary from place to place and variety to variety. Size of seed rhizome has a direct influence on the final yield. To obtain high yield and better returns, rhizome pieces weighing 25-50 g with two three sprouts are recommended. In general, seed rhizomes are cut into small pieces of 2.5-5.0 cm length, weighing 20-25 g with one or two viable buds. Higher yield and profit can be obtained by planting larger seed pieces of 50-80g. Planting of full mother rhizomes (50-60 g) has been found to result in the highest yield and lowest disease severity. However, neither the largest nor the smallest seed sizes are recommended.

Seed rate varies with variety and soil fertility. In general, seed rate varies from 1500 to 2500 kg per hectare and depends on seed size and spacing in India. An optimum seed rate of 1250 kg/ha with each seed rhizome weighing 30g is recommended. The optimal size of seed size and rate recommended for different states are given in table 5.

For plains and lower altitudes, 1500-1800 kg and for higher altitudes (> 1000m), 2000-2500 kg is recommended. In northeastern states, farmers plant whole rhizomes and unearth the mother rhizome when the crop reaches 30-35 cm height and 94.6 per cent recovery was obtained at 3 months after planting. By this method farmers get back 60 to 70 per cent of the seed cost. Thus, detaching and recycling the sets in the same season or later, provides a means of achieving rapid seed ginger multiplication and higher aggregate yield.

4.3. Seed treatment

The aim of seed treatment is to prevent seed-borne pathogens and pests and induce and ensure uniform germination. Farmers in Kerala dip seed rhizome in cow dung solution. The cut end of the seed may provide entry for pathogens and to prevent this, the cut rhizome pieces are dipped in benomyl 0.25 % for 10 min or mancozeb for 30 min. Treating the rhizome in ethrel (750 ppm) increases growth and development of ginger.

4.4. Transplanting

Though transplanting in ginger is not conventional, it is found profitable in Himachal Pradesh (Solan). It has been observed that transplants raised from seed rhizomes (about 5 g bits) in the nursery and planted in the field after 60 days with the onset of monsoon after treating with IBA (1 ppm) enhances the rhizome yield with a cost benefit ratio of 1:9.4. Transplanting in ginger though labour intensive and costly, helps in reducing the rhizome borne diseases to a greater extent.

5.0. PLANTING AND AFTER CARE

5.1. Preparation of land and planting

Land preparation may vary with soil type, slope and irrigation. The soil should be thoroughly broken up and pulverized. The land

Table 5. Seed size and rate in ginger for different states in India

State	Seed size and seed rate recommended
Kerala	1500 to 1800 kg ha^{-1} having 15 g each with at least one viable bud
Orissa	1800 kg ha^{-1} having 15-20 g each with 2-3 healthy buds
Himachal Pradesh	1800 to 2250 kg ha^{-1} having 25-30 g each with 2-3 viable buds
Bihar	1800 kg ha^{-1} having 18-20 g each with at least 2 healthy buds
Andhra Pradesh	1700 kg ha^{-1} having 20-25 g each with 2-3 viable buds

Source: Ramana *et al.* (2003)

is ploughed several times or dug thoroughly with the receipt of early summer showers to get a fine tilth. In Kerala and Tamil Nadu, the land is given about six ploughing and the soil is brought to a fine tilth. After initial ploughing, a cover crop of maize can be planted during summer to build up organic matter in the soil or land is fallowed. Poultry manure or press mud (by-product from sugarcane industry) is incorporated before cover crops are sown to provide additional organic matter. Root knot nematode is controlled by soil fumigation/ solarization, a month before planting. Solarization of beds for 40 days by using transparent polythene sheets with *Trichoderma* applicatioh are recommended for the areas prone to rhizome rot and nematode diseases.

In India, beds of about 1 m width, 15 cm height and of convenient length varying from 3 to 6 m are prepared with a width of 30 cm for the channels between the beds. In Bengal, the field is ploughed 12 to 13 times during March-April after the first rain, leveled and water channels are made to irrigate. In hill slopes, the beds are formed along the contours to reduce soil erosion. For irrigated crop, ridges and furrows method is followed with spacing at 40 cm apart.

Two distinct methods of cultivation are adopted in India. In the Malabar system, beds of 3 x 1 m are laid out at 30-45 cm apart from each other with small shallow pits on beds for planting at required spacing and handful of cattle manure is applied to each of these pits. In sloppy areas, smaller beds are formed. In the South Kanara system, no beds are laid out. A mixture of manure and burnt earth is applied in the form of a 5 cm thick ridge in between the rows 100-200 cm apart from each other and the seed rhizomes are placed in the rows and earthed up to make the ridges 15-20 cm high. Soon after planting, the field should be irrigated. Planting of ginger is recommended on raised beds in order to facilitate drainage. Planting ginger under irrigated conditions, in raised beds gave higher yields as compared to planting in ridges, furrows and flat ground in research trials. Raising ginger in flat beds in sandy loam soil and on raised beds in clay loam soil, followed by earthing up with the application of fertilizers are most suited for successful cultivation.

5.1.1. Planting time

The time of planting is important as it affects the yield and quality of ginger. The main factors to be considered while planting are time of planting, spacing and depth of seed placement. The planting time depends on the onset of the monsoon. In India, generally planting is done during March-June in various locations (table 6). Studies have shown that planting during April gives better growth and development of rhizomes and less incidences of diseases. However, under irrigated condition ginger can be planted at any time of the year, the best being middle of February. In India, ginger is planted with commencement of South West monsoon. A yield increase up to 200 percent was recorded by planting during the first week of April, with the receipt of summer showers, than the normal planting in May-June. Early planting of ginger is beneficial as the crop can grow sufficiently to withstand heavy rains.

Table 6. Planting time recommended for different states in India

State	Planting time
Kerala	April – June
Uttaranchal	Mid March
Orissa	April
Meghalaya	March – April
Sikkim	Feb – April

5.1.2. Spacing

Plant population is an important factor decided by spacing and it varies with soil type, variety, climate and management practices. Closer spacing gives higher yield with maximum plant density. Different spacings (15-45 x 15-45 cm) are recommended for various states in India (table 7). Seed rhizomes are planted at optimum depth for its proper and early germination/emergence. Planting depth may vary depending upon seed size, soil type and soil moisture content. In general, bolder seed rhizomes are planted deeper and smaller ones at shallow depths. Based on trials, planting on raised beds at a spacing of 20-25 x 20-25 cm and a depth of 4-10 cm with the viable bud facing upward is recommended. Light irrigation after planting is beneficial for better germination. Ginger takes 10-15 days for sprouting after planting under ideal conditions, which may be prolonged up to 2 months.

5.2. Mulching

Mulching enhances germination, conserves moisture, prevents run-off, increases infiltration, regulates soil temperature, suppresses weed growth and improves soil fertility by adding organic matter. The quantity of mulch to be applied varies with availability of material. In general, 10 to 30 t ha^{-1} is applied twice or thrice, one at planting, second at 45th day and third at 90th day after planting. Mulching the beds with green leaves at 15 t ha^{-1} after planting

Table 7. Spacing and depth of planting recommended for different states in India

State	Spacing
Kerala	20 x 20 cm to 25 x 25 cm with a depth of 4-5 cm.
Orissa	25 x 20 cm with a depth of 5 cm.
Himachal Pradesh	30 x 20 cm
Bihar	25 x 20 cm
Andhra Pradesh	30 x 20 cm
Meghalaya	30 x 30 cm
Tamil Nadu	30-45 x 20-25 cm
Sikkim	40-45 x 20-25 cm
Tripura	50 x 25 cm

followed by two mulching (at 7.5 t ha^{-1}) at 45 and 90 days after planting is an essential practice (Nybe and Miniraj, 2005).

Commonly used mulch materials are green and dry forest leaves, residues like sugar cane trash, paddy, wheat, finger millet, barely straws, coconut leaves, banana leaves, dry sal leaves and vegetation of the locality. Farm yard manure (FYM) and compost are also used as mulches. Live mulches like sun hemp, green gram, horse gram, black gram, niger, sesbania, cluster bean, *french bean, soybean, cowpea, daincha and* red gram can also be grown as intercrop and mulched *in situ* between 45-60 days after planting. Polythene as mulch material gave 19.9 mt of fresh rhizome per ha compared to 12.0 mt in unmulched plots. In Sikkim, ginger beds are covered by leaves and twigs of various forest trees after sowing. *Under Meghalaya conditions*, application of locally available organic mulches like paddy straw and dry leaf mulch of *Schima wallichii* at 16 mt ha^{-1} increased the yield of ginger. One-fourth quantity of the recommended dose (30 mt ha^{-1}) of green mulch could be saved if ginger is intercropped under coconut plantations with 25% shade In Tamil Nadu, daincha and sunhemp are raised as intercrops in alley spaces and incorporated as mulch.

5.3. Weed management

Weeds are serious problem in ginger cultivation and reduce the yield considerably. The traditional method of hand weeding is the common practice and is done just before fertilizer application and mulching. Two to three weedings are required depending on the intensity of weed growth. The first weeding is done on 45 days after planting and the second weeding during 120-135 days. Experimental studies revealed that highest fresh ginger yield can be obtained with 4 hand weedings. Among the herbicides tested, Atrazin @ 1.5 kg ai ha^{-1} or 2, 4-D @1 kg ai ha^{-1} after sowing and before emergence of ginger shoot and one hand weeding gave higher rhizome yield. Pre-sowing application of Stomp @ 2 kg a.i ha^{-1} is more effective in reducing the weeds. In India, Diuron is used as a broad spectrum pre-emergence herbicide and Paraquat as a post-emergence herbicide, during the early stages of plant growth between rows and in later stages only limited to spot spraying between beds.

5.4. Earthing up

Soil stirring and earthing up are essential to break the hardpan formed by rain or *irrigation. It also helps in checking weeds,* conserving moisture, mixing fertilizer with soil, enlargement of daughter rhizomes and provides adequate aeration for roots and protects the rhizome from scale insects. The first earthing up is done at 45^{th} day after palnting and second at $120\text{-}135^{th}$ day. Earthing up may be combined with hand hoeing (weeding) and mulching.

5.5. Irrigation

Ginger is cultivated both under rainfed and irrigated conditions.It is raised rainfed in Kerala and North eastern states and as irrigated in states like Orissa, Maharashtra, Andhra Pradesh etc. In areas receiving less rainfall, the crop needs regular irrigation. Irrigation is given at fortnightly intervals, usually during the middle of September to middle of November. Increased moisture supply increases the yield of rhizomes and essential oil content. Irrigation can be given from 10 am to 3 pm during the time of sunburn weather to establish a microclimate favorable for the crop. Ginger crop raised in the first week of May in Orissa may need two - four irrigations at an interval of 7 days depending on soil type and climatic conditions and after the receipt of monsoon, the crop thrives well till the end of September. Critical stages of water requirement are germination stage, rhizome initiation stage (90 days after planting) and rhizome development stage (135 days after planting). First irrigation is given to ginger immediately after planting and subsequent irrigations at an interval of 10 days in order to meet a total water requirement of 90-100 cm in 16-18 irrigations. During dry spell, a fortnightly irrigation helps significantly to improve yield and quality of the produce. Maximum rhizome yield could be obtained by scheduling of irrigation at 60 mm cumulative pan evaporation (CPE) and IW/CPE ratio of 1.0

5.6. Shade management

Even though shade is not absolutely necessary, ginger prefers light shade. Shading is helpful in reducing water loss and provides a micro climate suitable for the plant. Under full sunlight, the crop became shorter with fewer leaves per tiller and shade increased height, tiller number, net assimilation rate and chlorophyll content. Dry matter production, nutrient uptake, yield and quality are also higher under low to medium shade (25 per cent). A heavier shade (beyond 50 per cent) decreases number of tillers and yield. Ginger can also be gown under full sun (open condition). Ginger can be grown in homestead garden and also suitable for intercropping under coconut and other perennial crops, where low to medium shade intensity exists. Varieties like Himachal is found to perform well both in the open and low-light intensities (75% shade) with respect to dry matter accumulation and uptake of N, P and K. Ginger grown under low to medium shade (25 percent) produced good quality parameters (volatile oil and fibre contents), compared to those grown under open and heavy shade conditions.

5.7. Intercropping

Ginger can be grown as a sole crop (under open or shade) or as a component in inter or mixed cropping systems. Ginger can be intercropped with vegetables (cabbage, tomato, chillies french bean and lady's finger), pulses (pigeon pea, black gram and horse gram), cereals (maize, finger millet), oilseeds (caster, soybean, sunflower and niger) and other crops (sesbania, tobacco and pineapple) .Ginger being a partial shade loving crop, it can be grown as an intercrop in coconut, arecanut, rubber, orange, guava, mango, papaya, coffee and popular plantations. A higher fertilizer dose of N:P:K @ 150:100:100 kg ha^{-1} is required, if ginger is grown as intercrop in a coconut garden compared to open conditions. It is profitable to have ginger in coconut based cropping system which is reported to fetch a gross return of Rs. 1,00,500 ha^{-1}.

Green manure crops like daincha (*Sesbania aculeata*) can be raised successfully in inter-spaces of beds in a row, which adds to 50 per cent of the green leaves required for mulching, suppresses weed growth and reduces cost of production. Ginger can also be grown as mixed crop with castor, redgram, fingermillet and maize. Ginger is also the most favoured crop component under agroforestry. Growing fodder tree, *Quercus leucotrichophora* with ginger is found to be the most ideal and remunerative silvi-horticultural combination in hills of U.P.

5.8. Cropping system

Crop rotation with green manures and legumes is essential, as ginger depletes more nutrients in the soil coupled with rhizome rot problem under continuous monoculture. The crop is rotated with tapioca, chillies, seasame, little millet and dry paddy in rainfed conditions and vegetables under irrigated conditions. However, crop rotation using tomato, potato, chillies, brinjal and peanut should be avoided, as these plants are hosts for the wilt causing organism, *Ralstonia solanacearum*.

5.9. Organic ginger production

In recent years, organic agriculture has been gaining considerable importance and many farmers are switching to this traditional method of cultivation as a means to produce safe foodstuffs and preserve the environment. Organic farming favors lower input costs, high-value markets, conserves nonrenewable resources and boosts farm income. Estimate by SOEL-Survey shows that India has 41000 ha (0.03% of total agricultural area) under organic cropping with 5661 numbers of registered organic farms, producing agricultural crops like plantation, spices, pulses, fruits, vegetables and oil seeds etc. Since spices like ginger form part of many of ethnic medicines, the demand for organically produced ginger is also increasing considerably in the importing countries.

Ginger as a best component crop in agri-horti and silvi-horti systems, recycling of farm waste can be effectively done when grown with coconut, arecanut, mango, *Leucaena*, rubber etc. As a mixed crop it can also be grown or rotated with green manure/ legumes crops or trap crops enabling effective nutrient built up and pest or disease control. For certified organic production, for at least 18 months the crop should be under organic management *ie*. only the second crop of ginger can be sold as organic. It is desirable that organic method of production is followed in the entire farm, but in the case of large scale cultivation, the transition can be done in a phased manner for which a conversion plan is to be prepared. Traditional varieties adapted to the local soil and climatic conditions are promoted. In order to avoid contamination of organically cultivated plots from neighboring non-organic farms, a suitable buffer zone is to be maintained. In sloppy lands, adequate precaution should be taken to avoid the entry of run off water and drift from the neighboring farms.

Certification and labeling is usually done by an independent body to provide a guarantee that the production standards are met. Govt. of India has taken steps to have indigenous certification system to help small and marginal growers and to issue valid organic certificates through certifying agencies accredited by APEDA and Spices Board. Guidelines for organic production of ginger have been developed by Spices Board under National Programme for Organic Production (NPOP). Liming @ 400 kg ha^{-1} for acidic soils, application of 30 t ha^{-1} FYM as basal, 2.5 t of neem cake and 5-8 t of vermicompost and mulching with green leaves @ 10 t ha^{-1} at 45 days intervals are recommended. Combined application of different organic sources like FYM, oil cakes, rock phosphate, wood ash, vermi compost and biofertilizers have yielded on par to the conventional practice in addition with high quality. Application of FYM and organic cakes enhanced the residual nutrient availability to the second crop also with fewer incidences of pest and diseases. But research results during initial years showed 25% and 23% reduction in yield in ginger under organic system as compared to conventional and integrated managements, respectively. The quality parameters of ginger (oleoresin, starch and fibre) are found to be high under organic farming

Integrated strategy involving pruning and destroying freshly infested shoots during July-August (at fortnightly intervals) and spraying neem gold 0.6% during September-October (at monthly intervals) or Dipel (formulation of *Bacillus thuringiensis*) 0.3% during July to October is effective against the shoot borer of ginger. Effective management of leaf spot diseases can be done by spraying Bordeaux mixture (1%) and rhizome rot by selecting healthy rhizomes and soil solarization with incorporation of *Trichoderma*.

6.0. MANURING

6.1. Nutrient removal

Ginger is a nutrient exhaustive crop and responds well to the application of organic manures and fertilizers. Ginger rhizomes are mainly N and K exhausting, intermediary in P and Mg removal and the least in Ca removal. Nutrient uptake of a crop varies considerably with variety, soil type, climatic conditions etc. The development of ginger can be classified into three distinct growth phases namely, active growth (90-120 days after planting [DAP]), slow vegetative growth (120-180 DAP) and senescence (180 DAP) in which the rhizome development continues till harvest. The uptake of N, P and K in leaf and pseudostem increase up to 180 day and then decrease, whereas the uptake by the rhizome steadily increases till the harvest. An average dry yield of 4.0 t ha^{-1} ginger rhizomes removes 70 kg nitrogen, 17 kg P_2O_5, 117 kg K_2O, 8.6 kg calcium, 9.1 kg magnesium, 1.8 kg iron, 500 g manganese, 130 g zinc and 40 g copper per ha. In order to diagnose the foliar nutrient deficiencies of N, P and K, it is recommended sampling of 5^{th} pair of leaf as an index leaf between 90^{th} to 120^{th} DAP.

6.2. Organics

The requirement of organic matter may be met from various sources such as green/organic manures and mulches. The importance of organic manures are very much evidenced by good performance of ginger crop in high fertility conditions of Wynad, Kerala supplied with 10-30 t of organic manure and 15 t of green leaf mulch per hectare, without any fertilizer application. Ginger performs well with good supply of humus and organic matter. Farm Yard Manure, vermi compost, coir pith compost, poultry manure, green leaf, municipal composts, press mud, oil cakes, biofertilizers and cow urine are various sources of organics. The quantity of organics applied may vary between 5-30 t ha^{-1} depending on its availability and its nutrient content. Organics are mostly applied as basal doses and in certain places it is also applied after the emergence of crop as mulch. Maharashtra farmers apply heavy doses of FYM, about 40 to 50 t ha^{-1}. In Kerala the recommended dose of organic manure is 25-30 t ha^{-1} of FYM and 30 t ha^{-1} of green leaf mulch is applied in three splits.

Application of organic cakes (neem cake @ 2 t ha^{-1} or groundnut cake @ 1 t ha^{-1}) and coir pith compost @ 2.5 t ha^{-1} also increases nutrient availability, improves physical condition of the soil, increases the yield and reduces the rhizome rot incidence . In addition to neem cake, phosphobacteria and rock phosphate application increases the availability of P, Ca, Mg, Zn and Mn in soil.

6.3. Inorganic fertilizers

Response of ginger to fertilizer application varies with soil type, nutrient source, variety and climate. A fertilizer dose of 36-225: 20-115: 48-200 N, P_2O_5 & K_2O kg/ha has been adopted in different states in India. For field application, straight fertilizers or fertilizer mixtures containing grades of NPK are used.

Nitrogen application increases the number of third order shoots, fourth order rhizome branches, tiller number and total yield. However, higher dose of nitrogen application decreases the yield and reported to be ineffective also. The requirement of nitrogen is higher during active growth phase (120-135 DAP) and N deficiency can be rectified even at later stages of crop growth. N is beneficial when applied during the active growth and tillering stages of the crop during which foliar N content will go up to 3 percent. However, nitrogen use efficiency decreases with increasing rate of N application. The cost effectiveness of nitrogenous fertilizers for ginger is in the order of urea > ammonium nitrate > ammonium sulphate.

Mostly phosphorus is applied as a basal dose at the time of planting. Application of 56-112 kg of P_2O_5 ha^{-1} not only increased the yield by 14-20 per cent but also improved the dry matter content. Under Kerala conditions where the soils are lateritic with high P fixing capacity, available P increased with the application of rock phosphates incubated with FYM and among the sources, Rajphos was superior. Rhizome P concentration is higher when super phosphate and FYM incubated rock phosphates are applied. Not much variation was observed in oleoresin content of ginger due to application of different sources of P. Among all the sources, apparent phosphate recovery, agronomic efficiency of the applied P and percentage yield response was higher for Gafsaphos, followed by Rajphos incubated with FYM in ginger

Ginger removes a large amount of potassium from the soil (up to 500 kg ha^{-1}). Even though potassium increases the yield, a higher dose of K_2O reduces the height of plants and yield. Greater response for potassium application is expected when applied in split doses (20 per cent as basal dose, followed by 40 per cent at 2 months after planting and remaining 40 per cent at 4 months after planting) than as a single basal dressing.

For healthy growth of ginger, very low external calcium is required. The leaves of healthy plants contained 1.1 to 1.3% of Ca and concentrations as low as 2 ppm is sufficient to achieve 90 per cent of maximum yield. Lime application is practices in acidic soils to correct the imbalance in availability of other nutrients

Under Kerala conditions, the dose of 144 kg N and 109 kg ha^{-1} K is found optimum from the quadratic equation. An increased rhizome yield found to have greater association with K content in the leaf. The highest yield and oleoresin can be obtained with application of 10 t of FYM ha^{-1} + 1.25 t ha^{-1} of coir compost + 20 kg ha^{-1} of *Azospirillum* with higher nutrient uptake. Application of neem cake @ 2 t ha^{-1} along with NPK increases yield and reduce the rhizome rot incidence. Under low to medium shade, 150 per cent of the recommended dose of fertilizers (75:50:50 kg ha^{-1}) enhanced the rhizome yield. Under Bangalore conditions, the application of 150 Kg N, 75 kg P_2O_5 and 50 kg K_2O ha^{-1} increased the yield. In Orissa, integrated application of 20 t FYM with 125 kg N, 70 kg P and 150 kg K fertilizers per hectare is recommended for maximum yield of rhizomes. In acidic soils of Meghalaya, rhizome yield, N, P and K uptake and oleoresin contents of ginger increased significantly with the application of N at 100 kg ha^{-1} and FYM at 5 t ha^{-1}. Fertilizer requirement of ginger in different states from various studies are furnished in table 8.

Table 8. Manures and fertilizers recommendations for various agro-climatic zones of India

State	Recommendation
Kerala	FYM 30 t ha^{-1}; NPK 70:50:50 kg ha^{-1}. Full dose of P and 50% K may be applied as basal dose. Half of N applied at 60 DAP. The remaining quantity of N and K applied at 90 DAP.
Karnataka	FYM/compost 25 t ha^{-1}; NPK 100:50:50 kg ha^{-1}. Apply the entire dose of P and K at planting. Half of N applied at 30-40 DAP and other half at 60-70 DAP.
Orissa	FYM 25 t ha^{-1}; NPK 125:100:100 kg ha^{-1}. Full P and half K applied as basal dose in furrows before planting and N and K in 2 splits at 45 and 90 DAP.
Himachal Pradesh	FYM 20-30 t ha^{-1}; CAN @400 kg ha^{-1}, NPK 100:50:60 kg ha^{-1}. Apply P as basal and N in 3 equal splits, first at the time of planting and subsequently at monthly intervals. K_2O also in two splits, half at sowing and remaining at rhizome initiation.
Bihar	FYM 20-30 t ha^{-1}; NPK @60:60:120 kg ha^{-1}
Andhra Pradesh	FYM 20-30 t ha^{-1}; NPK @75:50:50 kg ha^{-1}
Chattisgarh	FYM 20-30 t ha^{-1}; NPK @150:125:125 kg ha^{-1}
Meghalaya	FYM 10 t ha^{-1}; NPK @60:90:60 kg ha^{-1}
Tamil Nadu	FYM 20-25 t ha^{-1}; 2 t ha^{-1} neem cake; 50 kg P_2O_5 + 25 kg K_2O as basal; 2 splits of 75 kg N at 45 & 90 DAS
Sikkim	FYM 40-60 t ha^{-1} + 20-25 kg ha^{-1} Diammonium Phosphate

6.4. Micronutrients

The order for micronutrients removal by ginger is Fe> Mn> Zn> B> Cu. Application of micronutrient increases the rhizome yield. Soil and plant analysis of samples across the country revealed 49% mean deficiency of zinc (Zn) in Indian soils with acid soils of Meghalaya having the highest deficiency rate of 57% .Foliar application of Zn @ 0.25% twice at May-June and August-September increases the rhizome yield as compared to soil application. Combined spraying of Zn (0.3%) + Fe (0.2%) + B (0.2%), twice at 45 and 75 DAP boost the rhizome yield in deficient areas.

Studies at Solan on the effect of micronutrients showed significant increase in the yield when NPK along with two sprays of Jagromin - chelated form of micronutrients (0.7%), once at rhizome initiation and again one month after the first spray was applied. The optimum fertilizer rate for obtaining maximum rhizome yield was determined as 6 kg Zn ha^{-1} for Inceptisols of Kerala with the maximum limit of soil DTPA-extractable zinc as 3.4 mg kg^{-1}.

6.5. Growth regulators

The endogenous levels of cytokinins and auxins have a greater influence on development of ginger rhizomes. Application of ethrel (ethiphon) at 50-400 ppm two months after planting and twice at 20 days intervals recorded the highest rhizome yield (25 t/ha) . Spray of urea @ 2% with planofix @ 400 ppm is also effective in increasing yield.

7.0. DIESEASES AND THEIR MANAGEMENT

Ginger is affected by many pests and diseases. Of these, soft rot, bacterial wilt, yellows, *Phyllosticta* leaf spot, and storage rots are major diseases that cause economic losses. In India, bacterial wilt and soft rot are prevalent in all major ginger-growing areas. *Pythium spp, Fusarium oxysporum, Ralstonia solanacearum* and *Pratylenchus coffeae* are potent pathogens causing soft rot, yellows, bacterial wilt, and dry rot, respectively, in the field or in storage.

7.1. Soft rot

Soft rot is also called *rhizome* rot. The incidence of this disease for the first time was reported from Surat (Gujarat) in India. The disease is prevalent in all the ginger growing countries across the world such as India, Japan, China, Nigeria, Fiji, Taiwan, Australia, Hâwaii, Sri Lanka, and Korea. *P. aphanidermatum, P. myriotylum, P. vexans, P. ultimum* and *P.deliense* have been recorded as causal agent of soft rot of ginger.

7.1.1. Symptoms

The disease is predisposed by water logging conditions and is caused by several species of *Pythium*. The plant is susceptible to *Pythium* infection at all stages of growth. All the underground parts like roots, stem and emerging sprouts are susceptible to this disease. The buds, roots, developing under ground stem the rhizome, and collar regions are the portals of infection. When the seed rhizomes are infected, they fail to sprout due to the rotting of young buds. After sprouting, the infection takes place through root or through the collar region, finally reaching the rhizome. Symptoms appear initially as water-soaked patches at the collar region. These patches enlarge and the collar region becomes soft and watery, and then rots.

Table 9. Diseases of ginger and the causal organisms

Disease	Pathogen	Distribution
Soft rot	*Pythium* species	
	P. aphanidermatum	Andhra Pradesh, Assam, Bihar, Gujarat, Kerala, Karnataka, Maharashtra, Madhya Pradesh, West Bengal
	Csyn: P. butleri	
	P. gracile	
	P. deliense	Madhya Pradesh
	P. myriotylum, P. ultimum	Himachal Pradesh, Kerala, Maharashtra, Rajasthan
	P. pleroticum, P. vexans	
		Himachal Pradesh
Bacterial wilt	*Ralstonia solanacearum*	All over the country
Yellows	*Fusarium* spp	
	F. oxysporum f.sp.zingiberis	Himachal Pradesh,
	F. solani,F. moniliforme	Rajasthan
	F. graminearum,F. equiseti	
Leaf spots	*Phyllosticta zingiberis*	Kerala, Karnataka,
	Helminthosporium maydis	Himachal Pradesh
	Colletotrichum zingiberis	Bihar
	Pyricularia zingiberis	Andhra Pradesh
	Leptosphaeria zingiberis	Assam
	Coniothyrium zingiberis	Meghalaya
	Curvularia lunata	Assam
	Vermicularia zingiberis	Bihar
	Septoria zingiberis	Andhra Pradesh
		Andhra Pradesh
Leaf blight/Dry rot	*Rhizoctonia solani*	Himachal Pradesh
	R. bataticola	Haryana, Kerala
Thread blight	*Pellicularia filamentosa*	Kerala
Basal rot	*Sclerotium rolfsii*	Maharashtra
	(Corticium rolfsii)	
Sheath rot	*Fusarium* sp.	Maharashtra
Virus	*Cucumber mosaic virus* (CMV)	Kerala
Diseases	*Chlorotic fleck virus* (GCFV)	
	Chirke virus	Assam

In grownup plants, collar infection leads to yellowing of leaves. This yellowing starts from the leaf tip and spreads downward, mainly along the margins resulting in death of leaves. The dead leaves droop and hang down the pseudostem until the entire shoot becomes dry. The basal portion of the plant exhibits a pale translucent coloration. This area later becomes water soaked and soft to such an extent that the whole shoot either topples or can easily be pulled out. Rhizomes first turn brown and gradually decompose, forming a watery mass of putrefying tissue enclosed by the tough skin of the rhizome. The fibro vascular strands are not affected and remain isolated within the decaying mass. Roots arising form the affected regions of the rhizome become soft and rot. The rotten parts emit a foul smell. Rotting attracts opportunistic fungi, bacteria, and insects particularly the scavengers

7.1.2. Management

Seed Rhizome Selection and Treatment: Infected rhizomes are the primary source of infection and spread of soft rot in the field. The best method to manage the disease is by the use of disease-free rhizomes for planting. Use apparently good looking and healthy rhizomes for planting.

Treat the seed rhizomes for 30 minutes with mancozeb (0.3%) or carbendazim (0.3%) in case of soft rot prior to storing and planting. Carbendazim alone or in combination with Mancozeb is also used to prevent the seed borne inoculum of both *Pythium* and *Fusarium*

Cultural Methods: One of the predisposing factors for soft rot of ginger is ill drained field in continuous wet weather. Proper drainage in sandy loam soil for cultivation ensures healthy crop of ginger.

Soil Solarization: Soil solarization is a soil disinfection practice achieved by covering moist soil with transparent polythene film during the period of high temperature and intense solar radiation. Wherever possible this practice can be adopted.

Chemical Methods : Soil drenching with Mancozeb (0.3%) or Cheshunt compound for controlling soft rot or metalaxyl @ 500 ppm as a soil drench was found to reduce the soft rot incidence.

Biological Control: Antagonistic fungi namely, *Trichoderma harzianum, T. hamatum, T. virens* and bacterial isolates *Bacillus* and *Pseudomonas fluorescens* have been reported to be suppressive to soil borne pathogens of ginger.

7.2. Bacterial wilt of ginger

Bacterial wilt disease of ginger is one of the most important production constraints in tropical, sub tropical and warm temperature regions of the world .Bacterial wilt of ginger inflicts serious economic losses to small and marginal farmers who depend on this crop for their livelihood. Once introduced in an area the soil become unsuitable for further cultivation of ginger. The severity of the disease is evident from its rapid and quick spread in the field when the environmental conditions (high rainfall and warm weather) are favorable for the disease development. Each of the infected plant is capable of releasing hundreds of thousands of bacterial cells in the form of bacterial ooze.

Bacterial wilt of ginger is caused by a bacterium, *Ralstonia solanacearum* biovar III (Smith) Yabuuchi. In India biovar 3 causes rapid wilt in ginger in 5-7 days under artificial stem inoculation and in 7-10 days under soil inoculation of the pathogen. Traditionally ginger is cultivated in previously fallowed soil or virgin soil. Incidence of bacterial wilt noticed in such field is one of the indirect evidences of rhizome borne nature of *R. solanacearum* in ginger. Being a vascular pathogen it is presumed that the pathogen *Ralstonia solanacearum* is surviving in ginger at very low inoculum level without affecting the normal state of the ginger.

7.2.1. Symptoms

Due to infection, water soaked spots appear at the collar region of the pseudostem and progress upwards and down wards. The first visible symptom is mild drooping and curling of the margins of lower leaves that gradually progresses to upper leaves. In the advanced stage, plants exhibit severe yellowing and wilting symptoms. The vascualar tissues of affected pseudostems show dark streaks. The affected pseudostem and rhizomes when pressed gently extrudes a milky ooze from the vascular strands.

7.2.2. *Management*

Various control measures have been evaluated to combat the disease with limited success. Bacterial wilt is a major problem in the production of ginger and other vegetable crops owing to its wider host range genetic variability it exhibits. Besides the pathogen is endowed with multiple modes of survival and fast lateral transmission within and between fields. The strategies for management of bacterial wilt are

i. Selection of healthy rhizome material from disease free area

ii Selection of field with no history of bacterial wilt in the past

iii Pre-plant rhizome treatment by heat or rhizome solarization

iv. Strict phytosanitation in the field including restrictions on movement of farm workers and irrigation water across the field

v. Clean cultivation and Minimum tillage

vi. Crop rotation with non-host plants like cereals such as paddy, maize etc

vii Insect pest and nematode control in the field

viii. Soil amendments including biological control agents

7.3. Fusarium yellows or dry rot

This disease is caused by *Fusarium oxysporum* for spp. *zingiberis*, predisposed by nematode infestation by *Pratylenchus coffeae*. Ginger yellow is originally reported from Queensland and subsequently from Hawaii (USA) and India.

7.3.1. *Symptoms*

On leaves, symptoms appear as yellowing of the margins of the lower leaves, which gradually spreads over the entire leaf. Older leaves dry up first, followed by the younger ones. Plants may also show premature drooping, wilting, and drying in patches in the field or in the whole bed. Plants, generally, do not lodge on the ground as noticed in soft rot or bacterial wilt. In rhizomes, a cream to brown discoloration accompanied by shriveling is commonly seen. Vascular rot is also prominent. In final stages, only the fibrous tissue remains within the rhizomes. A white cottony fungal growth may develop on the surface of stored rhizomes. This disease along with nematode infestation severely reduces the marketability of the rhizomes. When used as seed rhizome the disease may affect the germination of the rhizomes.

7.3.2. *Management*

Healthy Rhizome Selection: As the disease spreads through contaminated rhizomes, selection of healthy rhizomes has been found to be an effective preventive measure for the disease.

Rhizome Treatment : With hot water at 51°C for 10 min is recommended in places where the disease occurs in endemic proposition

Chemical Control: Mancozeb (0.3%) and carbendazim (0.05%) are found to reduce the disease

Biological control: Biocontrol agents like *T. harzianum, T. hamatum,* and *G. virens* as seed treatment and soil application are found to control the disease

7.4. *Phyllosticta* leaf spot

This disease is widespread in most ginger-growing countries including India. Leaf spot disease of ginger is reported for the first time in Godavari and Malabar regions of India.

7.4.1. Symptoms

A phyllosphere fungus *Phyllosticta zingiberi* causes this disease. Small, spindle to oval or elongated spots appear on younger leaves. The spots have white papery centers and dark brown margins surrounded by yellowish halos. The spots later increase in size and coalesce to form large spots, which eventually decrease the effective photosynthetic area on the leaf surface. As the plants put forth fresh leaves, they subsequently become infected. Such infected areas often dry up at the center, forming holes. In the case of a severe attack, the entire leaf dries up. The crop looks a grayish disheveled as a result of infection.

7.4.2. Management

Seed rhizome selection: The seed rhizomes should be selected from disease free area as the disease can spread through rhizomes that are looking normal

Rhizome treatment: Seed rhizome can be treated with carbendazim+mancozeb combination or carbendazim (0.25%) before planting.

Cultural method :The natural way to control leaf spot is by growing ginger under shade trees such as coconut as shade.

7.5. Thread blight

This disease was first reported in Malabar region of Kerala state. The disease is not of much significance and occurs very rarely during heavy rainfall. This disease is caused by *Pellicularia filamentosa.*

7.5.1. Symptoms

Small water-soaked lesions appear on the leaf margins or other parts of the leaf during the initial stage of this disease. Later on, the infected leaves lose their turgidity, wilt, and may get detached from the sheath. Fine hyphal threads spread over the infected parts, and small brown sclerotia are present on the lower surface. The infected portion turns white and papery upon drying.

7.5.2. Control

1. Protective spraying with Bordeaux mixture (1%) before the start of heavy rains.
2. The disease is also checked by a spray of carbendazim (0.2%).

7.6. Post harvest diseases

As ginger undergoes three months of dormancy in storage during Feb-April, it is important to protect it from various storage losses due to microorganisms and insect pests apart from abiotic stress like heat buildup. Under storage, different fungi and bacteria have been found associated with ginger rhizomes that result in rotting and decaying of the rhizomes. In storage, the fungi such as *Fusarium oxysporum*, *Pythium deliense*, *Pythium myriotylum*, *Geotrichum candidum*, *Aspergillus flavus*, *Cladosporium lennissimum*, *Gliocladium roseum*, *Graphium album*, *Mucor racemosus*, *Stachybotrys sansevieriae*, *Thanatephorus cucumeris*, and *Verticillium chlamydosporium* are known to affect the ginger rhizomes. Bacteria such as *Erwinia caratovora* and *Enterobacter cloacae* are known to affect ginger during storage. The fungus *A. flavus* in association with ginger rhizomes was implicated in the production of carcinogenic aflatoxin.The description of post harb vest pathogens is given in table 10.

7.6.1. *Control measures (Can be used for seed rhizome selection and storage)*

i Select healthy plots (which did not show any disease during the growing season) when foliage is completely dried out: this is usually in January.

ii Carefully harvest, removing all those that have rots, insect damage or are blemished in other ways.

iii For seed purposes, chose only rhizomes with roots.

iv Take out rotten rhizomes, burn or bury in a pit far away from ginger fields and streams.

v Under storage conditions, post harvest dip treatment of aureofungin (0.02 percent) and benlate (0.2 percent) provided better control of the disease.

vi Pre-storage treatment with Mancozeb (0.3%) is recommended to prevent storage rots in ginger.

vii Temperature rises in the rhizomes during storage. This predisposes the rhizomes for post harvest losses. Give proper ventilation and keep rhizomes at temperature of 24-28°C until they are planted. Choose dry shed or room, are a field clamp covered with grass, and/or other dry vegetation, above ground protected from rain. Use saw-dust or leaf from *Glycosmix* for proper aeration for the rhizomes.

viii Pile carefully and inspect regularly (every fortnight) for any sign of rot.

ix Rhizomes can be pre treated with biological control agents such as *Trichoderma* or *Pseudomonas fluorescens* for avoiding the losses due to post harvest diseases

Table 10. Organisms associated with storage rot in ginger

Name	Nature of microorganisms
Fusarium oxysporum *Pythium deliense, P. myriotylum*	Pathogens
Aspergillus flavus *Cladosporium lennissium, Gliocladium roseum* *Graphium album, Mucor racemosus* *Stachyobotyrs sansveriae*	Saprophytes
Thanetophorus cucumeris *Verticillium chlamydosporium* *Geotrichum candidum*	*Pathogenic during storage*

7.7. Viral diseases

7.7.1. *Mosaic disease*

The symptoms appear as a yellow and dark green mosaic pattern on leaves. The affected plants show stunting. The virus causing mosaic disease in ginger has spherical particles with a diameter of 23 to 38 nm. It shows a positive serological reaction with antiserum to cucumber mosaic virus (CMV). The virus is known to be transmitted by sap to different plants known to be hosts of CMV.

7.7.2. *Chlorotic fleck disease*

This is viral disease first described by Thomas (1986). The geographical distribution of the virus is uncertain, but is thought to occur in India, Malaysia, and Mauritius. The ginger chlorotic fleck virus (GCFV) has isometric particles approximately 30 nm in diameter with single-stranded RNA of MW 1.5×10^6 daltons, and a major coat protein, mw 29×10^3 daltons. The virus is mechanically transmitted by *Myzus persicae, Pentalonia nigronervosa, Rhopalosiphum maidis,* or *R. padi* (Thomas, 1986).

7.7.3. *Big bud*

The disease for the first time was reported in Queensland and suspected it to be a *Phytoplasma* disease. The tomato big bud organism causes this disease in ginger. The affected plants cease to grow and leaves become bunched at the top of the stem. As the disease advances, plants turn yellow and die. The pathogen has a wide host range, and the disease is transmitted by leafhoppers. In seed production areas, affected plants are removed and destroyed carefully.

7.7.4. *Chirke virus*

This disease was reported in 1965 in India on ginger, which is a known disease in large cardamom.

7.7.5. *Control of viral diseases:*

Avoid using rhizome from diseased plants for seed purpose

7.8. Minor diseases

Dry Rot by *Macrophomina phaseolina* (Tassi) Goid, Basal sheath rot by *Aphelenchus* (nematode) and a *Fusarium* sp, Basal rot by *Sclerotium rolfsii* (*Corticium rolfsii*), Violet rot pathogen, *Helicobasidium mompa* Tanaka, Black Rot by *Rosellinia zingiberis* Stevens, Leaf spot by *Leptosphaeria zingiberis, Coniothyrium zingiberis* and *Cercoseptoria* sp, *Curvularia lunata (Cochliobolus lunata), Vemicularia zingibereae, Pyricularia zingiberis, Colletotrichum zingiberis, Septoria zingiberis, Helminthosporium sp* were found associated with ginger leaves or rhizomes. *Rhizoctonia (Corticium) solani* causing Pseudostems rot and *Rhizoctonia bataticola (Macrophomina)* causing Leaf blight are other diseases affects ginger at limited scale. There is no need to have separate control strategies for these diseases as they appear very scantly.

8.0. INSECTS AND NEMATODE PEST MANAGEMENT

8.1. Shoot borer

The shoot borer (*Conogethes punctiferalis)* is the most serious insect pest of ginger. The adult is a medium-sized moth with a wingspan of about 20 mm; the wings and body are orange-yellow with minute black spots. The eggs are laid on the topmost unopened leaf and the newly hatched larva feeds on the unopened leaf and later they bore into the shoots. Fully-grown larvae are light brown with sparse hairs and measure 15-25 mm in length. The pest is observed in the field throughout the crop season and its population is higher during September-October. The shoot borer is highly polyphagous and has been recorded on more than 30 host plants including several economically important plants in India.

The larvae bore into shoots and feed on the internal tissues resulting in yellowing and drying of infested shoots. The presence of bore-holes on the shoots through which frass is extruded and the withered central shoot is a characteristic symptom of the pest infestation.

8.1.1. Management

An integrated scheduleis recommended for the management of shoot borer; including pruning of freshly infested shoots (as indicated by the extrusion of frass) at fortnightly intervals during July- August and spraying Malathion (0.1%) at monthly intervals during September- October . In ginger spraying malathion (0.1%) at monthly intervals during July- October is effective in controlling the pest infestation. The spraying should be initiated as soon as the first symptom of pest infestation is noticed in the field to achieve higher levels of control. Among the various predators and parasites documented on the pest in the field, the entomophagous nematode *Hexamermis* sp. and the hymenopteran parasitoid *Apanteles taragammae* are major natural enemies.

8.2. Rhizome scale

The rhizome scale (*Aspidiella hartii*) infests rhizomes of ginger in the field (especially at later stages) and storage. The pest feeds on plant sap and when the rhizomes are severely infested, they become shriveled and desiccated and fail to germinate. Adult (female) scales are minute (about 1 mm in diameter), circular and light brown to grey and appear as encrustations on the rhizomes.

8.2.1. Management

Severely infested rhizomes are to be discarded before storage of rhizomes. Storage of rhizomes in dried leaves of *Strychnos nux-vomica* + sawdust in 1 : 1 proportion helps in keeping the seed rhizomes free of scale infestation. In case the infestations are severe, dipping of seed rhizomes in quinalphos 0.075% before storage may be essential.

8.3. Root grubs

Root grubs (*Holotrichia* spp.) sometimes cause serious damage to ginger plants especially in Sikkim and parts of Kerala. The grubs feed on roots and newly formed rhizomes. The pest infestation leads to yellowing of leaves and in severe infestations, the pseudostems may be cut at the basal region. The entire crop may be lost in severely infested plantations. The adults of *H. seticollis* commonly occurring in Sikkim are dark brown beetles measuring about 2.3 x 1.3 cm in size. The adults emerge in large numbers with the receipt of summer showers during April / May.

8.3.1. Management

Mechanical collection and destruction of adults during their peak periods of emergence and application of the entomophagous fungus *Metarhizium anisopliae* mixed with fine cow dung is effective for the management of root grubs. However in severely affected plantations, drenching with chlorpyriphos 0.075% may be necessary along with mechanical collection of beetles.

8.4. Nematode diseases

There are everal plant parasitic nematodes infesting ginger and among them *Meloidogyne* spp., *Radopholus similis* and *Pratylenchus* spp. have been reported are the major ones of economic importance as they cause significant damage to ginger plants.

1. Chemical control: Soil application of carbofuran at 3kg a.i./ha, 3 weeks after planting of ginger decreased yield losses due to *Meloidogyne*
2. Integrated management: Pre-planting application of neem *(Azadirachta indica)* cake (1 t/ha) followed by post planting application of carbofuran (1kg a.i./ha) 45 days after planting is recommended for the control of *M. incognita*.

9.0. POST HARVEST PROCESSING AND VALUE ADDITION

9.1. Harvesting

In India normally harvesting is done from January to April, varying with the locations. Fresh and dry yields of rhizomes increase steadily up to 210 days. The quality of ginger is affected by the stage of the harvest. The fibre content will be low till 210 days and increases with rhizome maturity. For vegetable purpose, the crop has to be harvested from sixth month onwards. For dry ginger, matured rhizomes are to be harvested after eight months. Studies at Solan (H.P.) indicated that maximum fresh yield and dry recovery with highest oleoresin are obtained at 225-240 days after sowing. However, harvesting at 210 DAP gives minimum fibre with maximum essential oil. Irrigation is stopped one month before harvest, allowing the tops to dry, leaves and stem are cut to the ground and the rhizomes are dug out by hoeing or plowing. In the plains, where the average temperature is between 30-35°C the crop is ready for harvest in about 8 months after planting when they turn yellow and start drying up gradually. The clumps are lifted carefully with a spade or digging fork, and the rhizomes are separated form the dried up leaves, roots and adhering soil.

In Sikkim and Darjeeling extraction of mother rhizome after 2-3 months of sowing is a local practice. By this practice, farmers get back their investment on seed rhizome even if there is a severe outbreak of rhizome rot disease. The mother rhizome has equal market value as that of freshly harvested ginger because of the large size of rhizomes (100-500 g) planted. Late harvest is also practiced, as the crop dose not deteriorates by leaving it for some more months underground.

9.2. Processing

Ginger is harvested at full maturity when the pseudo stem turns yellow. The maturity varies between 210-240 days. After harvest the rhizomes are cleaned to remove the soil, soaked in water for 3-4 hours, outer skin is peeled and put for sun drying on a clean surface. It takes about 14 days for complete drying of rhizome to a moisture level of 10%. Black polyethylene sheet or cement floor can be used for drying. Fully dried rhizomes can be packed in airtight containers such as high-density polyethylene or similar packing materials. Dried ginger rhizomes on storage are generally attacked by storage pests such as *Lasioderma serricone*. To prevent pest attack Aluminium phosphide capsules, fumigation with methyl bromide, neem leaves etc. can be used. Dry recovery of ginger is 1/5th of fresh rhizomes. Dry ginger is used for making ginger powder, which serves as base for various end products. Crude fibre content of dry ginger varies between 3-8%.

Traditionally, ginger can be prepared in three ways

1. Coated ginger - dried with the skin whole or partly scraped
2. Uncoated ginger - skin completely peeled and dried to provide a light-colored smooth-looking product.
3. Bleached ginger - coated with lime, with or without skin and dried

Except for ginger from Jamaica (and formerly from Cochin), the rest of the ginger produced is largely dried with the skin. Soon after harvest, the rhizomes are trimmed to remove roots and are washed to remove the adhering earth; they are then spread on cemented yards to dry. The layers are turned occasionally and heaped into lots every evening. The drying is continued for 7 to 10 days, depending on weather conditions. The care taken during cleaning and prolonged sun drying will be reflected in the final product. The variety and maturity at harvest determine the bold or shriveled appearance. Some fleshy varieties, such as China and Rio de Janeiro, are not suitable raw materials as they take longer (12 to 14 days) time to dry and yield a shriveled product.

Jamaica traditionally produces peeled, dried whole ginger, which is valued in the retail market for its bold, clean, light buff appearance with a mild aroma. The sequence of operation is:

1. After harvesting, rhizomes are immediately washed free of soil.
2. They are soaked in water for 5-6 hrs or briefly put into hot water.
3. After breaking the rhizome into convenient sizes, the epidermis is completely hand-peeled or removed with a special blade that is narrow-edged.
4. Peeled rhizomes are spread on boards of corrugated metal sheets to dry in the sun for 5 or 6 days; they are collected into heaps every night. If drying is delayed by weather conditions, a second peeling may become necessary to produce an acceptable product.

Hand-peeling is a skilled and time-consuming operation, especially peeling the skin between the fingers (branches) of the rhizome. As the essential oil and resin-bearing cells are reported to be chiefly located under the epidermal tissues, excessive scraping substantially depreciates the aroma quality. The skilled labor required for the delicate operation is reported to be becoming scarce and costly, and production is, therefore, decreasing to the extent of becoming uneconomical.

Bleached (lime-coated) ginger, which is in high demand in Middle Eastern countries, is produced in Kerala (India). Mature green ginger is soaked in water in shallow cement cisterns and is trampled to remove the soil, roots, and loose skin; it is then left overnight after change of water. The process is repeated until the ginger is clean. The cleaned raw or peeled rhizomes are collected into bamboo baskets, dipped into cisterns containing slurry of slaked lime, and then spread on cement yards to dry in the sun. The process is usually repeated until the coating is uniform and bright. The dried material is then brushed with a piece of cloth to remove adhering remnants of skin and to give a smooth finish. In some areas, the lime-coated ginger is further treated with sulfur dioxide, produced from burning sulfur in a kiln. However, the bleaching treatment nearly doubles the processing cost.

9.2.1. Peeling

To aid peeling, early attempts were made to use a short lye-dip (Strong alkali), but this has generally been unsatisfactory, as the treatment interfered with the quality of flavor. Recently, abrasive peeling has been attempted in pilot experiments with equipment normally used for potato peeling. The variables (time of peeling, hot water dip, and degree of peeling) were studied in relation to volatile oil loss and drying time; a hand-peeled sample served as the control. Abrasive peeling for 60 sec gave a good grade of dried ginger with satisfactory drying characteristics and essential oil content compared to the laboriously hand-peeled sample. Abrasive peeling for 90 sec drastically reduced the volatile oil content (by over 75%); this emphasizes the importance of control of the layers removed in peeling for maintaining flavor quality. However, this product was not as clean as the hand-peeled product because the area between the fingers cannot be reached in mechanical peeling. Treatment with boiling water produced a dark product. A through-flow drier gave a faster rate of the peeled rhizome than the cross-flow drier, which tended to equalize at higher tray loads. Such mechanical devices have many advantages in producing a high-quality clean product and are worth further refinement and development.

9.2.2. Drying

Ginger used for making whole dry ginger is harvested at a maturity of about 8 to 9 months after planting, when growth is complete. This harvesting extends over a period of 3 to 4 months. Mature ginger can be held without deterioration for some weeks at ambient temperature. Early-harvest rhizomes are fleshy and are used for dehydration as whole dry ginger. With later harvests, the skin hardens, becoming impervious to moisture transfer from inside to outside for drying. Also, in certain areas such as Australia and the Solomon Islands, sun drying is not possible due to light showers at the harvest period and high humidity. As part of an effort to mechanize all stages of production, mechanical drying has been studied in Australia to find optimal design and conditions. The cost compared to sun drying would be high, but a consistently high-quality product can be expected which is valuable to flavor houses.

The lipid content of ginger varies greatly among varieties of ginger, from 5.8 to 11.0%, but is generally around 7%. The lipids of ginger are high in unsaturated acids and could create problems of rancidity and off-aroma in powdered ginger and extracts on storage.

Only a few early proximate analyses of world varieties of ginger are available. The moisture content is generally around 10%. The fibre content which is an index of maturity, varies from 2.3 to 4.7%, being low in the scraped and limed varieties and higher in the whole African ginger. Crude protein content is around 8% and starch, the dominant constituent and an index of maturity, is around 55%. Ash content, an indication of good processing and handling while preparing for market, is around 3.5%; it is as high as 8.3% in limed ginger (known as bleached in trade), due to coating of calcium carbonate. The two most important constituents contributing to flavor are the (1) volatile ether extract which varies form 1.27 to 2.73%, low for the scraped Jamaican varieties and limed ginger and high for the African and Cochin varieties and (2) nonvolatile ether extract which varies from 2.95% to 5.35%, low for the limed-varieties and high for African varieties. The Japanese ginger, which belongs to a different genus, analyses to a similar composition as genuine ginger except for low values of less than 1% for volatile ether extract.

Percentage of extracts by different solvents from another analysis is also available for some of the world varieties. Cold water extract of genuine ginger ranges between 12.6 and 15.5%. Low values of this constituent would indicate exhaustion by water extraction prior to sale. The volatile and nonvolatile ether extract values given are rather high. The alcohol-soluble extract values are unexpectedly low to the total of ether extracts.

The fibre content of different varieties, by any one set of analysis, varies from 5.17 to 8.13%, 4.32 to 7.03%, and 5.67 to 9.80%, and would be an important factor for selection in crop improvement programs. Total alcohol extract, an important index of the functional property of ginger, also varies by 100% among varieties. Varieties with high valued would be valuable if the extracts were mostly flavor contributing components and not nonflavor substances such as lipids, waxes, soluble carbohydrates, etc.

Selection of varieties suitable for specific processing, recommended in recent conference papers, will require information on the yield per hectare of the desirable functional constituents before planned programs for growing specific varieties can be designed. Of the 30 cultivars evaluated, yield of green ginger exceeding 20,000 kg/ha has been recorded for four varieties: one a traditional Kerala variety, two new selections from well-known Kerala varieties, and a newly introduced variety from Brazil, a country just emerging as an exporter of ginger. Yields of 15,000 to 20,000 kg/ha are given by 19 of the cultivars, while 7 cultivars yield less than 15,000 kg/ha. The high yielders are obvious selections for cultivation for green ginger harvests, provided they give the relatively high yield even at the early stage of growth, approximately 5 months after planting; more data on this aspect need to be collected. Ginger is a major crop in the northeast regions of India. The rhizomes are large and plumpy with over 85% moisture. On drying they yield a highly shriveled and unattractive product. Hence the crop is marketed largely as green ginger.

Recovery as dry ginger varied from 17 to 25% and bears no relation to green ginger yield or fibre content. This alters the ranking of the varieties for processing as dry ginger. Three of the high green ginger yielders and one of the medium yielders gave dry ginger yields of over 4000 kg/ha, while introductions from Brazil and Sierra Leone and six Indian varieties gave yields of 3500 kg/ha; the rest gave still lower yields. The obvious choices for manufacture and sale of dry ginger, the dominant marker for ginger, are the four high yielders unless other considerations such as appearance of dry ginger and resistance to diseases and drought conditions would influence the choice.

Fibre content, which is often quoted as an important factor in defining the quality of ginger, varied mostly between 5 and 7% only two varieties had less than 5% and three had more than 7%. This range may not make much difference for processing into powdered ginger. Low fibre content is important for making syrup or crystallized ginger; for this purpose, ginger is harvested at early maturity. Further data on fibre content for different varieties at the early stage are necessary.

9.2.3. Insect infestation and control

Dry ginger, usually packed in gunny bags, is highly susceptible to insect infestation during warehouse storage. The most important insect is *Stegobium paniceum* L., commonly known as the drugstore beetle. Other infestants identified in ginger are *Lasioderma serricorne* F., the cigarette beetle, and *Araceus fasciculates* Deg.

Disinfestations of spice and spice powders could be achieved by heat, but the risk of altering or loss of flavor is high. Heat treatment for bulk quantities is also time consuming and costly. For quick, efficient, and economic disinfestations, fumigation with suitable chemicals is used. The lethal dose of fumigants screened against *Stegobium paniceum* L. are as follows, shown in decreasing order of toxicity (mg/): phosphine, 1; hydrogen cyanide, 4; ethylene dibromide, 38; methyl bromide 40; and ethylene oxide, 78. It is essential that these concentrations be maintained for a defined time of exposure in the ambient intergranular atmosphere to achieve 100% control of insects at all stages of growth. Allowing for sorption of gas by commodities and loss by leakage, the working dosage in practical fumigation has usually been found to be four to five times the lethal dose. The fumigants generally recommended for use with spices are methyl bromide of hydrogen cyanide at 16 to 32 g/m^3 for 16 to 24 hr at 20^{0}C and above and an ethylene oxide-carbon dioxide mixture (1:9) at 640 g/ m^3 under sustained vacuum for 3 hr at 20^{0}C and above. While there is no fixed tolerance for methyl bromide, tolerances of 250 ppm HCN for a wide range of spices and 50 ppm ethylene oxide for whole spices are fixed.

Two vital considerations other than sterility in the application of fumigants are their effect on the flavor of the spice and fumigant residues. Observations on the effect on flavor appear to be meager.

Considering availability, safety, and ease of application, particularly in the spice-producing countries, the use of ethylene dibromide (EDB) and methyl bromide (MB) is recommended. It has also been shown that mixtures of EDB and MB in various proportions have synergistic effects.

Water-soluble inorganic bromides are formed as permanent residues from the use of these fumigants, and a tolerance of 400 ppm for residual bromides has been established for spices. The residues found with fumigation of ginger using 64 mg of EDB per litre for 96 hr and 64 mg of MB per litre for

48 hr are only 16.9 and 24.7 ppm, respectively.

Fumigation does not have any residual protective effect. For prophylactic treatment, spraying of the stacks with a residual insecticidal spray of lindane of malathion is necessary. Other pests of stored products, *Lasioderma sericorne*, F. and *Areaeceus fasciculatus* Deg., are reported to be controlled by the application of lindane (1%) followed by malathion (2%) and pyrethrum (0.5%) as dust on the outer surface of the bag.

9.3. Value added products

Ginger, in common with other imported spices, reaches the consumer, the housewife and the institutional and industrial sectors, mostly through the spice grinders. Spice grinding is a highly competitive but prosperous and expanding industry. Their knowledge and judgment on spice quality is valued and there is much brand name loyally among the consumers. Spice grinders provide the important steps of selection, cleaning grinding, blending, making proprietary spice mixtures, and unit packaging. Because of the number of steps involved and quality control to be exercised, the price at the retail level is high, varying from 4 to 13 times the imported price of raw spice, depending on the country and the type of unit packing. Ginger is available in commerce as wholes, grinds, proprietary spice mixes tailored to different uses, syrup and crystallized ginger bits, ginger oil, and ginger oleoresin.

9.3.1. Whole dried ginger

The fleshy, bold and clear appearance and mild flavor of the completely peeled rhizome, Jamaican ginger, is valued in retail trade. It is grade and unit packed. Other countries have generally not competed with Jamaica for the limited retail market of whole dried ginger.

9.3.2. Sliced and ground ginger

There are very few papers on the technology of grinding, but it is well known that the industry strives continuously to improve the hygienic quality of ground ginger and retain its flavor qualities. The unit operations involved in the production of grinds, though simple, require optimization of yield and maximal retention of quality, careful selection and storage of raw material, cleaning, and selection of appropriate grinding equipment and conditions of grinding, packaging, and storage. The preparation of grinds tailored to the needs of industry and preparation mixed tailored to consumer specifications are again specialized skills.

Storage of ginger as wholes and slices under optimum conditions of temperature and humidity for maximal retention of volatile oil and freshness should be valuable but surprisingly there have been no published studies. From the stray values for volatile oil content of dry ginger from the laboratories in the importing countries, there appears to be some loss of volatiles in stored imported ginger as compared to freshly dried sample available in producing countries. This aspect merits coordinated and extensive study.

Grinding

Dry ginger is available in commerce in the form of stone hard branched fingers, approximately 2 cm long, and would be required to be powdered in stages. In addition, the material is fairly fibrous at the stage of harvest maturity for making dried ginger. The choice of the type of grinding mill will be governed by these features. It is also necessary to keep in mind that at all stages of grinding, heating and much aeration of the mass should be minimized to optimize the retention of volatiles, reduce oxidative changes, and maximize throughput by minimal "gumming up" of "caking" at the rolls and screens.

Packaging

Hessian and straight plastic bags cannot be used for the storage of sliced ginger, as the cut surfaces are susceptible to insect attack resulting in material and quality loss. With ginger in powder form, these traditional packages are still less suitable due to rapid loss of volatiles. Fiberboard drums with or without coating or liners are in general use for powdered spices. Packaging studies of mechanically dried chips and dried immediately powdered have been made in Australia. Ginger in these two forms was packed in multiwall kraft bags, coated or laminated, mouth folded, and stapled as the most likely commercial package and stored up to 5 months at room temperature. Samples were analyzed every month for oleoresin (alcohol) and volatile oil. Samples stored in cans serves as control.

Freeze grinding

Since the use of liquid nitrogen for quick freezing came into use, the advantages of freeze grinding of spices have become obvious. The advantages are increased retention of volatiles, minimizing oxidation of the spice oils, improved storage stability by the very low temperature in the grinding zone, increased throughput by ease of grinding of the brittle frozen spice, and avoidance of the "gumming up" of the rolls and screens. An additional advantage is the extremely fine grinding that can be achieved which improves functional properties of the grind.

9.3.3. *Ginger-based beverages*

Among spices, ginger has the unique distinction of being used in beverages. Built around the central flavor of ginger and supported by other flavors from fruits, other spice, and herbs, there are two distinct classes of beverages, ginger beer and ginger ale. The principal difference between these two beverages lies in the rather higher gravity and higher extractives. Ginger beer has a complex flavor and cloudy appearance, whereas ginger ale is valued for its sparklingly clear appearance, distinct lemony-aromatic note on the basis ginger aroma, high pungency, and high carbonation. These two classes of beverages are made in a number of variations to cater to individual marker requirements and end uses. . There is much controversy about where these beverages started. Both however are very popular in the U.K. and U.S., and sizeable quantities of ginger are used in the production of these two beverages.

Ginger beer

There are three principal types in this class of beverage: (1) genuine brewed ginger beer, (2) artificially carbonated beverage made from brewed ginger flavor concentrate, and (3) non-brewed ginger beer.

Originally, ginger beers ere made by fermenting extracts of ginger and other spices and vegetable substances and brought into condition in bottles corked and tied to stand the pressure developed by secondary fermentation. The original bottles used were of stone, giving the brew the name "stone ginger beer", which also is reported to have given it a distinctive aroma different from the product in glass bottles later put into use.

Ginger ales

These are sparklingly clear carbonated beverages, made by dilution of concentrated with a basic ginger aroma and pungency, superimposed by citrus essences, fruit juices, and foam-producing substances; they are artificially carbonated. There are two general types namely sweet and sour.

9.3.4. Products based on fresh ginger

Salted ginger

Fresh ginger (with relatively low fibre) harvested at 170-180 days after planting can be used for preparing salted ginger. Tender rhizomes with a portion of the pseudostem may be washed thoroughly and soaked in 30% salt solution containing 1% citric acid. After 14 days it is ready for use and can be stored under refrigeration.

Ginger candy

i Take fresh ginger slices in a pot. Pour water to cover the rhizomes. Bring to gentle boil. Continue boiling for few minutes. Drain and repeat this 3-4 times to remove the spiciness.

ii Put holes in the ginger with fork. Blot the rhizomes with paper towels. Keep it in a big jar.

iii. In a pot combine 1½ cups sugar, 2 cups water, 2 tea spoon salt, 2 table spoon lime juice and bring to boil over medium heat. Remove from the heat and cool. Pour the syrup in to the jar and cover tightly. Leave it over night.

iv. Next day pour out only the syrup in to a pot; add 2 cups of sugar and 2 teaspoon salt. Bring to boil or until sugar and salt is dissolved. Cool and return the syrup to the jar. Cover and let stand over night.

v. Next day repeat 4, but with only ½ cup sugar and stand over night.

vi. Repeat step 5 once more. Keep it still for 2 nights.

vii. Pour ginger / syrup to a strainer, discard syrup. Spread ginger pieces in a single layer on a foil-lined cookie sheet, dry in the sun or in an oven until gingers become glazed and dried.

Ginger paste

Ingredients: 170 gm or 1 cup ginger; 45 ml or 3 table spoon of water.

Method:

i. Scrap, wash and roughly crop ginger.

ii. Put the chopped ginger in the blender, add water and make a fine paste.

iii. Remove and refrigerate

iv. Makes approximately 210 gm ginger paste.

Crystallized ginger

Fresh ginger with less fibre are peeled and sliced and following procedure is followed.

i Boil in water gently in a sauce pan until the rhizomes are tender for about 30 min.

ii Drain the water.

iii Weigh, place in a sauce pan, add equal amount of sugar, 3 table spoon of water.

iv Bring to boil, stir often until ginger is transparent and liquid evaporated.

v Reduce heat, cook, stir often until ginger is transparent and liquid evaporated.

vi Toss the cooked ginger in sugar to coat.

vii Store in airtight jar up to 3 months.

Ginger wine

Ingredients:

Fresh ginger pieces	1 Kg
Yeast	small pinch
Sugar	1 Kg
Water	1.5 litre

Method: Cook the washed ginger pieces in cooker for 10 minutes. When cold, keep for fermentation along with ¾ Kg sugar and yeast for 21 days. Mix the contents every alternate day. To improve appearance remaining ¼ Kg sugar is burned to brown colour and mix with wine.

Bleached (lime-coated) ginger

This is in high demand in Middle Eastern countries and is produced in Kerala (India). Mature green ginger is soaked in water in shallow cement cisterns and is trampled to remove the soil, roots, and loose skin; it is then left overnight after change of water. The process is repeated until the ginger is clean. The cleaned raw or peeled rhizomes are collected into bamboo baskets, dipped into cisterns containing slurry of slaked lime, and then spread on cement yards to dry in the sun. The process is usually repeated until the coating is uniform and bright. The dried material is then brushed with a piece of cloth to remove adhering remnants of skin and to give a smooth finish. In some areas, the lime-coated ginger is further treated with sulfur dioxide, produced from burning sulfur in a kiln. However, the bleaching treatment nearly doubles the processing cost. The lipid content of ginger varies greatly among varieties of ginger, from 5.8 to 11.0%, but is generally around 7%.

10.0. ECONOMICS AND MARKETING

10.1. Cost of production

The cost of cultivation of ginger and net profit realized will vary from region to region. A few studies are available on the estimation of production cost and cost benefit ratio. Experience shows that ginger crop is subjected to violent price fluctuations. One of the common practice resorted by the farming community to combat price related risk is inter cropping and multiple cropping. Studies have shown that maximum profit is obtained in banana - ginger intercropping system.

Ginger is a labour intensive crop. The estimate of operation wise labour requirement indicated that it requires 337 workdays per hectare for the entire period of cultivation. Compared to other spices, ginger is input intensive also. The share of fertilizer cost approximately amounts to 26 per cent of total cost while labour accounts to 65 % of total cost. A study carried out in Kerala, a leading ginger producing state indicated that, per kilo gram production cost of ginger is Rs. 5.52. The per kilo gram cost

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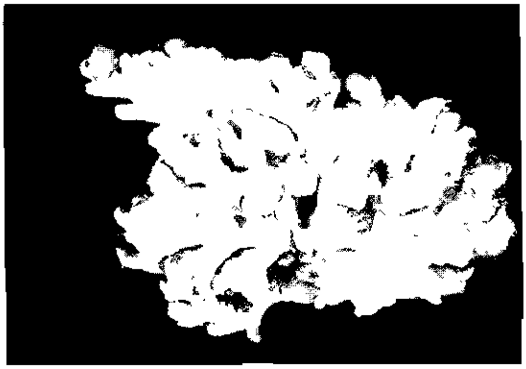
Improved varieties of Ginger



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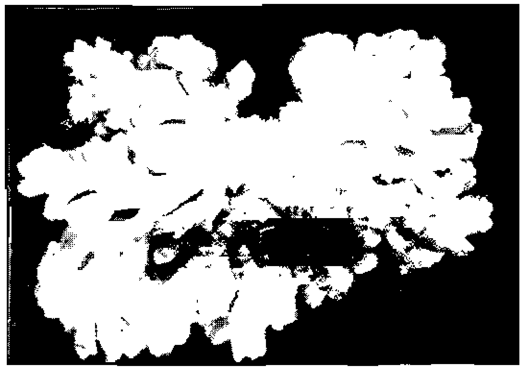

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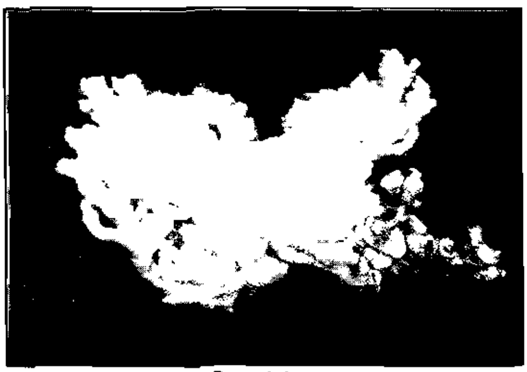

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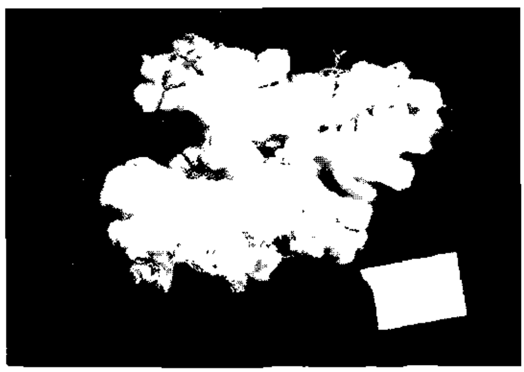

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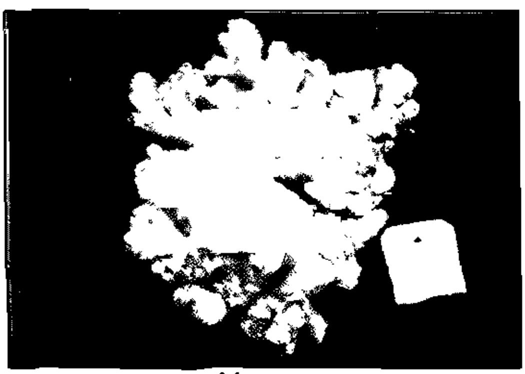

Maran

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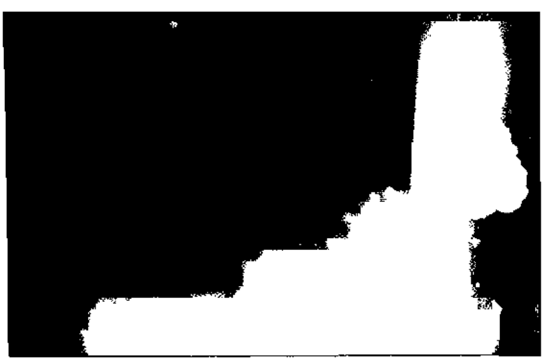
Pests and diseases of Ginger

Foft rot

Bacterial wilt

Leaf spot



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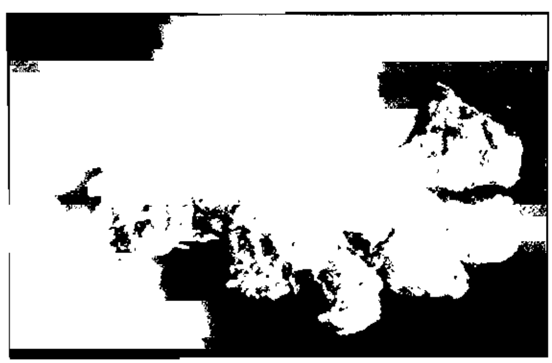

Rhizome scale

TURMERIC

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1.0. INTRODUCTION

Turmeric is an ancient spice, a native of South East Asia, used from antiquity as dye and as a condiment. It is cultivated primarily in India, Bengal, China, Taiwan, Indonesia, Sri Lanka, Java, Peru, Africa, Australia and the West Indies. Its' use dates back nearly 4000 years, to the Vedic culture in India where it was used as a culinary spice and had some religious significance. The name derives from the Latin word 'terra merita' meaning "meritorious earth", referring to the colour of ground turmeric which resembles a mineral pigment. In many languages turmeric is simply named as "yellow root". The botanical name is *Curcuma domestica* Val. syn: *Curcuma longa* L. belonging to the family *Zingiberaceae*.

Over the last several years, there has been increasing interest in turmeric and its medicinal properties. This is partially evidenced by the large number of scientific studies published on this topic. Turmeric is widely used as a food colorant and is one of the principal ingredients in curry powder. Turmeric has long been used in both Ayurvedic and Chinese medicine as an anti-inflammatory, to treat digestive disorders and liver problems, and for the treatment of skin diseases and wound healing. The active ingredient in turmeric is curcumin. It is still used in rituals of the Hindu religion, and as a dye for holy robes, being natural, unsynthesized and cheap. Although as a dye it is used similarly to saffron, the culinary uses of the two spices should not be confused and should never replace saffron in food dishes.

A tropical perennial related to ginger, it grows to 60 – 100 cm (2-3 ½ feet). It has long stemmed, bright green lily-like leaves, which surround conical clusters of pale yellow flowers. Turmeric thrives in the tropics and sub tropics where it requires a hot, moist climate and a fairly light soil. The economic part is the underground rhizome. It is propagated through division of the rhizome. The roots are boiled, dried for over a week and their rough skins are often polished before sale.

1.1. Area and production

India is the largest producer and exporter of turmeric in the world and among spices grown in India, it ranks fifth position in area (1, 61,300 hectares), second in production (6, 53,600 metric tonnes) and third in export (both in quantity (35,556 t) and value (Rs.121.7 crores)) during 1999 – 2000 (Spices Board, 2000). The yellow coloring factor 'curcumin' present in turmeric rhizome is gaining wider use in food industry, pharmaceuticals and preservatives and in health and body care. With the ban on artificial colour in food industry, use of 'curcumin' has become wide spread. In India, turmeric is produced from 230 districts in 22 states (table 1). The states like Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, and West

Bengal are the major producers of turmeric and these states contribute 90 per cent of the total production.

1.2. Chemical composition

The general chemical composition of turmeric trade samples are given in table 2. The rhizomes contain curcuminoids (2.5–6%) *which are responsible for the yellow* colour consisting of Curcumin I (diferuloylmethane), Curcumin II (Demethoxycurcumin) and Curcumin III (Bisdemethoxycurcumin). The essential oil (5.8%) obtained by steam distillation of rhizomes has α-phellandrene (1%), sabinene (0.6%), cineol (1%), borneol (0.5%), zingiberene (25%) and sesquiterpines (53%).

1.2.1. Oleoresin

. Turmeric oleoresin chiefly functions as a food color, and secondarily, in some of the products, to impart a characteristic mild spicy aroma compatible with mustard, pickles, relish formulas, etc. Product from industrial practice using good, clean turmeric, with curcuminoid content of 4.5 to 5% is a highly viscous, deep brownish- orange product, obtained in a yield of about 12%. This analyzes 30 to 40% as curcumin, 15 to 20 % volatile oil and has a characteristic fresh,

Table1. State wise area, production and yield of turmeric

State	2001-2002		
	Area ('000 ha)	Prodn. ('000 mt)	**Yield (mt / ha)**
Andhra Pradesh	61.7	249.5	4.0
Arunachal Pradesh	0.5	1.9	4.2
Assam	11.8	8.2	0.7
Bihar	2.9	3.0	1.0
Gujarat	0.7	12.2	17.7
Himachal Pradesh	0.1	0.1	0.8
Jammu & Kashmir	<0.1	0.2	11.5
Karnataka	6.7	35.6	5.3
Kerala	3.6	7.9	2.2
Madhya Pradesh	0.4	0.4	1.1
Maharashtra	6.8	8.5	1.3
Manipur	0.3	0.2	0.7
Meghalaya	1.5	8.6	5.6
Mizoram	0.3	2.8	10.0
Nagaland	0.6	3.0	5.0
Orissa	25.3	60.6	2.4
Rajasthan	0.1	0.5	3.7
Sikkim	0.4	1.2	3.1
Tamil Nadu	23.6	118.3	5.0
Uttar Pradesh	1.2	2.0	1.7
Uttaranchal	0.1	0.2	1.5
West Bengal	12.8	22.0	1.7
Total	**161.3**	**546.9**	3.4

Source: Spices Board Quoted by Global AgriSystem Pvt. Ltd., New Delhi

Table 2. Chemical Composition of turmeric-Trade samples

Source	Moisture	Starch	Protein	Fibre	Ash	Fixed oil	Volatile oil	Alcohol extractives
			%					
China	9.0	48.7	10.8	4.4	6.7	8.8	2.0	9.2
Pulena	9.1	50.1	6.1	5.8	8.5	7.6	4.4	7.3
Alleppey	8.1	50.4	9.7	5.8	6.0	7.5	3.2	4.4
Indian	13.1	69.4	6.3	2.6	3.5	5.1	5.8	--
Alleppey (Finger)	11.0	30.8	--	4.0	--	--	3.4	24.2
Alleppey (Bulbs)	12.0	26.3	--	4.6	--	--	3.4	16.2
Kadur	19.0	32.1	--	3.7	--	--	4.5	16.3
Duggirala	11.0	32.8	--	1.8	--	--	2.9	13.9

Source: CRC critical Reviews in Food Science and Nutrition, 1980

clean, mildly pungent, woody pungent, woody-spicy aroma of turmeric.

1.2.2. Volatile oils

Turmeric owes its aromatic taste and smell to the oil present in the rhizome. The volatile oil obtained by distillation of ground turmeric is pale yellow in color, consisting of a mixture of predominantly sesquiterpene ketones and alcohols. Two major ketonic sesquiterpenes viz; ar-turmerone and turmerone ($C_{15}H_{20}O$ and $C_{15}H_{22}O$) are responsible for the aroma in turmeric. The composition of essential oils from trhe various vegetative parts of turmeric are given in Table 3.

The rhizome oil of turmeric from Northern Plains of India contains 59.7% of ar-turmerone. The major constituents of the rhizome oil from the North Eastern region of India -Bhutan are found to be ar- turmerol (16.7-25.7%), ar-turmerone (32.0%), β-turmerone(14.7-18.4%).Similarly, the leaf oil of Bhutanese origin had α-phellandrene (18.2%), 1,8-cineole (14.6%),p-cymene (13.3%) and terpinolene(11.6%), while the leaf oil from North Indian plains contains p-cymene (25.4%),1,8-cineole (18%), cis-sabinol (7.4%)and β-pinene (6.3%).

1.2.3. Curcuminoids

The main coloured substance in the rhizomes is curcumin, which belong to the group of diarylheptanoids. It is an important active ingredient responsible for the biological activity of *Curcuma longa*. It is a yellow crystalline, odorless powder (mp 184 to 186^{0} C), poorly soluble in water, petroleum ether, benzene and soluble in methyl and ethyl alcohols, glacial acetic acid, and in propylene glycol, very soluble in acetone and ethyl ether. In a finely powdered form, curcumin can be dispersed in oil. With excess potassium hydroxide, curcumin forms a characteristic salt, as globular radiating flame colored crystals. This salt is insoluble in ether, but soluble in alcohol and water.

The content of curcuminoids in turmeric ranges from approximately 2.5% to 6%, of which curcumin accounts for 49% of the total pigments, demethoxy curcumin for 29% and bisdemethoxy curcumin for 22%. The absorption spectra of these three components vary slightly, with their maxima at 429nm for curcumin, 424nm for demethoxy curcumin and 419nm for bisdemethoxy curcumin respectively.

Table 3. Composition of essential oils from various vegetative parts of *Curcuma longa* L.

Component	Concentration(%)			
	Leaf	Flower	Root	Rhizome
α-pinene	2.1	0.4	0.1	0.1
β-pinene	2.8	0.1	0.1	tr
Myrcene	2.3	0.2	tr	0.1
α-Phelladrene	32.6	-	0.1	0.1
s-3-carene	1.1	0.6	-	-
αterpinene	1.3	0.1	-	-
p-cymene	5.9	1.1	3.3	3.0
β-phelladrene	3.2	tr	-	tr
1,8-cineole	6.5	4.1	0.7	2.4
z-β-ocimene	0.2	-	-	-
E-β-ocimene	0.4	-	-	-
γ-terpinene	1.5	-	-	tr
Terpinoline	26.0	7.4	0.1	0.3
Linalool	0.7	1.1	0.1	-
1,3,8-paramenthatriene	0.2	0.3	-	-
p-methylacetophenone	0.1	0.3	tr	tr
p-cymene-8-ol	0.8	26.0	1.5	0.3
α-terpineol	0.4	1.1	0.1	0.2
thymol	0.3	-	0.1	-
Carvacrol	0.1	-	0.3	0.1
γ-curcumene	-	-	-	-
Ar-curcumene	0.1	tr	0.4	0.1
α-gingiberene	0.2	1.9	7.0	6.3
β-bisabolene	0.5	0.8	tr	tr
b-sesquiphellandrene	-	0.9	2.3	1.3
E-nerolidal	0.3	1.1	tr	2.6
Dehydrocurcumene	0.1	1.1	-	-
Ar-turmerone	-	-	4.3	2.2
Turmerone	0.1	1.2	46.8	31.1
Curlone	0.9	1.0	-	10.0
curcuphenol	0.2	0.3	0.6	10.6
6S-7Rbisaboline	tr	tr	0.6	0.5
Others	0.1	0.4	1.2	0.9

1.2.4. Uses

Turmeric powder is considered auspicious in many religious ceremonies in Hindu families. It is also very commonly used as household remedy for minor cuts and wounds. Turmeric is an important condiment and a useful dye, with varied uses in drug and cosmetic industries. It is used medicinally for external application and taken internally as a stimulant.

- Turmeric has powerful antioxidant properties, is reported to protect against the development of cancer, and has a long history of use in the treatment of various cancers. In China it is used to treat the early stages of cervical cancer and shows protective effect against colon and breast cancer.

- Turmeric enhances the flavour of food and also aids digestion, particularly of protein, promotes absorption and regulates metabolism.
- Turmeric helps to regulate intestinal flora and is well worth taking during and after a course of antibiotics thereby reducing the risk of gastritis and ulcers.
- It lowers blood sugar in diabetics. Dietary curcumin brings about significant inhibition in the progression of renal lesions. Curcumin is an effective protective agent against cataract formation induced by lipid peroxidation in diabetics.
- Turmeric stimulates the flow of bile, protecting against damage from toxins and improving the metabolism of fats.
- It plays a significant role in the prevention of heart and arterial disease.
- Turmeric extract, volatile oil from turmeric and curcuminoids are reported to possess anti-inflammatory activity and hence effective for treating arthritis and diseases affecting liver and gall bladder.
- Curcumin prevents the development of radio resistance following radiotherapy.
- Turmeric acts as a potential anti-viral agent against human immunodeficiency virus (HIV), effectively decreasing the replication of the virus.
- The anti-bacterial effects of alcoholic extract of turmeric, curcumin and oil from turmeric are well-known. The aqueous and alcoholic extracts of turmeric as well as curcumin inhibits production of aflatoxins by *Aspergillus parasiticus in vitro*.

2.0. BOTANY AND CROP IMPROVEMENT

Turmeric belongs to the family Zingiberaceae which comprises of 40 genera and 400 tropical species in the whole world. Genus *Curcuma* has 40-50 species, situated in tropical Asia. Members of *Curcuma* are strong erect herbs with rhizome bearing habit. Among 40 species of *Curcuma*, only two species viz., *Curcuma longa* L. and *C. aromatica* Salisb. are commercially cultivated for the production of turmeric.

2.1. Botany

***Curcuma longa* L:**

Pseudo stem is tall, robust with oblong / elliptic leaves narrowed at the base. Plant height ranges from 67-69 cm in short and 67-83 cm in long duration types, 8-10 leaves in long and 7-8 in short duration types. The leaf length may range from 30-45 cm and breadth from 14-16 cm with petiole equaling the blade. Flowering is stray and the species is a sterile triploid ($3n = 63$) and do not set viable seed. Rhizomes are bigger with a stout mother rhizome with branching primary and secondary fingers exhibiting yellow to bright orange yellow core. Most of the high yielding varieties are long duration types which take 8-9 months for maturity.

***Curcuma aromatica* Salisb:**

Pseudo stem is slender with elliptic/oblong leaves. Plants are tetraploids ($2n=84$) and fertile. Flowering is common in this species and set viable seeds which produce weak seedlings. Plants produce peculiar root tubers at the end of fibrous roots. Rhizomes possess pleasant aroma and hence this turmeric is called as 'Kasturi' in Andhra Pradesh. Besides culinary preparations, this is also used as aromatic spice. Rhizomes are slender, rich in volatile oil and moderate in curcumin content. Rhizome yield is much less compared to *C. longa* types and takes only 6-7 months for maturity.

Flowering

Flowers are borne on spikes. Flowering is acropetal within a spike. First flush of flowers open completely in 5-12 days. The time of anthesis is between 6 and 6.30 A.M. Anther dehiscence takes place at the time of opening of flowers. Mode of pollination is by insects. Flowering period is between June and October. Cultivars of *C. longa* flower rarely and setting of seeds is hardly seen. Studies on morphology and anthesis of turmeric did not result in any suitable technique for controlled pollination. Number of days taken for flowering varied from 118-143 days in *C. longa* and from 95-104 days in *C. aromatica*. Flowering to seed maturity took 23-29 days in *C. aromatica*. Pollen stainability in acetocarmine varied from 45-48 per cent in *C. longa* and from 68-74 per cent in *C. aromatica*.

2.2. Popular cultivars

Popular cultivars are traditionally grown in each state and mostly are confined to certain regions/pockets of a state. Some are common in the entire state.

Andhra Pradesh

Andhra Pradesh has a rich varietal diversity. Several quality turmeric varieties are traditionally grown in the state. Varieties grown in Andhra Pradesh could be classified into 3 groups.

1. Short duration Kasturi types (*C. aromatica*) maturing in 7 months.

   These are rich in volatile oil but low in curcumin. These cultivars are tolerant to leaf blotch but susceptible to leaf spot and rhizome rot disease.

2. *Medium duration Kesari types* belonging to *C. longa* maturing in 8 months, moderately rich in volatile oil and curcumin, more susceptible to leaf blotch and rhizome rot.

3. *Long duration types* maturing in 9 months, superior to both the groups in yield and quality but susceptible to leaf spot disease.

Popular Kasturi types: (C. aromatica)

Kasturi Kotapeta is popular in East Godavari district of Andhra Pradesh. It has a yield potential of 10-14 t/ha with a curing percentage of about 24. *Kasturi Tanuku* is popular in West Godavari with a comparable yield and curing percentage as that of Kasturi Kotapeta. *Kasturi Amalapuram* is common is Central Delta in East Godavari. It yields around 10-12 t/ha with a curing percentage of around 25. *Chayapasupu* is another cultivar commonly grown in Godavari, Visakhapatnam and Srikakulam districts in small pockets. It has moderate yield (10-12 t/ ha) but the curing percentage is low (19 %), mainly grown for good colour and aroma of rhizomes. *Gummalakshmipuram* is grown in Srikakulam district. It has moderate yield potential (12-14 t/ha), but higher curcumin (5 %) and oleoresin content (15 %). But it has very low curing percentage (14 %).

Table 4. Improved varieties of turmeric

Variety/Year of release	Pedigree/Parentage	Institution/University	*Av. yield t/ha (fresh)	Salient features	Recommend State/Region
CO 1 1983	Vegetative mutant by x-ray irradiation of Erode local	Dept. of Spices and Plantation Crops, HC & RI, TNAU, Coimbatore-641 003, Tamil Nadu	30.5 (Pot. yield 35.0)	Bold and bright orange yellow rhizomes, curcumin 3.2%, oleoresin 6.7%, essential oil 3.7%, dry recovery 19.5%, suitable for drought prone, hilly, saline and alkaline areas. Crop duration - 270 days. Plants are robust, vigorous and taller (40-60cm) with more leaves (25-32 Nos) and tiller production(3.7 to 5.0)	Tamil Nadu
BSR 1 1986	Clonal selection from Erode local irradiated with x rays	-do-	30.7 (Pot. yield 39.6)	Bright yellow rhizome, curcumin 4.2%, oleoresin 4.0%, essential oil 3.7%, dry recovery 20.5%, crop duration 285 days, suitable for drought prone areas of Tamil Nadu.	**Tamil Nadu**
BSR 2 1994	Induced mutant from *Erode local*	-do-	32.7	A high yielding short duration variety (245 days) with bigger rhizomes, resistant to *scale insects*	Tamil Nadu
Krishna 1983	Clonal selection from Tekurpeta collection	Maharashtra Agrl. University, Kasba, Digraj, Maharashtra-416 305	9.2 (Pot. yield 11.8)	Plumpy rhizomes, curcumin 2.8%, oleoresin 3.8%, essential oil 2.0%, dry recovery 16.4%, duration 240 days Moderately resistant to pests and diseases.	Maharashtra
Sugandham 1984	Clonal selection from germplasm	Spices Research Station GAU, Jagudan-382701 Mehsana, Gujarat	15.0 (Pot. yield 20.0)	Thick, round rhizomes with short internodes. Curcumin 3.1%, oleoresin 11.0%, essential oil 2.7%, dry recovery 23.3%, duration 210 days. Moderately tolerant to pest & diseases.	**Gujarat**

	Roma 1988	Clonal selection from T.Sunder	High Altitude Research Station, OUA&T, Pottangi-764 039, Korapurt (Dist), Orissa	20.7 (Pot. yield 40)	Suitable for both rainfed and irrigated condition. suitable for hilly areas and late season planting. Curcumin 6.1%, oleoresin 13.2%, essential oil 4.2% and dry recovery 31.0%, duration 250 days.	Orissa, TN, HP, AP and Kerala
	Suroma 1989	Clonal selection from T. Sunder by x-ray irradiation	-do-	20.0 (Pot. yield 44.9)	Round and plumpy rhizome, field tolerance to leaf blotch, leaf spot and rhizome scale, curcumin 6.1%, oleoresin 13.1%, essential oil 4.4% and dry recovery 26.0%, duration 253 days.	Orissa, TN, HP, AP and Kerala
	Ranga 1992	Clonal selection from Rajpuri local	-do-	29.0 (Pot. yield 37.1)	Bold and spindle shaped mother rhizome, suitable for late planting and low lying areas. Moderately resistant to leaf blotch and scales, curcumin 6.3%, oleoresin 13.5%, essential oil 4.4% and dry recovery 24.8%, duration 250 days.	Orissa, Tamil Nadu, HP, AP and Kerala
	Rasmi 1992	Clonal selection from Rajpuri local	-do-	31.3 (Pot. yield 37.5)	Bold rhizomes, suitable for both rainfed and irrigated condition, early and late sown season, curcumin 6.4%, oleoresin 13.4%, essential oil 4.4% and dry recovery 23.0%, duration 240 days.	Orissa, TN, HP, AP and Kerala
	Rajendra Sonia 1989	Selection from local germplasm	Dept. of Hort., Tirhut College of Agriculture, RAU, Dholi-843121, Bihar	(Pot. yield 42.0)	Bold and plumpy rhizome, grows widely under all north Indian conditions. Curcumin 8.4%, essential oil 5.0% and dry recovery 18.0%, duration 225 days.	Bihar

	Megha turmeric-1 1996	Selection from Lakadong type	ICAR R.C. NEH Region, Shillong, Meghalaya	23.0	Suitable for the North East hill and North West Bengal. Bold rhizomes, high curcumin content 6.8% and dry recovery 16.37%, duration 300-315 days.	Meghalaya
	Pant Peethabh 2001	Clonal selection from local types	Department of Vegetable Science, GB Pant Univ of Agriculture and Technology, Pantnagar-263 145, Uttaranchal	20.0 (Pot. yield 27.5)	Long attractive fingers, curcumin 7.5%, essential oil 1.0%, dry recovery 18.5%, resistant to rhizome rot.	Uttar Pradesh and Uttaranchal
	Suranjana (TCP-2) 2000	Clonal selection from local types of West Bengal	Uttar Bengal Krishi Viswa Vidyalaya, North Bengal Pundibari (PO)- 736 165, Dist. Cooch Behar, West Bengal	(Pot. yield 29.0)	Suitable for open or shaded and rainfed or high rain fall conditions, sole or intercrop, Curcumin 5.7%, oleoresin 10.9%, essential oil 4.1%, dry recovery 21.2%, duration 235 days, tolerant to leaf blotch and rhizome rot. Resistant to rhizome scales and moderately resistant to shoot borer.	West Bengal
	Suguna 1991	Selection from germplasm collected from Assam	Indian Institute of Spices Research, ICAR, Calicut-673 012, Kerala	29.3 (Pot. yield 60.3 t)	Short duration type (190 days), curcumin 4.9%, oleoresin 13.5%, essential oil 6.0% and dry recovery 20.4%, field tolerance to rhizome rot.	Kerala and Andhra Pradesh

Suvarna 1991	Selection from germplasm collected from Assam	-do-	17.4 (Pot. yield 43.5)	Bright orange coloured rhizome with slender fingers. Maturity 200 days, field tolerant to pest and diseases. Curcumin 4.3%, oleoresin 13.5%, essential oil 7.0% and dry recovery 20.0%.	Kerala, Karnataka and Andhra Pradesh
Sudharsana 1991	Selection from germplasm collect from Singhat, Manipur	-do-	28.8 (Pot. yield 54.9)	High yielding variety, short duration type (190 days). Field tolerant to rhizome rot. Curcumin 5.3%, oleoresin 15.0%, essential oil 7.0% and dry recovery 20.6%.	Kerala and Andhra Pradesh
IISR Prabha 1996	Open pollinated progeny selection	-do-	37.47	High yielding variety, curcumin content 6.5%, oleoresin 15.0%, essential oil 6.5% and dry recovery 19.5%, crop duration 205 days.	Kerala and Tamil Nadu
IISR Prathiba 1996	Open pollinated progeny selection	-do-	39.12	High quality line, 6.2% curcumin content with high yield, 16.2% oleoresin, 6.2% essential oil, 18.5% dry recovery, crop duration 225 days.	Kerala, Tamil Nadu and other states
IISR Alleppey Supreme 2004 (identified)	A clonal selection from Alleppey turmeric	-do-	35.4 5.58 (dry)	Shows tolerance to leaf blotch disease. Rhizomes contain 5.55% curcumin, 16.0% oleoresin, 19.0% dry recovery, crop duration 210 days	Kerala (rainfed) Maharashtra, Karnataka and N. Bengal (irrigated)
IISR Kedaram 2004 (identified)	Clonal selection from germplasm	-do-	34.5 5.28 (dry)	Tolerant to leaf blotch disease, Rhizomes contain 5.5% curcumin, 13.6% oleoresin, maturity 210 days and 18.9% driage.	Kerala (rainfed) Maharashtra, Karnataka and N. Bengal (irrigated)

	Kanthi 1996	Clonal selection from Mydukur variety of Andhra Pradesh	Dept. of Plantation Crops and Spices, College of Hort., KAU, Vellanikkara – 680 656, Trichur, Kerala	**37.65**	Erect leaf with broad lamina, big mother rhizomes with medium bold fingers and closer internodes. Medium duration. Curcumin content (7.18%), oleoresin 8.25%, essential oil 5.15%, dry recovery 20.15%, duration 240-270 days.	Kerala
	Sobha 1996	Clonal selection from local type germplasm	-do-	35.88	Mother rhizome big with medium bold and closer internodes. Inner core of rhizomes is dark orange like Alleppey. More tertiary rhizomes. Dryage 19.38%, curcumin content (7.39%), oleoresin (9.65%), essential oil (4.24%), medium duration 240-270 days.	Kerala
	Sona 2002	Clonal selection from local germplasm	-do-	**4.02 (dry)**	Orange yellow rhizome, medium bold with no tertiary fingers. Best suited for central zone of Kerala. Rhizome medium bold, field tolerant to leaf blotch. Curcumin 7.12%, essential oil 4.4%, oleoresin 10.25%. 18.88% dry recovery, medium duration. 240-270 days.	Kerala
	Varna 2002	Clonal selection from local germplasm	-do-	4.16 (dry) (Pot yield 6.37)	Bright orange yellow rhizome, medium bold with closer inter nodes, tertiary fingers present. Suited to central zone of Kerala. Field tolerant to leaf blotch, curcumin 7.87%, essential oil 4.56%, oleoresin 10.8%, 19.05% dry recovery, medium duration 240-270 days.	Kerala

Popular Kesari types: (C. longa)

Kesari Duvvur is cultivated to a limited extent in Cudapah district, moderate in yield and curing percentage, susceptible to leaf blotch. *Amruthapani Kothapeta* is popularly grown in East Godavari district. It has high yield potential (25 t/ ha) with a curing percentage of around 19.

Popular long duration types: (C. longa)

Duggirala is extensively grown in Krishna and Guntur districts. It has high yield potential (25-30 t/ha) under heavy fertilization. Dry recovery is 22.4 % and curcumin content ranges from 3.2 - 3.4., susceptible to leaf spot and rhizome rot. *Mydukur* is a popular variety of Cuddapah district with a high yield potential (32 t/ha) in red soils, low in curing percentage (19), low curcumin (2 %) and highly susceptible to leaf spot and rhizome rot. *Tekurpet* is common in Rayalaseema region. It has comparable dry recovery and curcumin content as that of *Duggirala*. Fingers are hard and on drying produce metallic sound and have longer shelf life, susceptible to leaf spot. *Armoor* is commonly grown in northern districts of Telangana, short compared to *Duggirala*, *Mydukur* and *Tekurpet* with a yield potential of 25 t/ha and 22 % dry recovery. Curcumin percentage is around 3 and susceptible to leaf spot and rhizome rot. *Avanigadda* grown in Krishna district is good in curing percentage (23), volatile oil (4 %) *and curcumin (3.8 %) but is a low yielder* (15-18 t/ha).Other common varieties are *Sugandham* and *Vontimitta* cultivated in Cuddapah district, both are low yielders and have low curing percentage, but moderate in curcumin percentage (3.5-3.9). *Nandyal* grown in Kurnool district is a high curcumin variety (4.25 %).

Tamil Nadu

Erode and *Salem* are popular cultivars (*C. longa*) of Tamil Nadu. Both are high yielders (30-32 t/ha), and have moderate curing percentage, but Salem is rich in curcumin also (4.75 %).

Assam

Shillong variety is popular in Assam. It matures in 8 months, high yielder (40t/ha) with very low curing percentage (14 %) but good in curcumin (4.1 %). Tolerant to leaf blotch, rhizome rot and resistant to leaf spot. *Tall Karbi* is grown in Karbi region of Assam, matures in 7 months, good yield potential (30-40 t/ha), low in curing (17.6) and curcumin (3.06) percentage and tolerant to leaf spot and rhizome rot, but susceptible to leaf blotch.

Orissa

Duhgi is a popular variety of Orissa. Very low yielder (10 t/ha) but rich in volatile oil (5 %). *Katingia* is also a very low yielder (8 t/ha) but has a very high curing percentage (36 %). Other common varieties are *Jobedi, Sarangado, Luzurmunda, T. Sundar*, and *Phulbani.*

Maharashtra

Rajapuri is a popular cultivar of Maharashtra and Gujarat. Moderate yielder (20 t/ha), moderate in curcumin (3.4 %) and has moderate resistance to leaf spot.

Evaigon is a high yielder (45 t/ha) but has low curing percentage (17).

Kerala

Alleppey is a very popular variety in Kerala and also in Indian market for its high quality, has average yield potential (25 t/ha) and rich in curcumin (4.4%) but low in curing percentage (19%). *Mannuthy Local* is another popular variety very rich in curcumin content (7.6%).

Uttar Pradesh

Gorakhpur is grown in certain parts of U.P., low yielder (15 t /ha) with a curing percentage of 18 and 3.5 % curcumin.

Other states

Nahin in H.P., *Lakadong* in Meghalaya (Singh, 1982), *Arukona* in Tripura, *Kasturi, Mundaga, Balaga* and *Yalachaga* in southern parts of Karnataka .The other species of *Curcuma* which are cultivated to a limited extent are *C. anguistifolia* Roxb. and *C. cassia*.

2.3. Improvement

Characters aimed at improvement are higher curcumin content, yield, tolerance to drought and diseases such as leaf blotch.

2.2.1. Selection

Many varieties were released as selection from germplasm. Variety Krishna was released for cultivation in Maharashtra for high yield and tolerance to diseases and pests. Crop improvement carried out at High Altitude Research Station, Pottangi, Orissa indicated that PTS 10 and PTS 24 had higher curing percentage and comparatively less susceptible to leaf blotch, rhizome rot and scale. These were later released as Roma and Suroma for large scale cultivation in Orissa.

Screening germplasm for important pests and diseases revealed various sources of resistance. Among 19 turmeric types, Mannuthy Local shows least infestation of pest and diseases of turmeric. Heritability and genetic advance of resistance to leaf spot disease suggests scope for selection of resistant types. Open pollinated progeny selection led to the development of two high yielding and high quality turmeric varieties, IISR Prabha and IISR Prathibha. In Meghalaya, a high curcumin selection from local Lakhadong cultivar was released as RCT1.

2.2.2. Hybridisation

Varietal improvement in turmeric is mainly through selection and the hybridization could not be practiced since the commercial types are sterile triploids of *C. longa*. Cultivars of *C. aromatica* are tetraploids and set seed. Hybridisation of *C. aromatica* with *C. longa* could be attempted through polyploid and haploid breeding techniques which produced plants with differential chromosomal types. The possibility of selecting better types with short duration types as that of *C. aromatica* with high yield, curcumin and oil content as that of *C. longa* types is indicated. The sterility in *C. longa* is probably due to its autotriploid nature. There is difficulty in crossing short duration types with medium and long duration types as one of the parents in these crosses were triploid (Nazeem and Menon, 1994). *In vitro* pollination and fertilization can be an effective tool to overcome such incompatibility. Seed set could be obtained through *in vivo* pollination in three combinations of short duration turmeric types and the same could not be achieved in crosses of medium duration cultivars and short x medium duration cultivars.

2.2.3. Mutation breeding

Mutation breeding was successful in releasing the variety CO-1 through X-ray radiation treatment of Erode Local variety. The variety recorded 71.1 % higher yield than Erode Local. BSR 1 was another variety released through mutation breeding. The variety recorded a mean fresh yield of 30.69 t/ha as against 24.7 t recorded by CO-1.

3.0. SOIL AND CLIMATE

3.1. Soil

Well drained, deep loamy to clay loam soils with good organic status are well suited for this crop. Red loamy or alluvial soils are ideal. Very coarse and heavy soils are unsuitable for rhizome development. Turmeric is grown in wide range of soil types of varying fertility grouped under Inceptisols, Entisols, Vertisols, Alfisols and Ultisols. Soils that are having high organic carbon, base saturation, major and secondary nutrients are suitable for turmeric cultivation. The crop can thrive well in the soil pH range of 4.3 to 7.5.

3.2. Climate

Turmeric is a tropical crop cultivated commercially as an annual extensively from India to South East Asian countries. It is successfully cultivated from subtropical dry to wet through dry to wet tropical zone at an altitude of 1200 m above MSL, with an optimum range of 450-900 m. In India it is widely grown in warm to hot, per humid to humid eco sub regions. Annual rainfall range in growing region is 640mm to 4290mm. Moderate rainfall at sowing, fairly heavy and well-distributed rain during growing period and dry weather about one month before harvest is much suitable. The temperature range of 18.2°C – 27.4°C is optimum. The crop is raised as rain fed where rainfall is high and distributed for 5 to 7 months and with irrigation where rainfall is low.Air temperatures of 30-35°C, 25-30°C, 20-25°C and 18-20°C during germination, tillering, rhizome initiation and bulking, respectively are noticed at Orissa.

4.0. PLANTING AND AFTERCARE

4.1. Seed rhizomes

Healthy and disease free rhizomes should be selected for seed and stored on moist sand under shade or in ground pits. Adequate aeration is required during storage. Apparently healthy turmeric seed rhizomes are dipped in fungicide solutions for 15 min and after shade drying they are kept in aerated pits under the shade. The incidence of rhizome rot was lowest when treated with fungicides besides the treatment enhanced germination and yield. Hot water treatment at 50°C for 30 min without affecting germination can be followed to eradicate all fungi associated with turmeric seed rhizomes. Bavistin is the most effective fungicide on rhizomes infected with rot.

Both mother and finger rhizomes can be used for propagation. Mother rhizome produces vigorous plants, but availability will be less. Generally primary fingers are used for planting. A general seed rate of 2500 kg ha^{-1} is optimum. The turmeric seed rhizome of 30-40 g with a larger diameter weighing 25-34 g, free from daughter rhizomes having one or two buds can be used. Increasing tuber size from 20-29 to 80-89 g increased yields. The shoot biomass and yield are highest in the plants grown directly from mother rhizomes when compared to the plants from daughter rhizomes attached to that of mother rhizomes. Although the mother rhizomes are better yielders, during shortages of mother rhizomes, secondary rhizomes could be used successfully with 150 kg N/ha for obtaining higher yields.

4.2. Preparation of land

The land is prepared with the receipt of early monsoon showers. The soil is brought to a fine tilth by giving about four to six deep ploughings. Hydrated lime has to be applied for laterite soils to bring to desirable pH and thoroughly ploughed. Immediately with the receipt of pre-monsoon showers, beds of 1.0-1.5 m width, 15 cm height and of convenient length are prepared with spacing of 50 cm between beds. Planting is done on ridges and furrows and broad ridges also ensuring good irrigation and drainage. Flat beds are preferred in red soils and raised beds in black dry loams. Fresh rhizome yield was significantly higher in ridge method of planting than flat method of planting. It produced significantly taller plants and more number and weight of primary and secondary rhizomes. Planting primary fingers 20 cm apart in broad ridges (80 cm long, 10 cm wide, 20 cm high with 30 cm wide irrigation channels) gave 52% higher yield than the ridges and furrow method. In Meghalaya, turmeric is grown by *bun* method of cultivation, where a series of beds (called *buns*) are formed along hill slopes. Experiment showed that flat bed planting followed by earthing up as the best planting method for higher rhizome yield.

4.3. Planting

Planting starts with the commencement of southwest monsoon rain in most parts of India. Planting is also advanced for better utilization of summer showers as in Kerala where the crop is rain fed. When cultivated under irrigation, depending upon the water availability, the crop is planted in the field. In general, planting is done between April and August in India. Normally, turmeric is planted from middle of March to early April in Punjab, between 15th April and 15th May in Kerala, first week of May to June in Orissa. Planting season is spread over from first week of May to the first week of August in Tamil Nadu. Planting from the first fortnight of May to the first fortnight of July is the ideal planting period for reduced disease incidence and high rhizome yield. The rhizome yield decreased with delayed planting from March to May.

Even though planting later than the normal period decreases leaf blotch (caused by *Taphrina maculans*) intensity, the yield reduction will also be high. Planting at the end of April gave the highest yields. Under delayed planting, turmeric should be planted in a nursery and then transplanted rather than direct planting in the field. In Orissa, early planting at third week of May was the best. Higher fresh rhizome yield can be obtained May 16 planting by using finger and mother rhizomes as seed material, compared to (early)April 16 and (late) June 16 planting under Madhya Pradesh conditions. Planting time varies with locations.

4.4. Spacing

Plant population per unit area influences the yield. Spacing to be adopted depends on soil type, fertility level, season, cultivar and irrigation facility or rainfall distribution. On raised beds, planting is done in small pits with spacing of 25cm x 30cm and covered with soil or dry powdered cattle manure. Spacing of 25cm x 25 cm was optimum for 'flat bed' method and 45 to 60 cm x 25 cm for 'ridge and furrow' method. Different spacings are used at different locations, (30 x 45cm, 45 x 20cm, 30 x 15cm). In Kerala, 30 x 15 cm was recommended under 'flat bed' system. Planting whole mother rhizomes with 30 x 22.5 cm for getting higher yields found to be the best in Andhra Pradesh. Higher fresh rhizome and cured yield was obtained with 30x15 cm spacing with a fertilizer dose of 150: 125: 250 kg NPK ha^{-1} at Karnataka. Planting turmeric at 45 x 45 cm spacing (49383 plants per hectare) reduced leaf blotch intensity without any significant reduction in yield. Planting of turmeric at different spacings did not influence the curing percentage and curcumin content. Yields generally decreased as the planting depth increased from 15 to 20 and 30 cm.

4.5. Mulching

Application of mulch after planting in high rainfall or sloppy lands adjacent to forest is a common practice. Mulching with locally available leaves or straw is beneficial. The crop is to be mulched immediately after planting with green leaves @ 12-15 tonnes/ ha and repeated after 45 days at the time of top dressing. In Orissa 12.5 t/ha green mulch materials are being applied thrice in a cropping season (at planting, 45 and 90 DAP) for maximizing yield. Mulching with Daincha and Sunnhemp leaves was also found to be useful. Mulching, in addition to improving the organic status of the soil, also hastens germination by a week and decreases the weed growth. Sugarcane trash mulch was found to increase the germination rate and rhizome yield in Punjab.

The quality of mulch is also more effective in conserving soil moisture and increasing the growth and yield of turmeric under rain fed conditions. The application of mulches at 10 t ha^{-1} conserved more moisture and increased the yield of turmeric by 12% and paddy straw mulch resulted in 18% increase in yield over *Gliricidia* mulch. But, no difference in rhizome yield and growth due to application of fresh sal leaf or paddy straw as mulch was also noted.

The application of straw mulch is more beneficial than intercropping turmeric with pigeon pea, maize or green gram in getting net returns. However, it has no effect on the oil and curcumin content. Early planting (on 23 May) and mulching with *Dalbergia sissoo* leaves gives the highest yield of fresh rhizomes and the highest returns on non-irrigated calcareous soil compared to mulching with mango leaves or rice straw. Highest yield and return per rupee investment are obtained with dry forest leaf litter mulch + intercropping with French bean (Rs 2.16), followed by dry forest leaf litter mulch alone.

4.6. Irrigation and weed control

Irrigating 70-80 L per bed (3m x 1m) once in 7-10 days increases the rhizome yield by 30-40%. Frequency of irrigation can be at 5 day intervals in red loam and 7-9 days in black soils. The water use efficiency and rhizome yields of the crop were found to increase in drip irrigation 40 or 80% of surface irrigation treatments along with highest N rate. Water use efficiency of turmeric under drip-irrigation system was highest under 60% evaporation replenishment (of USWB class A pan evaporation) with 60 cm lateral spacing and 100% evaporation replenishment with 60 cm lateral spacing produced highest yield.

Weed growth may not get affected by the planting depth of turmeric until 50-60 days after planting (DAP), but affected thereafter due to mutual shading with the canopy. Application of Pendimethalin and oxyfluorfen, each followed by hand weeding at 80 DAP, resulted in 45 and 39% more fresh rhizome yields and pendimethalin @ 1.0 kg/ha application resulted in significantly lower weed dry matter (WDM) as compared to atrazine @ 1.0 kg/ha or fluchloralin 1.0 kg/ha and glyphosate 0.5 kg/ha. All the weedicide applications are effective in reducing the weed growth significantly and increasing the rhizome yield over unweeded control.

4.7 Nutrient requirement and uptake

The uptake of nutrients increases as the dry matter production increases. The maximum uptake was observed in active vegetative growth phase. Higher uptake of K upto third, N upto fourth and P upto fifth months of development was observed with subsequent decrease in their uptake. Use of mother rhizomes enhances the uptake of N, P and K as compared to primary or secondary rhizomes for planting. The uptake of nutrients by turmeric is in the order of potassium > nitrogen > magnesium > calcium (table 5). An average dry yield of 5.5 t ha^{-1} turmeric rhizomes removes 91 kg N, 16.9 kg P_2O_5, 245 kg K_2O.

Approximately 9% of the turmeric growing area in Tamil Nadu is severely limited by mineral nutrition and about 20% of samples were identified as having deficiencies. The optimum levels for 12 nutrients (N, P, K, Ca, Mg, Na, S, B, Zn, Cu, Fe and Mn) in the leaves of turmeric using Diagnosis and Recommendation Integrated System (DRIS)/Modified Diagnosis and Recommendation Integrated System (MDRIS) and Compositional Nutrient Diagnosis (CND) approaches has been worked out.

5.0. MANURING

5.1. Role of organics

Many experimental evidences show the beneficial effects of organic matter alone or in combination with inorganic fertilizers in turmeric. Farm yard manure (FYM) or compost @ 40 tonnes/ha is applied by broadcasting and ploughing at the time of preparation of land or as basal dressing by spreading over the beds to cover the seed after planting. The increase is over 37 per cent in the fresh yield. Kerala Agricultural University (KAU) recommends 40t/ha compost or cattle manure as basal dressing for Kerala conditions, where as in Orissa 15 kg has been applied in 5m² bed area in three splits along with chemical fertilizers. Organic manures like groundnut cake, vermicompost

Table 5. Removal of nutrients by turmeric at harvest (kg ha^{-1})

Location/soil type	Nutrients (Kg/ha)				
	N	P_2O_5	K_2O	Ca	Mg
Kasaragod-Laterite	124	30	236	73	84
Vellanikkara-Lateritic	72-115	14-17	141-233	--	--
Bhavanisagar-Sandy loam	166	37	285	--	--
Coimbatore- Clayey loam	187	39	327	--	--
Calicut – Lateritic	86	31	194		

and neem cake can also be applied. In such cases, the dosage of FYM can be reduced. Application of FYM increases the organic carbon, available P and effective cation exchange capacity content in the soil there by improving the fertility which inturn significantly improves plant height, number and weight of mother, primary and secondary rhizomes and fresh rhizome yield. Nitrogen, phosphorus and potassium contents in leaves and rhizome improved with farmyard manure application. Application of FYM at 50 t /ha increased the fresh rhizome yield up to 11.72 t/ha under Mizoram conditions.

FYM + 90 kg N/ha is optimum for turmeric production in acidic alfisols of Meghalaya, with considerable N use efficiency (34.3%) and nutrient build up in the soil. Application of cow dung (50t/ha) followed by 90, 60 and 90 kg N, P_2O_5, K_2O/ha yielded the highest with maximum profit under Mizoram conditions. In Wynad (Kerala), application of 100 kg N per ha along with FYM (15 t/ha) and green leaf mulch (50t) produced maximum yield. The application of groundnut cake (1.1 t/ha) or neem cake (2.5 t/ha) significantly increased the dry yield and curcumin content (table 6) on par with neem cake application (2.5 t/ha).

5.2. Biofertilizers

Turmeric shows good response to the application of organics and biofertilizers. Integrated application of coir compost (@ 2.5 t/ha) combined with FYM, biofertilizer (*Azospirillum*) and half recommended NPK significantly increased yield and quality. Application of FYM (5 t ha^{-1}) with 50% inorganic N and *Azospirillum* (5 kg ha^{-1}) produced higher yield of mother, primary and secondary rhizomes with a cost benefit ratio of 1:2.28. Up to 16% increase in yield by the application of 25 kg *Azospirillum* with 50% of the recommended dose of inorganic N and 5 tonnes FYM/ha over the recommended dose of fertilizer application was observed, which is found beneficial considering the savings on the cost of 50% of the inorganic N. The rhizome yield and nutrient uptake by turmeric were significantly higher in inoculation of both single or combined inoculation of *Azotobacter* and

Table 6. Yield and quality of turmeric as affected by organic and inorganic fertilizers

Treatment	Turmeric	
	Dry yield (Kg/ha)	Curcumin (Kg/ha)
Check	2374	169
FYM	2596	250
Neem cake	2602	**287**
Cotton cake	2640	**284**
Brassica cake	2784	243
Groundnut cake	2669	277
Gingily cake	2768	249
NPK fertilizer*	2480	268
NPK fertilizer + micro nutrients**	--	--
CD at 5%	--	32.2

* NPK @ 60, 50, 120, ** Zn, B, MO @ 5, 2, 1 kg/ha.

Azospirillum and the percentage increase in yield due to inoculation integrated with fertilizer N ranged from 15.2 to 30.5% with enhanced N-use efficiency.

Turmeric is found to have effective mycorrhizal association by extra-, intra- and intercellular hyphae of VAM fungi in their roots. The cultivars, Suguna followed by Prabha and Sugandham, are the most heavily colonized with mycorrhizal fungi with mycelium, arbuscules, vesicles and spores of *Glomus*, *Gigaspora* and *Sclerocystis* with domination of *Glomus* population. The mycorrhizal inoculation is advantageous in improving plant growth and plants inoculated with different species of VAM fungi recorded a significant increase in growth compared to uninoculated plants.

5.3. Inorganic nutrition

Being an exhaustive crop, turmeric responds well to judicious application of fertilizers. Location specific fertilizer recommendations are made (table.7). The response to N varies from location to location depending on soil type, variety and other factors. Studies at various states indicated that turmeric responded economically up to 300 kg N ha^{-1}. In Tamil Nadu, increased N levels up to 120 kg N ha^{-1} significantly increased the fresh rhizome yield (41 t/ha) and the yield increase was up to 62 percent. N at 150 kg ha^{-1} was identified as the optimum dose for higher rhizome essential oil yield at Jabalpur, Madhya Pradesh conditions.

Under Punjab conditions, application of 60 kg N ha^{-1} in three equal splits produced the maximum fresh rhizome yield than basal application of whole N. N content in leaves and rhizomes as well as the available soil nitrogen increased with the increase in N level and number of split application. Under Maharashtra conditions yield response to application of N up to 120 kg ha^{-1} was observed in var. Krishna.

Phosphorus application increases root growth by enhancing the production of numerous lateral roots with increased water use efficiency and yield. The response to applied P is reported up to 175 kg P ha^{-1} with the combination of other nutrients. Application of rock phosphate (RP) and single super phosphate (SSP) in ratios of 1:3, 1:1, 3:1

Table 7. Fertilizer recommendations for turmeric in different agro-ecological situations

Location	Recommended dose			
	FYM (t/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Andhra Pradesh	25	300	125	200
Assam	20	30	30	60
Bihar	NA*	150	50	100
Kerala	40	30	30	60
Maharashtra	NA	120	60	60
Tamil Nadu	25	120	60	60

NA - Not available*

combinations also increased the yield of turmeric in comparison to the control. Among P sources, super phosphate and FYM incubated rock phosphate increased the rhizome P concentration. Significantly higher dry yield in turmeric was obtained in Gafsa phos followed by Raj phos applications when incubated with FYM. Not much variation was observed in curcumin content due to application of different sources of P. Among all the sources, apparent phosphate recovery, agronomic efficiency of the applied P and percentage yield response was higher for Gafsa phos followed by Raj phos incubated with FYM. N and P uptake, curcumin content and P use efficiency were increased with the application of 1:3 Rock Phosphate + SSP + FYM in Meghalaya.

The response to K was varying with increased yield up to 180 kg K_2O ha^{-1}. Application of potash fertilizers in splits (basal, 40, 80 and 120 DAP) responded in terms of higher rhizome yield (30 t ha^{-1}) up to the level of 90 kg ha^{-1}. N and P fertilizers significantly affected plant height and tiller number. K significantly affected the yield and curcumin content. Application of 80 kg of both potassium and nitrogen per hectare on the low hills of Nagaland increased the productivity of turmeric with enhanced accumulation of N, P and K contents as well as curcumin contents in the rhizome. Under rain fed conditions of Madhya Pradesh, maximum yield of 16.3 t ha^{-1} was recorded with the application of 120 kg N and 60 Kg K_2O ha^{-1} and N and K application up to 150 kg ha^{-1} had positive effect on rhizome yield at North Bihar. Maximum curing percentage (22.07) and cured rhizome yield was obtained at 100:100 kg P & N ha^{-1}.

Maximum yield (35.3 t ha^{-1}) and cost-benefit returns (1:2.58) were recorded with the application of 150:125:250 kg NPK ha^{-1}, in Karnataka. NPK rates of 187.5:62.5:125 kg ha^{-1} have been recommended for getting better quality rhizome in cultivars Mydukur and Gorakhpur. The fertilizer levels adopted by different workers for maximizing productivity in different locations are summarized in table 8.

N: P: K at 200:100:100 kg ha^{-1} resulted in the maximum green rhizome yield, the highest net return (Rs. 30 227 ha^{-1}) with a benefit cost ratio of 1.62 under Maharashtra conditions and split application of N was better compared to one time application. N applied in 3 splits recorded the highest rhizome yield, maximum net returns and benefit: cost ratio. Application of NPK (125:62.5:62.5 kg ha^{-1}) + 1 t ha^{-1} farm boon (an organic manure obtained from sugarcane waste) resulted in the highest fresh rhizome yield (25.75 t ha^{-1}).

Table 8. Optimum levels of N, P and K (kg ha^{-1}) recommended for different locations

Optimum N P K	**Recommended Location**
150:125:250 kg ha^{-1}	Karnataka
120: 60:120 kg ha^{-1}	Hillzone of Karnataka
60: 50: 120 kg ha^{-1}	Calicut, Kerala
130: 90: 70 kg ha^{-1}	Arunachal Pradesh
200: 60: 200 kg ha^{-1}	Alluvial plains of West Bengal
75: 60: 150 kg ha^{-1}	Allahabad agro climate
100: 50: 50 kg ha^{-1}	Shimla Hills
200: 100: 100 kg ha^{-1}	Maharashtra
100: 100: 100 kg ha^{-1}	Uttar Pradesh, India

N: P: K at 90:60:90 kg ha^{-1} gave the highest net returns with 25.5 t ha^{-1} rhizome yield under rain fed conditions. The application of 100% NPK with humic acid as potassium humate applied to soil (at 10 kg ha^{-1}) and 0.1% foliar spray of humic acid with recommended dose of fertilizer significantly enhanced the growth and yield attributes, fresh and cured rhizome yields of turmeric.

5.4. Micronutrients

Intensive cropping in certain areas depletes the soil reserve of nutrients and creates imbalances in nutrient status in soil that leads to low production. Application of $FeSO_4$ @ 30 kg ha^{-1} increased rhizome yield up to 24% in Fe deficient soils of Tamil Nadu. Similarly, application of $ZnSO_4$ @ 15 kg ha^{-1} increased the rhizome yield by 15%. Combined application of 50 kg ha^{-1} each of $FeSO_4$ and $ZnSO_4$ recorded an increased yield up to 21.4 t ha^{-1}. Application of 120 kg N and 120 kg K_2O ha^{-1}, together with the trace elements B (2 kg ha^{-1}) and Zn (10 kg ha^{-1}) gave the maximum economic yield in turmeric intercropped under partial shade of coconut. Foliar application @ 0.25% $ZnSO_4$ twice has given higher rhizome yield on par to soil application of 7.5 kg Zn ha^{-1}.

5.5. Growth regulators

Application of growth regulators influences the curing percentage, yield of cured produce and curcumin content significantly. NAA and KNO_3 applications increased the curing percentage, yield of cured produce and curcumin content compared to that of kinetin sprays. Spraying Planofix [NAA] at 10 ppm once at 6 months after sowing recorded highest yield of fresh rhizomes.

5.6. Organic farming

In recent years, organic agriculture has been gaining considerable importance and many farmers are switching to this traditional method of cultivation as a means to produce safe foodstuffs and preserve the environment. Organic farming favors lower input costs, conserves nonrenewable resources, high-value markets and boosts farm income. A survey by SOEL (Foundation Ecology and Agriculture) shows that India has 41000 ha (0.03% of total agricultural area) under organic cropping with 5661 numbers of registered organic farms, producing agricultural crops like plantation, spices, pulses, fruits, vegetables and oil seeds etc. Internationally, there is a shift towards traditional / ethnic system of medicines. Since spices like turmeric form part of many of these medicines, the demand for organically produced turmeric is also increasing considerably in the importing countries.

Turmeric as a best component crop in agri-horti and silvi-horti systems, recycling of farm waste can be effectively done when grown with coconut, arecanut, mango, *Leucaena,* rubber etc. As a mixed crop it can also be grown or rotated with green manure/ legume crops or trap crops enabling effective nutrient built up and pest or disease control. For certified organic production for at least 18 months the crop should be under organic management *ie.* only the second crop of turmeric can be sold as organic. Traditional varieties adapted to the local soil and climatic conditions are promoted.

An independent body to provide a guarantee that the production standards are met usually does certification and labeling.

Govt. of India has taken steps to have an indigenous certification system to help small and marginal growers and to issue valid organic certificates through certifying agencies accredited by Agriculture Produce Export Development Authority (APEDA) and Spices Board. Spices Board under National Programme has developed guidelines for organic production of turmeric under National Programme of Organic Production (NPOP). Liming @ 400 kg ha^{-1} for acidic soils, application of 40 t ha^{-1} FYM as basal, 2 t of neem cake and 5-8 t of vermi-compost and mulching with green leaves @ 12-15 t ha^{-1} at 45 days intervals are recommended. In turmeric, combined application of different organic sources like FYM + pongamia oil cake + Neem oil cake + Stera meal + Rock phosphate + wood ash has yielded on par to the conventional practice in addition with high quality. But research results during initial years showed 15% and 23% reduction in yield in turmeric under organic system as compared to conventional and integrated managements, respectively. The quality parameters of turmeric (curcumin and starch) are found to be high under organic farming. Among organics, highest fresh rhizome yield of 34.4 t ha^{-1} was recorded in combined application of vermicompost and coir pith compost (@ 5 t ha^{-1} each) followed by FYM, vermicompost and coir pith compost application. Application of vermi compost at 10 t ha^{-1} increased the rhizome yield from 6.7% - 25.5%. Application of FYM and organic cakes enhanced the residual nutrient availability of nutrients to the second crop also with fewer incidences of pest and diseases.

5.7. Inter cropping

Intensive cultivation in the form of intercropping to exploit slow growing turmeric during initial stages is a common practice. Turmeric can be grown as an intercrop in coconut and arecanut plantations and mango orchards. It can also be raised as a mixed crop with chillies, colocasia, onion, brinjal and cereals like maize, ragi, etc. Nutrient competition in intercropping system systems can be minimized by selecting crops of different rooting patterns and nutrient requirements by proper spacing. Growing maize in the inter row space of turmeric till the harvest with application of 188 kg N, 70 kg P_2O_5 and 125 kg K_2O for turmeric and 120 kg N, 60 kg P_2O_5 and 40 kg K_2O for maize resulted in higher yield and more economic returns. Significant decrease in turmeric rhizome yield due to maize intercropping was also observed.

Intercropping turmeric with pigeon pea, maize or green gram reduced the availability of light and the rhizome yield. However, net returns were higher under intercropping, compared with monoculture.

Intercropping with turmeric can be a substantial source of extra income in forest plantations. Turmeric can be grown as an effective intercrop (benefit:cost ratio of 2.51) in a silvi-horti system with fodder trees like bhimal (*Grewia optiva*), khark (*Celtis australis*), banj (*Quercus leucotrichophora*) and kachnar (*Bauhinia variegata*). The highest rhizome yield of turmeric was recorded (18.70 t/ha) with *Q. leucotrichophora* in Uttaranchal, India with a benefit:cost ratio of 3.21. Teak based Agroforestry and mango based agri horti systems can accommodate turmeric as a successful inter crop. Turmeric cultivation yielded a gross returns of Rs 208 428 ha^{-1}, with Rs 183 975/- from the main product and Rs 24, 453/- from the by-product with the benefit:cost ratio of 2.76 in Belgaum district of Karnataka.

Arecanut based high-density multispecies cropping system (HDMSCS) with component crops like pepper [*Piper nigrum*] trained on arecanut palms, banana in a triangular system (5.4 m x 2.7 m), turmeric spaced 30 cm x 30 cm, and pineapple in two rows spaced 60 cm x 30 cm between two palms of arecanut resulted in higher production with arecanut *chali* yield of 2405 kg ha^{-1}, dry pepper yield of 1252 kg ha^{-1}, pineapple fruit yield of 988 kg ha^{-1} and turmeric yield of 2127 kg ha^{-1} at the full dose of recommended fertilizer application in Kahikuchi, Assam. *Leucaena leucocephala* and *Eucalyptus camaldulensis* are most compatible agroforestry systems for turmeric intercropping. Maximum rhizome yield of turmeric when grown within the rows of *Leucaena* planted 4.0 x 1.0 m apart and pruned 5 times/annum. The yield of intercrop per unit area slightly increased with increasing tree spacing and frequency of pruning, whereas the yield of *Leucaena* decreased with increasing both the spacing and frequency of pruning. Increased rhizome yield in sole cropping system compared to alley cropping of turmeric within 2m distance from 5 years old established tree plantation of *Leucaena leucocephala*.

The total yield and all yield attributing characters of turmeric are adversely affected under shade in comparison to open cultivation. Yield characters, such as number of tillers per clump and fresh rhizome yield were lowest under heavy shade as compared to open cultivation. Severity of *Colletotrichum* leaf spot was significantly lower (1.8%) in heavy and partial shade (4.5%) in comparison to open cultivation (23.7%) (Singh and Edison, 2003). Higher solar energy input under open condition helps in higher crop growth rate during bulking of rhizomes.

Multiple cropping systems in Assam involving coconut + betel vine + banana + Assam lemon + turmeric + colocasia improved the nutrient availability, soil fertility, population of *Azotobacter* and the net income per hectare. Pigeon pea-turmeric inter cropping during the first 10 years of a poplar (*Populus deltoides*) plantation is also an economically viable system with a BC ratio of 6.68 in Bihar. Following table (table 9) provides technologies developed for turmeric intercropping systems in India.

6.0. DISEASES AND THEIR MANAGEMENT

The crop is susceptible to a number of fungal diseases. Bacterial and viral diseases are not so common and are of minor importance. The important fungal diseases affecting the crop are rhizome rot, leaf blotch and leaf spots.

6.1. Major diseases

6.1.1. Rhizome rot

It is the most destructive of all the diseases affecting turmeric and is reported as a major problem in turmeric growing tracts of Andhra Pradesh and Tamil Nadu. The disease occurs during the Southwest monsoon period when the crop is in the active growing stage. Water logged conditions predisposes the plant to infection.

Symptoms

The disease is characterized by the appearance of water soaked lesions at the

Table 9. Technologies for turmeric intercropping system

State	Station / Location	Experiment	Technology
Andhra Pradesh	Northern Telegana Zone	Turmeric + Maize Profitable Intercropping	Turmeric variety- Armoor, Duggirala, Mudukur Spacing (30X15cm) Maize variety – Poineer, Ganga-4, Deccan Spacing (60X30 cm)
	Regional Agricultural Research Station, Rudroor	Turmeric inter cropped with Maize, Okra, Caster, Chilly	Best are Turmeric+ Maize (2 1) Turmeric+Chilly (2:1)
	Regional Agricultural Research Station, Jagatial	Turmeric + Maize intercropping	100% population of both crop at 2:1 ratio with fertilizer for both crop at recommended dose
Karnataka	Gandhi Krishi Vigyana Kendra (UAS), Bangalore	12 lines tested under coconut garden	Acc.No. 10/8, Rajapuri, PCT 8 are the best
Kerala	Agricultural Research Station, Mannuthy	14 lines tested under coconut garden	Amruthapani Kothapetta, Chayapa- subha, Amalapuram, Kasthurithanka, Kodur type, Kuchupudi, Mannuthy Local are the best
	Regional Agricultural Research Station, Pilicode	15 lines tested under coconut garden	VK-11, VK-77, VK-114, VK-116, PTS-10, Vontimitta are the best
	College of Agriculture, Vellayani	Turmeric under coconut	Application of 120:120 kg N K_2O along with boron (2 kg) and zinc (10 kg) ha^{-1} for turmeric recorded maximum economic yield. P application as per soil status.
Maharashtra	Agricultural College, Pune	Turmeric + Maize	Adoption broad ridge system of planting was the best
Orissa	High Altitute Research Station (OUA & T), Pottangi	Mulch and Intercropping (French bean, Red gram)	Sowing French bean at 45 days after turmeric planting serve as a cover crop and need not go for 2nd and 3rd mulching
Tamil Nadu	Tamil Nadu Agricultural University, Coimbatore	Double intercropping with turmeric, Intercrops tested - Bhendi, Coriander, Onion, Amaranthus, Radish, Fenugreek, Bush bean, Beet root,	Turmeric + Fenugreek + Onion was the best treatment
	Agricultural Research Station, Bhavanisagar	Rely intercropping with turmeric Crop tested Coriander, Onion, Fenugreek, Fennel, Radish	Turmeric – Coriander Turmeric – Onion
	Agricultural Research Station, Bhavanisagar and Coimbatore	Turmeric-Maize and onion Intercropping	Raising turmeric with 50 % population of maize at 100 cm between maize rows and raising onion planted at 23 % population and application of 250 kg N ha^{-1} was the best
West Bengal	Bidhan Chandra Krishi Vishwa Vidyalaya, Kalyani	Turmeric intercropping with Pigeon pea, soybean, green gram, maize, rice	Short duration cereals like maize, rice or green gram provided the food to the subsistence farmers

base of the pseudo stem and yellowing of the lower leaves. The root infection is manifested as browning and rotting of the roots which later advances into the rhizomes which become soft and rotten. The colour of the rhizome changes from bright orange to different shades of brown. The infection gradually spreads to all the fingers and mother rhizomes and eventually the plants die. When the affected rhizomes are split open, brown to dark brown fibro vascular tissues are seen. The infected plants show gradual drying up of leaves along margins and later the entire leaf dries.

Pathogen

A survey conducted in different turmeric growing regions of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh showed the predominance of *Pythium* species in causing the disease. Different species of *Pythium* viz. *P. myriotylum, P. graminicolum, P. aphanidermatum* etc were recorded as pathogens of rhizome rot. The pathogen is soil and seed borne in nature. Infected rhizomes can harbor the maggots of *Mimegrella coerulifrons*, which in certain cases is suspected to be the cause of the disease. This fly was found to be the primary casual agent of rhizome rot.

Disease management

As the disease can also be seed borne in nature and harbor maggots of *Mimegrella coerulifrons*, dipping rhizomes in a combination of fungicide and pesticide solution greatly prevent the incidence of seed borne infection. This is usually done just before storage of the rhizomes after harvest and just before sowing of the rhizomes. Treated rhizomes may be air dried before storage. Rhizome treatment with a combination of mancozeb (0.25%) and quinalphos 0.075% for 15 minutes is the recommended practice. Soil drenching with metalaxyl mancozeb (0.2%) or mancozeb (0.25%) at 15-20 day interval twice with the first appearance of the symptom is effective in managing the disease. Crop rotation is also recommended to reduce the incidence of rhizome rot.

Disease resistance

PCT-13 and PCT-14 from Andhra Pradesh and Ca 69 and shillong from Assam were found to be tolerant to rhizome rot.

6.1.2. Taphrina *leaf spot / Leaf blotch*

Symptoms

The disease in characterized by the appearance of small scattered oily looking translucent spots on the lower leaves when the plants are in 3-4 leaf stage. The leaf spots later turn dirty yellow and deepen to colour of gold and some times to bay shade. The adjacent individual leaf spots of 1-2mm in diameter coalesce forming reddish brown blotches leading to varying degrees of leaf blight. In severe case of attack, hundreds of spots appear on both the sides of leaves. The lower leaves are more prone to infection than upper leaves.

Pathogen

The disease is caused by *Taphrina maculans*. Moist cloudy weather with temperature of 25-30°C during August-September months predisposes the plant to infection. The disease incidence is influenced by soil borne inoculum. Primary infection can also occur on the lower leaves during October-November months when the temperature falls to 21-23°C with 80%relative humidity. The secondary infection is by ascospores discharged from successively maturing asci, which grow into octosporus micro colonies and infect fresh leaves with out any dormancy.

The disease perpetuates from one season to other through viable ascogenous cells borne on the infected leaf debris in the field after harvest as well as through desiccated ascospores and blastospores ejected from mature asci during the crops season and over summering in the soil and leaf trash.

Curcuma amada, *C.angustifolia*, *Zingiber cassumnar*, *Z. zerumbet* and *Hedychium* sp. are alternate hosts of *T. maculans.*

Disease management

Crop rotation: Since the infected plant material serves as the perpetuating media for the fungus, crop rotation is important to reduce the inoculum build up in the soil.

Phytosanitation: Phytosanitation is the first and foremost practice in managing this disease. Cutting and burning of diseased leaves would greatly help in preventing the spread of the disease.

Chemical control : Foliar spray using fungicides such as Dithane-Z 78 (0. 2%), Dithane-M 45, Blitox 50, Bavistin and Cuman L are effective in controlling the disease.

Disease resistance

All short duration cultivars are found resistant to *Taphrina maculans.* The varieties such as CLL 324, Amalapuram, Mydukur, Karhadi local, CLL 326, Ochira 24 and Alleppey among *C. longa* group and ca 68, ca 67, Dahgi and Kasthuri among *C. aromatica* types were reported to be resistant to infection.

6.1.3. *Colletotrichum leaf spot*

The disease is prevalent in turmeric growing areas of South Gujarat. The disease appears usually during Southwest monsoon period in the month of September when there is high and continuous humidity in the atmosphere. The pathogen attacks mostly on the leaves. When the incidence of disease is heavy, most of the leaves dry up and the field present a scorched appearance.

Symptoms

The disease appears in the form of elliptic or oblong spots of variable size. In the initial stages of infection the spots appear small and measure 1.5-20 inches in length and 1.0-1.5 inches in breadth and later they may increase in size. In advanced stages, two or more spots coalesce and develop into irregular patches occupying a major portion of the leaf, which eventually dries up. The centre of the spot is grayish white and thin with numerous black dot like acervuli springing on both surfaces. These are arranged in concentric rings. The grayish white portion is surrounded by a brown region with a yellow halo around it. The spots are markedly visible on the upper surface in new leaves. The central region of the spot may become papery and easily torn. The infection is usually confined to left blades and may occasionally extend to leaf sheaths. Stromatoid bodies are formed even on the scale of rhizomes. The infection is also noticed on turmeric flowers as spots.

Pathogen

Leaf spot disease of turmeric is caused by *Colletotrichum capsici*. The pale brownish hyphae accumulate inside the epidermal cells and form the basis of stromatal development. The stomata are made up of light to dark brown pseudo – parenchymatous cells. The outer wall of the epidermis is ruptured and the setae and conidiophores are exposed. The pathogen survives on infected leaf debris for one year, which forms the source of primary infection.

Disease management

Cultural: Application of chemical fertilizers (Nitrogen @120kg/ha, Potash @ 70-120/kg/ha) is found to be effective in reducing the disease incidence irrespective of the split doses applied.

Chemical control: The disease can be managed by spraying 1% Bordeaux mixture during August, before the appearance of the disease.

Two sprays of carbendazim (0.2%) at disease initiation and twice at 15 days interval is effective in controlling the disease. Four sprays of captan (0.2%) or Dithane Z-78 at monthly intervals or six sprays of *Dithane M-45 @ 0.25% at 15 days interval* was also recommended for the control of the disease.

Disease resistance: Long duration types are highly susceptible to the disease. The varieties Nallakatla, Sugandham, Duvvur and Gandikota were resistant to leaf spots. 'Mannuthy local' showed high degree of field tolerance

6.1.4. Leaf blight

The disease occurs during the warm and humid weather.

Symptoms

The disease is manifested as water soaked spots of varying shapes and sizes on the lower leaves which gradually increase in size resulting in blightening of entire leaf area. The blighted leaf area is divided or banded into various sectors which are characteristic symptoms for early diagnosis.

Pathogen

Leaf blight of turmeric is caused by *Corticium sasaki*. The fungus thrives well in a wide range of temperature varying from 15-30°C.

6.2. Minor diseases

6.2.1. Leaf spots

Turmeric is also susceptible to leaf spots caused by various other species of fungi viz. *Phaeodactylium alpiniae*, *Thirumalacharia curcumae*, *Phyllosticta zingiberii*, *Phaeorobillarda curcumae*, *Cercospora curcumae-longae sp. nov.*, *Myrothecium roridum Toxde Ex.Fr.*, *Pyricularia curcumae* and *Pestalotiopsis* sp. These diseases are of sporadic occurrence and noticed only in few areas and have not of much importance.

The leaf spot caused by *Thirumalacharia curcumae*, a new gen. and sp., cause oval to oblong, 4-9 X 3-5 cm, grey brown leaf spots on *Curcuma* sp.

Disease management

In general, the leaf spots of turmeric can be controlled by foliar sprays with fungicides such as mancozeb (0.2%), Captan, Zineb or Bavistin (0.2%) twice at 15 day interval with the first appearance of the symptoms.

6.2.2. Brown rot

The disease was noticed in the germplasm collections *C. aromatica* and *C. longa*.

Symptoms

The disease was characterized by unusual discoloration and rotting of mature rhizome. During the early stages of infection, *rhizomes are dull in colour.* In advanced stage, the rhizome becomes deep grey to dark brown, less turgid, lose weight, wrinkled and exhibit dry rot symptoms. The fingers are more severely affected than the mother rhizomes. On cutting open, affected rhizomes show dark brown necrotic lesions starting from the margin in to the internal tissues. In initial stages, these necrotic lesions are localized, remain discontinuous and extent to a depth of 2-5 mm. At later stages, the lesions coalesce to form larger necrotic areas and progressively extend over a major portion of the rhizome.

Pathogen

A *Fusarium* sp. and a nematode, *Pratylenchus* sp., have been recorded from affected tissue (Described elsewhere also).

6.2.3. *Leaf blast*

The turmeric cultivars CLL325, CLL326, CLL327, Sugandham and Rajpuri (all belonging to *Curcuma longa*) and Ca69 (*C. aromatica*) were immune to infection by *Pyricularia curcumae*. They were also immune to *Taphrina maculans* infection. Kasturi and a Mikkir type (both *C. longa*) were very susceptible to *P. curcumae*.

6.2.4. *Storage rot*

Storage rot is a serious problem in turmeric. Improper storage as well as heaping harvested rhizomes under sun will lead to rotting of the rhizomes. Many species of fungi are found associated with rotting of the rhizomes. Favourable incubation temp. and relative humidity at 60% leads to maximum spoilage. But no rotting occurs at 15°C even when the RH varied from 30 to 90%. Storage rot of rhizome of turmeric is more than 60% in some districts of Andhra Pradesh. The rot is maximum in September and minimum in May in the Delhi Market.

Pathogen

The most virulent and widespread of the fungi causing storage rot of *Curcuma longa* are *Macrophomina phaseolina* and *Cladosporium cladosporioides*. Other species viz. *Aspergillus, Fusarium, Rhizoctonia* and *Sclerotium rolfsii* were also reported to be associated with storage rot. *Drechslera rostrata* is also found to be associated with storage rot.

Disease Management: Storage rot can be controlled by treating the rhizomes with ceresan wet or mancozeb at 0. 25% concentration. After seed treatment with fungicide, the rhizomes should be well air dried before storage.

7.0. INSECT AND NEMATODE PESTS MANAGEMENT

Various species of insects have been recorded to infest turmeric (*Curcuma longa* L.) in India among which shoot borer and rhizome scale can be considered as major insect pests. The lacewing bug, turmeric thrips, leaf beetles and leaf roller are minor insect pests causing sporadic damage in certain areas.

7.1. Major insect pests

7.1.1. *Shoot borer*

Distribution

The shoot borer (*Conogethes puctiferalis* Guen.) is the most serious insect pest of turmeric in India. Though the pest is reported to be widely distributed in India, authentic information on the incidence of the pest on these crops in various regions of the country is not available.

Damage and crop loss

The larvae bore into pseudostem and feed on the central growing shoot resulting in yellowing and drying of infested leaves. The presence of a bore hole in the pseudostem through which frass is extruded is the characteristic symptom of the insect attack. The withered central shoot is also typical of pest infestation.

Life history

The adults are medium sized moths with a wingspan of 18–21 mm; the wings are orange-yellow with minute black spots. Studies on biology of the pest on turmeric conducted under laboratory conditions at Kasaragod (Kerala) indicates that the egg period lasts for 3–4 days. There are five larval instars and they lasted for 3–4, 5–7, 5, 3–8 and 7–14 days, respectively. Fully grown larvae are light brown with sparse hairs and measure 16–26 mm in length. The pre-pupal and pupal periods lasted for 3–4 and 9–10 days, respectively.

Seasonal population

The shoot borer is observed in the field throughout the crop season (June to December) in Kerala and its population is generally higher in the field during October to November.

Natural enemies

Eleven species of hymenopterous parasitoids and an entomophagus nematode in addition to five species of predators (earwig, asilid flies and spiders) were recorded as natural enemies of shoot borer on turmeric at Kasaragod.

Management

Monthly spraying of malathion 0.1% during July–October is effective for the management of shoot borer of turmeric.

7.1.2. Rhizome scale

Distribution

The rhizome scale (*Aspidiella hartii* Ckll.) infests rhizomes of turmeric both in the field (especially during the later stages of the crop) and in storage.

Damage

The pest infestation is generally seen in the form of encrustation on the rhizomes during the later stages of the crop and severely infested plants wither and dry. In storage, the pest infestation results in shriveling of buds and rhizomes leading to loss in weight of rhizomes. When the infestation is severe, it adversely affects the sprouting of rhizomes.

Life history

The adult females are minute, circular and light brown to grey and measure about 1 mm in diameter. Females are ovovivipa rous and also reproduce parthenogenetically; a single female lays about 100 eggs.

Natural enemies

The natural enemies recorded on rhizome scale include *Physcus* (*Coccobius*) *comperei* Hayat, *Adelencyrtus moderatus* Howard and two types of mites. Apart from *Coccobius* sp., a predatory beetle and ant were also observed to predate on rhizome scale.

Management

Dipping the seed rhizomes of turmeric in quinalphos 0.075% for 15 minutes after harvest and before planting is effective for controlling the pest infestation.

7.1.3. Rhizome fly

Organism

Mimegrella coeruleifrons Macquart (Micropezidae: Diptera). A survey conducted in Maharashtra during 1978-80 revealed this species as an important pest of turmeric and ginger in Sangli and Satara districts. It was recorded for the first time from Parbhani, Bhir, Nanded and Solapur districts. Infestation tended to be patchy, and less damage was caused in light, well-drained soils. Crop losses averaged 25.35% for turmeric.

Biology

Females laid 76-150 eggs in the soil in the laboratory. The egg stage lasted 2-5 days, and the 3 larval instars 4-7, 4-8 and 3-10 days, respectively. Larval development took 13-25 days, the pupal period 5-15 days, the adult lifespan was 7-24 days and the total lifespan 38-62 days. The sex ratio was about 1:1. The pupal stage appeared to be responsible for carrying over infestation in planting seed rhizomes from one season to another. The peak period of infestation in endemic areas was from mid-August to mid-October.

Parasitoid

The parasitoid *Trichopria* sp. was recorded from pupae.

Management

Field experiments were carried out in Maharashtra, in 1970-71 and 1971-72 to determine the effectiveness of some insecticides applied by foliar spray and soil drenching against the turmeric pest *Mimegralla coeruleifrons* (Macq.). It was found that spraying with 0.05% or 0.03% parathion followed by soil application of diazinon, chlordane or aldrin at 0.75 kg/acre were found to be the most effective insecticides against the pest, showing the minimum percentage of dead heart and infested rhizomes, and increased the yield of rhizomes.

7.1.4. Minor pests

Lace wing bug

The lacewing bug (*Stephanitis typicus* Dist.) infests the foliage of turmeric plants causing them to turn pale and dry up. The pest infestation is more common during the post monsoon period especially in the drier parts of the country.

Management

Of several insecticides tested against *S. typica*, the best results were obtained with dimethoate and phosphamidon, each at 0.05%. These gave complete control after 7 days, and a reduction in *S. typica* populations of about 90 and 78%, respectively, after 30 days.

Turmeric thrips

Turmeric thrips *Panchaetothrips indicus* Bagn. infest leaves of turmeric causing them to roll up, turn pale and gradually dry up. The pest infestation is more common during the post monsoon period especially in the drier parts of the country.

Management

Of the twelve insecticides applied to 6.5-month-old *Curcuma longa* plants of the cv. Karur Local, the best control of *P. indicus* was obtained with dimethoate at 0.06% followed by methyl-demeton at 0.05% and quinalphos at 0.05%.

Leaf beetles

Adults and larvae of leaf feeding beetles such as *Lema* spp. feed on turmeric leaves especially during the monsoon season and form elongated parallel feeding marks on the leaves.

Management

The pest can be controlled by spraying malathion 0.1%.

Leaf roller

The larvae of the leaf roller (*Udaspes folus* Cram.) cut and fold the leaves of turmeric, remain within and feed on them especially during the monsoon season. The adults are medium-sized butterflies with brownish black wings with white spots on the fore wings and a large patch on the hind wing. Fully grown larvae are dark green.

Management

The pest can be controlled by spraying carbaryl 0.1%.

7.2.0. Nèmatode infestations

Three types of Nematode sps. were recorded in Turmeric.

7.2.1. *Meloidogyne incognita*

Infestation due to root rot nematode *Meloidogyne incognita* cause severe crop losses in Orissa. Carbofuran @ 3kg ai/ha is effective in reducing the gall index to 465.

7.2.2. *Practylenchus sp.*

Brown rot is characterized by unusual discoloration and rotting of mature rhizomes at the time of harvest. Initially the rhizome appears dull in colour, which becomes gray to dark brown. Rhizome become less turgid loses some weight, wrinkled and exhibits dry rot symptoms. The fingers are more severely affected than the mother rhizomes. Inside of the rhizome show dark brown necrotic lesions, remain discontinuous and extend to a depth of 2-5mm. At later stages, the lesions coalesce to form larger necrotic areas and progressively extend over a major portion of the rhizomes. The infestation is due to *Practylenchus* sp. along with *Fusarium* sp. Brown rot disease mentioned elsewhere is the same.

7.2.3. *Radopholus similis*

Infested rhizomes show shallow water-soaked, brownish areas and rotting of roots. . Nematodes can be disseminated by infested plant materials. Damage is greatest in plants, which had an initial inoculum of 100 or more nematodes. Least plant-growth occurred in the 1,00,000 population level.

Management

Using hot water to treat the rhizomes at 55°C for 10min. or 45°C for 50min. can kill the nematodes inside the rhizomes. *C. zedoaria* was found more resistant to nematode infestations.

8.0. HARVEST, POST HARVEST PROCESSING AND VALUE ADDITION

In India, at various places, different methods and equipments are used for processing of turmeric, but the traditional method consists of the following steps:

1. Harvesting
2. Washing
3. Boiling/Blanching/Cooking
4. Drying
5. Polishing

6. Colouring
7. Grinding/Powdering
8. Packaging
9. Marketing

8.1. Harvesting

The turmeric crop is ready for harvesting in about 7 to 9 months after sowing depending upon the variety. In India, sowing takes place between June and July and harvesting is done from February to April. Late harvest is also practised since the crop does not deteriorate by leaving it for some months underground. Before harvest, the dry leaves and stem are cut close to the ground. The land is irrigated, if necessary, to facilitate digging out the rhizomes, and ploughed in between the rows if the crop is planted on ridges. Otherwise a crowbar is used. The rhizome bunches are carefully lifted and adhering soil was removed by soaking in water and further cleaned of roots and scales before they are collected in the curing yard. The curing quality and the proportion of the cured and dried produce to the green produce depend mainly on the variety. Mother-rhizomes give a higher curing percentage than the fingers. The mother-rhizomes and fingers are separated. If need be, the former is kept for seed and the latter is cured for selling.

8.1.1. *Storing seed rhizomes*

Rhizomes for seed purpose are generally stored by heaping in well-ventilated rooms and covered with turmeric leaves. The seed rhizomes can also be stored in pits with saw dust, sand, leaves of *Glycosmis pentaphylla* , *Srtychnos nux-vomica*. The pits are to be covered with wooden planks with one or two openings for aeration. The rhizomes are to be dipped in quinalphos (0.075%) solution for 15 minutes if scale infestations are observed and in mancozeb (0.3%) to avoid storage losses due to fungi.

8.2. Post harvest processing

8.2.1. *Washing*

Rhizomes are separated after digging out from the soil. The globular mother rhizome and the longitudinal fingers are separated into lots. Root hairs and poorly developed and shrivelled portions are then removed. These are washed, so that particles of soil, spray residues and non-useful particles attached with the rhizomes are removed. For this rhizomes are kept soaked in water throughout the night. Later on, rhizomes are taken out and water is sprayed. This process can be achieved by soaking and spraying equipment. Spraying is done at low pressure and wide-angle jet or with high pressure jet. Mother rhizome is kept for seed while finger rhizomes are further processed and sold.

8.2.2. *Boiling/Blanching/Cooking*

The next step of processing is boiling or blanching. Traditionally boiling is done in metal or mud pots along with ¾ water. Top of the pots are covered with a lid or dry leaves. Boiling process is continued till foams and white foams start coming out. These come out with a special quality of flavour. Rhizomes are tested by pressing with fingers. If rhizomes are soft and inner color has become yellow instead of red then this process is said to be complete. The time required for the desired level of cooking varies from 1 hr to 4-6 hrs, depending on the quantity.

The rhizomes as wholes or cut longitudinally into halves and the fingers are generally cured separately, as cooking time varies with difference in thickness. Cooking helps in producing a product of fairly uniform color, due to the diffusion of the yellow pigment from the individual oil cells into the surrounding tissues. Boiling for periods varying from 30 minutes to 3 hrs, steaming up to 20 min, use of 0.1% sodium carbonate in the curing step influences the rate of drying,.moisture, volatile oil and the curcumin content after drying. Boiling considerably reduces the drying time both in the sun and the mechanical drier, while the total color and the volatile oil remained practically the same. Steaming and sun drying tends to give slightly less curcumin. Slicing and drying gives a rate of drying equal to 1 hr boiled rhizome and additionally give a product with the lowest moisture content.

By using developed method of boiling or blanching, both colour and quality are improved. Time taken is less. In this method, bulbs are treated with 0.1% Soda (Sodium carbonate, Sodium bicarbonate or Ammonium carbonate) and water solution. The time required for this process is 30 minutes to 6 hours. Boiler is used in this method, which is metal kettle open from the top. Soda solution is filled in it and it is heated from the bottom by electric heater or fuel oil. Perforated frame loaded with turmeric tubers or bulbs are sunk here. Water from all sides of perforations enters inside making turmeric tubers soft. After 30 or 40 minutes bulbs/tubers are taken up and tested along with the frame.

8.2.3. Drying

Sun drying in specially prepared toughened earth or cemented yards is the usual practice. The cooked material is spread two or three layers thick. Spreading in single layers is avoided to minimize the bleaching effect from the sun. The material is occasionally turned to ensure uniformity in drying. Drying is slow, taking 10-15 days for completion, when properly dried, the rhizomes become hard, almost horny, brittle and of uniform yellow color. The moisture content of the dried rhizomes is one of the lowest for spices; generally being less than 5%. The dry yield of the low moisture product is 20% on an average. Mother rhizome takes comparatively more time while finger rhizomes dry up quickly. Therefore these are dried separately also. After drying these become hard and solid. Completely dried turmeric holds 6% moisture content.

8.2.4. Polishing

Dried turmeric has a poor appearance and a rough and dull outer surface with scales and root bits. The appearance of dried rhizomes is improved by rubbing them against ground or below the foot to take out the hard layer over them and small roots are removed. By this process colour of turmeric becomes bright or shining. Later on removed roots, light garbage and thin layering are cleaned. Another manual method is tumbling the dried rhizomes placed in bamboo reed baskets along with granite stones when the pieces are both smoothened and polished. The product is known in the trade as 'polished turmeric'. Manual methods give low output around 20 kg for 8 hrs for two persons.

Mechanical polishing drums have been developed for handling large quantities. For this a drum having 0.9m diameter and 0.6m length is used. It is kept horizontally on a shaft and operated by a handle. Average capacity of this machine comes to 32kg per batch. Dry turmeric is filled and polishing is done at least for 7 minutes. During this period water is also sprinkled which causes improvement in the color of turmeric. Mechanical power-oil or steam engines or electric motor- is now used for large sized drums (which may be circular, hexagonal or octagonal in shape) when handling larger batches of dried rhizomes. During polishing, scales, rootlets and some of the epidermal layer are removed as dust through the sieve mesh and surrounding the polishing drums and the sieved dust is generally used as manure. The material loss during polishing caries from 2 to 8 % depending on the degree of polishing. The turmeric polisher available at IISR, Calicut, has a capacity of 100 kg per batch and takes 1 ½ h for fine polishing of the rhizomes.

8.2.5. Colouring

Exporting turmeric is given special colour by mixing yellow so that powder and processed materials can give better look and quality by a dry or wet process. In the dry process, turmeric powder is added to the polishing drum in the last 10 min. In the wet coloring process, turmeric powder is suspended in water and mixed inside by sprinkling inside the polishing basket. After coloring is complete, these are dried for one week. Later on these rhizomes are kept in sacks and closed for exporting.

8.2.6. Grinding/Powdering

Traditionally dried and polished turmeric are cut into pieces and beaten in mortar and pestle. After this is milled or ground with hand operated chakki. Hammer mill is also used for grinding. Powder should be so fine that it passes through 300-micron sieve and nothing is left over the sieve.

8.2.7. Packaging

Cured dried turmeric with moisture content of 15-30% is transported in gunny bags to assembling centers where it is further dried, polished and colored, if necessary. Dried turmeric is graded according to Agmark specifications before bagging in strong gunny bags generally in 65-75 kg lots. The bags are then transported to warehouses and port centers. Fumigation and prophylactic treatments are routinely given during warehousing and before export. The color of turmeric has been found to be stable as long as it is not exposed to sunlight.

8.3. Standards and grade specifications

The Indian standard specification for turmeric whole and powder incorporating the country's Agmark grade specifications are summarized below and in table 10 & 11.

8.4. Processed products

India is the global leader in value-added products development and exports. Value added products from turmeric include curcuminoids, dehydrated turmeric powder, oils, and oleoresin. Turmeric like other spices is available as wholes, grinds and oleoresin. The institutional sector in West buys ground turmeric and oleoresins, while in the industrial sector, the spice grinder and flavour houses buy whole dry turmeric from importers. The nature of the material, the curcuminoids and the aromatic components are stable to moderate heat.

Table 10 Indian Specification for turmeric-grades

Grade designation	Pieces max;wt%	Foreign matter Max; wt%	Defectives Max: wt%	Bulbs Max; wt%	Characteristics
Fingers(General)					Finger-like shape; breaks with a metallic twang; well set and close grained be perfectly dry; free from damage from weevils, over boiling etc.
Special	2.0	1.0	0.5	2.0	
Good	3.0	1.5	1.0	3.0	
Fair	5.0	2.0	1.5	5.0	
Fingers, Alleppy					As above
Good	5.0	1.0	3.0	4.0	
Fair	7.0	1.5	5.0	5.0	
Fingers, Rajapore	7.0				
Special		1.0	3.0	2.0	As above; Admixture of other curcuma varieties allowed at a maximum 2,5 and 10% in the three grades respectively
Good		1.5	5.0	3.0	
Fair		2.0	7.0	5.0	
Bulbs(round)					
Special	-	1.0	1.0	-	Well developed, smooth, sound, free from rootlets The Rajapore variety has higher allowance of 3,5 and 7% defectives in the three grades respectively
Good	-	1.5	3.0	-	
Fair	-	2.0	5.0	-	

Source: Marketing of turmeric in India, Agric. Market. Ser. No. 148, Directorate of Marketing and Inspection, Govt. of India, Nagpur. 1965

Table 11. Analytical specification for turmeric

Sample	Moisture (max %)	Total (max %)	Acid insol (max %)	Starch (max %)	Crude fibre (max %)	Volatile oil (max) (%)	Color as curcu min (%)	Lead (max ppm) (%)	Chromate test
Whole BP	8-10	6-9	-	-	4-6	2-5	-	-	-
US	9	7	0.5	-	6	4	5	-	-
DDR	-	7	-	-	-	2.6	3-4	-	-
Powder Indian	10	7	1.5	60.0	-	-	-	1.5	NMegative
WHO	10	7	1.5	-	-	-	-	3	negative

Source: Specification for turmeric powder, IS..2446 Indian Standards Institution, Delhi, India. 1961

8.4.1. Turmeric powder

Dried turmeric is powdered to fine mesh (60) to use in various end products.

8.4.2. Turmeric oil

The peculiar turmeric aroma is imparted by ar-turmerone, the major aroma principle in the oil and leaves are also used for extracting the volatile oil.

8.4.3. Turmeric oleoresin

Turmeric oleoresin is the organic extract of turmeric, a ground powder from the root of the Curcuma plant, and is added to food items as a spice and coloring agent. Supercritical CO_2 extraction and molecular distillation-to extract and separate turmeric is the latest high technology process followed to get quality product., Turmeric oleoresin is essentially used in institutional cooking in meat and fish products and certain products such as mustard, pickles and relish formulas, butter and cheese.

8.4.4. Curcumin

Curcumin or curcuminoids concentrate for use as a food color is not a regular article of commerce, because for most current uses the cheaper turmeric oleoresin has been found suitable. However, when demand for natural color increases in foods as in icecreams, gelatins and lemonades, the use of curcuminoids concentrate could become established.

9.0. ECONOMICS AND MARKETING

The countries like Japan, USA, Iran, UK, Germany, Netherlands and Sri Lanka are the major importer of turmeric in the world. China, Pakistan, Bangladesh, Haiti, Jamaica, Peru and Taiwan are producing and exporting turmeric besides India. The increasing use of curry powder and spice mixes in the world and the trend in the developing countries towards shifting to natural colors in food, from artificial coloring matter, the prospects of increased trade in turmeric appears to be quite good. Turmeric exported in the form of dry, powder and oleoresin.

The arrivals of turmeric start from February and more than 70% of the harvested crop is assembled in the markets during the next 3-4 months. It is utilized mostly after raw turmeric is processed and polished. The producers for seed purposes retain a small percentage of the raw turmeric produced. Only less than 15% of the production is exported annually and the remaining quantity is consumed internally.

9.1. Marketing practices

The system of agricultural marketing in India is saddled with a long chain of middlemen. Since the producers are mostly small and marginal farmers, they generally do not hold up the produce for long period since it is difficult for them to arrange for its storage. The general pattern of marketing is that the producers bring the dried produce to the primary markets and sell it to the village/itinerant merchants. The marketable produce in turmeric is either polished or unpolished in the form of fingers or mother rhizomes (bulbs). The village merchants fix the price based on quality factors such as hardiness, intensity of the core, polished or unpolished etc. Generally, village merchants have an upper hand in settling the price. When substantial stocks are accumulated, the commodity is carried to main assembling center. It has been estimated that the village merchants assemble more than 60 % of the production and the producers sell rest direct to the wholesalers at the assembling centers through commission agents who play an important role in the trade. Exporters generally have direct contact with foreign buyers and also with upcountry markets, purchase their requirements mostly through commission agents.

Due to price fluctuation and lack of price stability, producers are affected. The reasons for low price are attributed to (i) lack of holding power of the producers due to their poor financial position; (ii) loss in quality due to pest and diseases; (iii) competition among the growers to find buyers immediately after harvest and declining prices; (iv) poor bargaining power of the farmers; and (v) lack of scientific storage facility at village level.

9.2. Economics

A survey conducted at Nizamabad in Andhra Pradesh and Erode in Tamil Nadu found that farmer gets only a nominal profit and if the price falls further, he may not get any profit. Cost of cultivation for conventional method fo turmeric is Rs 93, 000 / per ha whereas organic cultivation recorded less expense Rs. 85, 125 / per ha with more dry yield 7 to 9 MT /ha compared to 6 to 7.5 MT / ha in conventional method. The cost of harvesting per hour was Rs. 5,500 with the harvester while it was Rs. 7,400 with manual harvesting. The saving in cost was 26 per cent by harvesting with mechanical harvester over manual harvesting. Economics of turmeric production vary at production centers and mainly depends on demand for produce in the market. Further cost of inputs like fertilizer, labor, and seed mainly influence the total cost of production.

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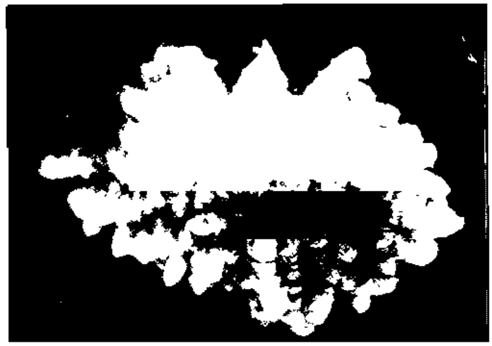
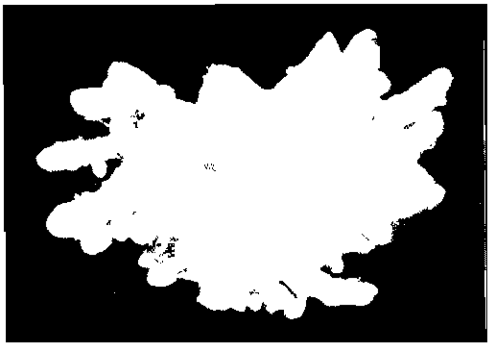
Improved varieties of Turmeric

Prabha



Prathibha

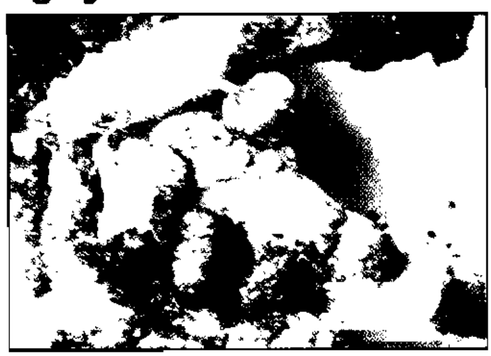


Alleppey Supreme

IISR Kedaram

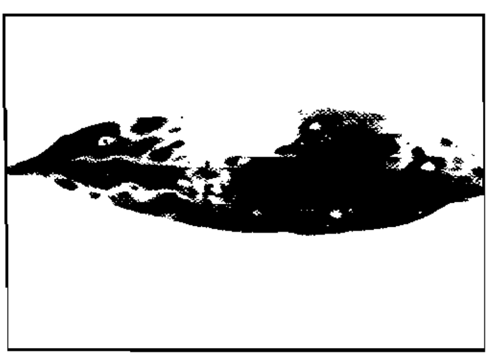
Pests, diseases and cropping system of Turmeric

Rhizome rot



Rhizome scale

Pests and diseases of Black pepper



Colletotrichym leaf spot

Intercroppomg of turmeric in coconut garden

VANILLA

A.I.Bhat, P.A.Mathew, R.R.Nair, M.S.Madan

1.0. INTRODUCTION

Vanilla (*Vanilla planifolia* Andrews) is a tropical orchid which is cultivated for its pleasant flavour. It was first introduced to Reunion in 1793, but its cultivation picked up momentum only after about eight decades. From Reunion the crop was taken to Mauritius in 1827 and to Madagascar in 1840. Admiral Hemelin is said to have introduced vanilla to Tahiti Island from Manila in 1848. Simultaneously, the plant was introduced to Indonesia. In these two countries vanilla cultivation was taken up on a plantation basis. Towards the end of the nineteenth century the crop spread to Seychells and Comoro Islands.

No authentic information is available on the introduction of vanilla into India. According to Corell (1953) attempts to introduce vanilla cultivation in India dates back to 1835, however these plants died after flowering as was experienced in similar attempts in different parts of the world other than Mexico. Evidence available reveal that this crop was experimentally introduced to West Bangal, Bihar, Tamil Nadu, Pondicherry, Karnataka, Kerala and Assam only 100 years ago. The earliest record which could be traced with regard to cultivation of vanilla in India was at Kallar-Burliar Fruit Research Station in the Nilgiris. According to the data available in that station, vanilla was under cultivation there since 1945. Later in 1960 preliminary investigations on the cultivation aspects of vanilla was also initiated at the Regional Agricultural Research Station, Ambalavayal in Wyanad district of Kerala. Both these stations worked mainly on propagation, hand pollination, disease management and curing with a fair degree of success. Impressed by the results, a few enthusiastic planters in Wyanad district took up cultivation of this unique crop. The government of Kerala also initiated a small scheme at Cheengeri at Ambalavayal for settlement of tribals through cultivation of vanilla in an area of two hectares each. A number of coffee planters in Kalpetta in the same district also took up vanilla and grew it on the shade trees available in the plantation. Some growers in and around Kallar-Burliar Fruit Research Station, Thirunelveli and Gudallur of Tamil Nadu also started cultivating vanilla. However almost all these initial attempts did not succeed due to various reasons like lack of proper care, poor technical support and absence of marketing arrangements for the produce. However, these plantations served as a source of planting material for vanilla development programmes initiated later by various agencies.

In Karnataka, three decades ago an enterprising planter established a vanilla plantation in an area of about one hectare in Sasthan in Dakshina Kannada district. He looked after the plantation in a systematic manner which resulted in getting reasonably good yield and was able to market the produce. Cultivation of this crop was gradually taken up by the growers of the Dakshina Kannada and Uttara Kannada districts and now Karnataka state accounts for the maximum area under vanilla in India. Realizing its export potential, the Spices Board launched various schemes for developing vanilla in potential areas in Kerala, Tamil Nadu and Karnataka resulting in an expansion of area to 2545 ha. The crop is also suitable for cultivation under north-eastern states. Thus efforts to propagate and popularize vanilla cultivation in India have resulted in large number of farmers taking up vanilla cultivation particularly in Karnataka and Kerala. Research and Development activities of Spices Board, Indian Institute of Spices Research and Kerala Agricultural University have given the required impetus for its cultivation. With a result, the area under vanilla has been steadily increasing.

1.1. Area and production

The total area under vanilla cultivation in the world during 2002 was 38066 hectares with the production of around 4956 metric tones (FAO Rome). The major vanilla producing countries are Madagascar, Comoro, Indonesia, Mexico and Reunion (table 1). Area under vanilla in India during 2002-03 is 2545 hectares with the production of 92 metric tones. World over, there is an increasing trend for using natural flavour and therefore the share of natural vanillin is likely to increase to a great extent.

1.1.1. World scenario

Most producing countries with less or no domestic consumption, export the entire production of vanilla to developed country markets. As on today around 16-20 countries are producing vanilla in the world. The number has almost doubled during the nineties and many have entered into the market in the recent past mainly because of sudden spurt in the prices. However, the share of traditional producing countries in the total production has not come down. Among these countries, Madagascar was holding the prominent position with a cultivated area of 25900 hectares. Of late, with an average production of more than 2000 metric tones from 1998-2002, Indonesia leads the world production of vanilla (Table 1). These two countries together contribute about 76 per cent of the world average production of 4863 during 1998-2002. Mexico, the native land of vanilla is in third position now after losing its first position to Madagascar in nineteen eighties.

The support side for the commodity is characterized by unstable productions largely due to natural reasons and dominance of market by very small number of countries. This combined with an aggregate price-inelastic demand provides the necessary conditions for a highly unstable and speculative vanilla market. There is a decreasing trend in Indonesia's production for the last few years, mainly due to unforeseen agro-climatological factors. During 2003-04 there was a short fall in vanilla production in Madagascar leading to high price rise. This increasing price level acted as catalyst to increase area under crop in many new entrants including India.

1.1.2. Indian scenario

Organized cultivation of vanilla in India started in 1990s. Hefty price in recent past for the crop and falling price for other competing crops like coffee and black pepper etc. led to an accelerated growth in vanilla industry in the country. Its cultivation is mainly concentrated in certain areas of Karnataka, Kerala and Tamil Nadu. During

Table 1. Country wise production of vanilla (Metric Tonnes)

Country	1998	1999	2000	2001	2002	Average
Traditional producing and exporting countries						
Madagascar	1650	1650	1815	1815	1518	1690
Indonesia	1900	2102	2102	2102	1800	2001
French Polynesia	30	34	40	40	35	36
Mexico	564	300	550	550	300	453
The Comoros	160	150	180	180	140	162
Reunion	30	30	28	28	35	30
Tonga	100	50	130	130	130	108
Zimbabwe	10	10	10	10	10	10
Cook Islands	2	NA	NA	NA		2
Guadeloupe	8	40	8	8	8	14
Malawi	22	NA	NA	NA	20	21
New entrants						
Kenya	10	NA	NA	NA	8	9
China	550	NA	NA	NA	650	600
Uganda	60	NA	NA	NA	40	50
Turkey	100	NA	NA	NA	170	135
India		10	NA	60	92	54
World	5196	4376	4863	4923	4956	4863

Source: FAO, Rome
NA: Not available

the last few years area under cultivation has expanded rapidly in these states. There are also reports that vanilla cultivation is getting spread to other states like Maharastra, Andhra Pradesh, Madhya Pradesh, Orissa, West Bengal, Andamans and Northeastern states.

Only 36 per cent of area is now under yielding stage and a significant portion of this is in the age group of 3-4 years i.e. stage I of the life cycle of vanilla plantation, while the maximum productivity is achieved between 6-9 years i.e. IInd stage. With a maximum life of 15-20 years, stage-III starts from 12th years onwards i.e. decline in productivity. This implies that from the existing area itself, the production and productivity is likely to increase substantially in the near future. Table 2 indicates that India has produced 92 Mt of vanilla during 2002-03 with total area of 2545 ha, this is hardly 1.90 per cent of total average world production.

Indian production was estimated to be 10 tons during 1999 and has gone up to 131 tones from 3427 ha of area under the crop

Table 2. State-wise area and production of vanilla in India (2002-03)

State	Total Area (ha)	Yielding Area (ha)	Yield (cured) (kg/ha)	Production (mt)
Karnataka	1465	545	100	54
Kerala	812	239	78	19
Tamil Nadu	268	130	147	19
Total	2545	914	101	92

Source: Spices Board, India

during 2003-04. For the period ending 2007 the targets have been fixed at 15,000 ha. About a third of this area (5,000 ha) would receive support from Spices Board. While most of the vanilla farms in Karnataka are big, the farmers in Kerala grow it in small plots. The area has increased to around 3,000 hectare and the production edged towards 200 tonnes in 2003 with Karnataka leading the way. With an average yield of at least 120 kg/acre, assuming half of the targeted area is under yield, the production is expected to touch 3600 kg of cured bean by year 2007.

1.2. Composition and use

Vanilla is the only member of orchidaceae which has a real economic value in the food and related industries, owing to its unique flavour and pleasant aroma while the other counter parts being well known for their most attractive flowers. Vanilla is one of the expensive spices traded in the global market. Vanilla is obtained by subjecting the fully grown but un-ripened fruits or 'beans' to fermentation-curing process to produce characteristic aroma. The substance chiefly responsible for the fragrance, flavour and pleasant aroma of the vanilla beans is vanillin (4-hydroxy-3-methoxybenzaldehyde, $C_8H_8O_3$). Vanilla essence is largely used for the preparation of ice creams, chocolates, bakery products puddings, pharmaceuticals, liquors and perfumes. Three types of vanilla extracts and flavours are manufactured. They include pure vanilla extracts, vanilla with other material flavours and vanilla flavours, which may contain artificial substances.

Apart from *V. planifolia* two other vanilla species, *V. tahitensis* J.W.Moore, the Tahitian vanilla which is cultivated in the Tahiti Islands and *V. pompona* Scheide, cultivated in some of the South Pacific Islands also yield vanilla, but of inferior quality. Based on flavour profile, organoleptic and analytical properties (as a result of growing conditions, harvesting and curing process), four types of vanilla beans are distinguished in the world market. They are (i) The Bourbon vanilla (produced in Madadascar, Comoro and Reunion), (ii) The Java vanilla (produced in the island of Java in Indonesia), (iii) The Bourbon-like vanilla (produced in the island of Bali in Indonesia) and (iv) Mexican vanilla. Among them, The Bourbon vanilla ranks top in terms of quality.

The annual global trade of natural vanilla accounts for more than 100 million US$ giving direct and indirect employment to many thousand of persons both in the producing and consuming countries. With the advent of appropriate chemical technology, various types of low cost synthetic vanillin substitutes such as ethyl vanillin, synthetic vanillin, and related artificial flavours were commercially synthesized and they replaced the use of vanilla beans, the source of natural vanillin. Nevertheless, natural vanillin is still the most preferred spice for flavouring food owing to it's delicate aroma, yet rich and mellow with a pleasant taste. World over, there is an increasing trend for use of natural products and therefore the share of natural vanillin is likely to increase to a great extent.

2.0. BOTANY AND IMPROVEMENT

2.1. Botany

2.1.1. Origin and distribution

Vanilla planifolia Andrews (syn *V. fragrans* (Salisb.) Ames) is indigenous to the humid tropical rain forests of South-eastern Mexico, Central America, West Indies and Northern part of South America, where it is growing wild as a climber. The generic name *Vanilla* is derived from the Spanish name *vainilla*, and is a diminutive of vaina (sheath, vagina, pod), perhaps motivated by the sheath-like shape of the fruit or its resemblance to a true pod. The species name *planifolia*, refers to the striking flat shape of the leaves. The common names of vanilla are almost the same in practically all the languages of the world with slight variations.

In a wild state *V. planifolia* usually grows climbing on trees in wet lowland forests. Vanilla thrives well from sea level up to 1500 meters MSL under hot, moist tropical climate with adequate well distributed rainfall. Natural growth is obtained at latitudes, 15 degree north and 20 degree south of the equator. The optimum temperature ranges from 21-32 °C and rain fall 2000-2500 mm annually. Partial shade is necessary and this is usually provided by the shrubs or small trees up on which wines are trailed. The crop requires a short dry spell of about two months for flowering. The cultivation of vanilla spread after the discovery of America by Columbus. Presently vanilla is grown in more than 14 countries of the world and the major producers being Indonesia and Madagascar.

2.1.2. Systematics

Vanilla belongs to the family *Orchidaceae*, which is the largest family of flowering plants and advanced group of monocotyledons with about 700 genera and 20000 species. While species of many genera of *Orchidaceae* are well known for their ornamental value with showy flowers, *Vanilla* is the only genus which has species of economic importance. Taxonomically, the genus *Vanilla* comes under family *Orchidaceae*, subfamily *Epidendroideae*, tribe *Vanilleae*, and subtribe *Vanillinae*. As per the description of Swartz the genus *Vanilla* is composed of stout, terrestrial climbing, branched, leafy or leafless shrubs, with branches emitting adventitious roots. *Stems* are terete or angled and *leaves* sub-sessile, coriaceous or fleshy. *Racemes* are usually axillary, subsessile or peduncled. *Flowers* are large, *sepals* and *petals* sub-equal, spreading. *Lip* with the claw adnate to the column, which is embraced by its broad concave limb, entire or three lobed. *Column* is elongate; anther incumbent, cells separate; pollen granular. *Capsule* is long, fleshy, 1-celled, loculicidally 3-valved, without septa. Porte'res in Bouriquet (1954) describes 110 species of *Vanilla* distributed in the tropics of both the Old and the New World. About 200 species of *Vanilla* have been recorded and list of these species are available in many world-wide-web sites displaying information on vanilla (eg: http://www.plantamed.com, http://encyclopedia.worldsearch.com). Some of them may be synonyms of the same species, reported differently by different authors.

The commercially important species of *Vanilla* are *V. planifolia* Andrews (Syn. *V. fragrans* (Salisb.) Ames, *Epidendrum vanilla* L., *Myrobroma fragrans* Salisb., *V. mexicana* P. Miller, *V. aromatica* Swartz, *V. planifolia* B D. Jackson) - the true Mexican vanilla, *V. pompona* Schiede (Syn. *V. grandiflora* Lindl., *V. lutescens* Moquille – Tand, *V. surinamensis* Reichb f., *V. planifolia* var. gigantea Hoehne) – West Indian vanilla, Guadeloupe vanilla, Antilles vanilla and *V. tahitensis* J. W. Moore – Tahitian vanilla. *Vanilla planifolia* is the only species commercially cultivated in India.

The basic chromosome number of the genus Vanilla is x=16 and *V. planifolia* is being considered as a diploid with 2n=32. Other cultivated species' *V. pompona* and *V. tahitensis* also have the same chromosome number. Though somatic chromosome number of vanilla was reported as 2n=32 by many workers, variation from this number was noticed by a few.

2.1.3. Classification and varieties

At commercial point of view the vanilla from different regions of the world are classified based on country of origin and species of origin. Purseglove *et al.* (1981) described the different commercial varieties of vanilla as detailed below.

Mexican vanilla

Mexico has traditionally been regarded as the supplier of vanilla possessing the finest aroma and flavor. Consumers accustomed to artificial vanilla, however, often dislike the aroma of Mexican vanilla and consider it deficient in "body".

Bourbon vanilla

This vanilla has a deeper "body" flavor than Mexican vanilla but lower aroma. Bourbon vanilla is frequently "frosted" and is marketed in grades of whole and split beans and a category known as "vrac", comparable to Mexican cuts.

Indonesian vanilla

The main area of production is initially Bali and South Java. But later, vanilla culture has been spread out all over Sulawesi, Sumatra (North and South), Lomboc, Flores and Timor Timor. Generally speaking, Indonesian vanilla is known as a mixed quality with little attention paid to grading. However, quality has improved year after year and today it is possible to find some lots comparable to "bourbon" vanilla. Indonesian vanilla possesses a deep full-bodied flavor well appreciated in America.

South American and West Indian Vanilla

The small volume of true vanilla entering trade from this region is more similar in properties to Bourbon vanilla than Mexican vanilla and frequently of poor quality.

Tahiti vanilla

The vanilla produced in French Polynesia is obtained from *V. tahitensis* and possesses a characteristic aromatic odour and usually has lower vanillin content than true vanilla. It is generally less favored for flavoring due to its relatively high volatile-oil content which can result in cloudy extracts. Tahiti vanilla is exported in five main grades which rarely frost.

Vanillons (Guadeloupe vanilla or Antilles vanilla)

This is produced from *V. pompona* on certain of the former French West Indian islands, principally on Guadeloupe. Vanillons has low vanillin content and possesses a characteristic floral aroma, bearing similarities to Tahiti Vanilla. It is mainly employed in perfumery as its flavor is considered to be poor and it tends to provide gummy aqueous alcohol extracts. Vanillons was exported in three grades, but today this quality is not traded anymore.

2.1.4. Morphology

Vanilla planifolia is a fleshy, herbaceous perennial vine, climbing by means of adventitious roots. It grows to a height of about 10-15 m supporting itself on the host trees or other supports. Under cultivation conditions, vanilla is trained and pruned to a height that will allow hand pollination of the flowers and subsequent harvest of the beans. If allowed to grow continuously on un-branched trees like coconut or arecanut palm the vine will grow even up to the top of the tree, without producing any branch

Stem

The stem is long, cylindrical in shape and monopodial in growth pattern with or without branches. The branches produced from the central stem will always remain subsidiary to the main stem. Stem is succulent, flexuous and brittle. It is usually 1-2 cm in diameter and is dark green and photosynthetic with stomata. The internodes are 5-15 cm in length. Stem thickness and internode length in newly raised cuttings are less, compared to the mature vines, but attain normal size as they grow to maturity. The epidermal layer of cells of the stem is single layered, consist of thick walled, rectangular to polygonal cells which are rich in chloroplasts. Stomata are present on the epidermis.

Leaf

Leaves in fully grown vines are large, plane, fleshy, sub-sessile and dorsi-ventral. They are oblong-elliptic to lanceolate in shape, 8-25 cm long and 2-8cm broad and alternate in arrangement. Tip is acute to acuminate and the base is almost rounded. The veins are numerous, parallel and indistinct. Short and thick petiole is canalized at adaxial side. Leaves in newly raised cuttings and seedling progenies arc small in size but attain the normal size within 3-4 years of growth.

Both the upper and lower epidermis of leaf consists of rectangular to polygonal cells with thin wall. The upper epidermis is composed of 2 layers of cells, while the lower epidermis is composed of 2-3 layers of cells. The upper epidermal cells are slightly larger than the lower epidermal cells. Cuticle is present on both the epidermal layers and measured 5.5 µm in thickness. Stomata are present only on the lower epidermis of the leaf (hypostomatic). Stomata are anomocytic in nature with 5-7 subsidiary cells. Mesophyll is not differentiated into palisade and spongy parenchyma tissue and is 10-13 layered, rich in chloroplasts.

Roots

Two types of roots are observed in vanilla. They are aerial roots which help the plant in climbing supports and terrestrial roots which help the plant in absorbing nutrients from the soil. Occasionally long aerial roots resembling buttress roots are produced from the main shoot or branches, which grow down to soil and function as feeding roots. This usually happens when feeding roots are damaged or the stem of the plants are cut interstitially by disease infection or by mechanical damage. The aerial climbing roots are long, greenish white, adventitious, about 2mm in diameter and are produced singly from the nodes, slightly away from the point of leaf attachment. They adhere firmly appressed to the support, upon which the plant grows. The outer parchment-like sheath or velamen is rather poorly developed. The terrestrial roots ramify in the humus or mulch layer and have root hairs. Endotrophic mycorrhiza is reported to be present in terrestrial roots. There is no principal difference in anatomical or morphological structure between aerial roots and terrestrial roots. The main distinction is the limited growth and rapid maturity of climbing aerial roots compared with unlimited growth of terrestrial roots. The adventitious roots produced at the nodes in *V. planifolia* either adheres to the supports or dropped freely to the ground where they branch. Some remain above the soil while others achieved a shallow penetration. The aerial roots are free of hairs while those that penetrated the leaf litter produce hairs.

Inflorescence

Inflorescences are stout axillary racemes, usually simple and rarely branched. It has been observed that certain plants frequently produce branched inflorescences. Inflorescences are usually borne towards the top of the vine in the leaf axils of stems with sufficient maturity and are 5-8 cm long. There may be as many as 100 flowers in a raceme but usually there are about 20. Branched inflorescences usually have 40-50 flowers. Flowers open from base to upwards, generally with only 1-3 flowers open at a time. Unlike the other ornamental orchid flowers, vanilla flower will remain for only one day and shed off by next day, if not pollinated. The rachis is stout, often curved and 4-10 mm in diameter. Bracts are ovate, rigid, concave, persistent, 5-15 mm long and about 7mm wide at the base.

Flowering period of a raceme will last an average of 24 days. Flowering season for an average plant in Puerto Rico begins in January, reaches a peak in March, and ends in June. In the Philippines, flowering extends from March to June, with the largest percentage of the flowers appearing in April. Flowering in Mexico is usually during April-May and in the Malagasay Republic, Reunion and the Comoro Islands between November and January. In India, flowering is observed usually from December to May and it takes 45-60 days from the initiation of inflorescence to flowering.

Flowers

Flowers are large, waxy, pale greenish-yellow in colour, zygomorphic in symmetry and are bisexual .Fully opened flowers are about 10 cm in diameter and are fugacious. The pedicel is very short. Sepals and petals are three each in number. Sepals are oblong-lanceolate, obtuse to sub-acute, slightly reflexed at the apex and are 4-7 cm long and 1-1.5 cm wide. The two upper petals resemble the sepals in shape, but are slightly smaller. The lower petal is short, broad and modified to form the trumpet-shaped lip or labellum. Labellum is 4-5 cm long and 1.5-3 cm broad at its widest point. It is attached to and envelops a central column comprised of the united stamen and pistil (gynostemium). The tip of the labellum is obscurely three lobed and is irregularly toothed on its revolute margin. There are longitudinal verrucose darker coloured papillae forming a crest in the median line and with a tuft of hairs in the middle of the disc. The cultivars available at India have a tuft of imbricate scales in the middle of the disc, instead of hairs.

The column or gynostemium is 3-5 cm long and is attached to the labellum for most of its length. The single anther is at the apex of the column and hangs over the stigma, but a flap or rostellum separates them, preventing natural pollination. Anther contains two pollen masses or 'pollinia' covered by a cap. But some researchers are of the opinion that, in *V. planifolia* the pollen grains do not remain united to form compound grains, massulae, or pollinia, but lie freely inside the anther. If this is true, the clump-like appearance of pollen may be simply due to stickiness.

The slender stalk-like portion of the flower is the ovary which is inferior, cylindrical, often curved, 4-7 cm long and 3-5 mm in diameter. Ovary is tricarpellary, syncarpus and unilocular. A cross section of the ovary of an opened flower shows three carpels, three pairs of fibrovascular bundles, and three pairs of placentae. The placentae extend throughout the length of the ovarian cavity. The three parietal placentae in the ovary of non-pollinated vanilla flower is weakly developed and separated from each other by the smooth inner epidermis of the ovary. Pollination triggers the placenta to begin extensive branching followed by ovule development.

Fruit and seed

Fruit set is achieved by artificially pollinating each flower by hand which is described in the section 5.3.4. Botanically, fruit of vanilla is capsule and is popular in the trade as a bean. Fruit is pendulous, narrowly cylindrical, obscurely three angled, 10-25 cm long and 5-15 mm in diameter. The fruits are aromatic on processing and drying. Each fruit contains myriads of very minute globose seeds of about 0.3 mm in diameter on ripening. Seeds are liberated by the longitudinal splitting of the capsule along three lines at maturity. In commercial production the capsules are harvested before they start ripening.

2.1.5. Pollination and fruit set

Vanilla planifolia usually flowers only once in a year over a period of about 2-3 months. In India the peak flowering period is during January to March. There may be slight variations in each year depending upon seasonal changes.

Irrespective of the fact that vanilla flower is self-fertile the floral architecture of vanilla is such that natural self pollination is impossible, due to the separation of anther from stigma by a flap-like structure called rostellum. A pollinating agent is essential for transferring pollen from anther to stigma. In Mexico and Central America, where vanilla is indigenous some of the flowers are pollinated by the bees of the genus *Melipona* and also by hummingbirds. Elsewhere hand pollination is unavoidable for fruit set. Even in Mexico, natural fruit set is very low and hand pollination is practiced in commercial cultivation. Thus, flowers are to be hand-pollinated to achieve fruit set. The method of hand pollination was discovered by Morren in Liege in 1836, and Edmund Albius a former slave in Reunion, discovered a practical method of artificial pollination in 1841, which is still practiced for commercial production of vanilla fruits.

The flower opens early in the morning and closes in the after noon, and never reopens. They are receptive for more than eight hours and wither the following day. The ideal time for pollinating vanilla is between 6.00 AM and 1.00 PM. Researchers of Spices Board obtained maximum fruit setting percentage when pollinated at 8.00 A M

Fruit set

If fertilization has been achieved successfully, the flowers remain on the rachis and ovary starts growing into fruit. If unsuccessful, the flowers drop off in two or three days. This will help to judge the number of fruits which have set, so that number of fruits per bunch can be regulated as per the requirement. After fertilization, ovary elongate rapidly for 45 days until the full length and girth of the bean is attained within 75 days. Fruit takes 254-284 days for maturity and average weight of fresh bean is about 12 g. The harvesting period varies according to altitude and latitude, and differ from one country to other.

2.2. Improvement

Popular, 'Breeders varieties' are not known in vanilla. As vanilla cultivation spread from its country of origin to different growing countries through vegetative cuttings, little variation can be expected. As far as it can be ascertained, there are few, if any cultivars of *V. planifolia* recognized. Vanilla cultivars in introduction areas must have evolved from a limited number of recent introductions, and the variation in the cultivated collections is likely to be the result of somatic mutations and subsequent preferential cultivation of the mutants. Vanilla cultivars found in Reunion are 'Classique', 'Mexique', 'Magic' and 'Bleue'. Similarly, a few cultivars of *V. tahitensis* available at French Polynesia are 'Parahurahu', 'Haapape' and 'Rearea' .. Four different local cultivars of vanilla are recognized by growers in Veracruz, Mexico. They are 'mansa' (dura), 'acamaya' (rayada, variegate), 'albo-marginata' and 'oreja de burro' (ibid.). Mansa is the most widely cultivated and is the same clone as was used to initiate vanilla production in Madagascar, Asia and Africa.

Comparatively little work has been done on the improvement of vanilla by breeding. This may be mainly due to lack of sufficient genetic variability for yield and flavour characters in vanilla due to continuous vegetative propagation and absence of natural fruit set and seed germination. The limited variability observed may have originated as somatic mutations and adaptive changes occurred in places of introduction. Pioneering attempts were made in Puerto Rico and Madagascar to develop disease resistant varieties of vanilla by interspecific hybridization, back crossing, seedling selection and induced mutagenesis. But, the success was limited in most of these attempts. In India also efforts are on to improve vanilla through breeding between species, selection, mutation and evaluation of seedling progenies.

3.0. NURSERY MANAGEMENT

3.1. Propagation

Vanilla is propagated vegetatively using vines for raising productive gardens, whe reas seed propagation is invariably done only for research purposes employing special techniques because the seeds do not germinate readily under natural conditions.

Three types of planting materials are used for raising vanilla gardens:

i) Cuttings

ii) Rooted cuttings in bags

iii) Tissue culture derived plants

3.1.1. Cuttings

Cuttings are directly used for planting if sufficient material is available. These are to be collected from high yielding healthy vines free from diseases especially of virus. As *Vanilla planifolia* is the only cultivated species popular in India the genuine material of the same should be used for planting. There are unscrupulous nurseries selling other species of *Vanilla* claiming superiority and one has to be careful in selecting the right species. Normally, one metre long cuttings having about 10 leaves on the nodes are selected. It is necessary to ensure that the growing tip of each cutting is pointed. Cuttings from already yielded shoots should be avoided for fresh planting as it takes a very long time for sprouting. Such shoots can be identified by the presence of peduncle stubs that remains after the beans are harvested. Actively growing vines will have the vegetative buds in a pointed shape.

The cuttings after separation from the mother vines need to be kept under shade for one week to condition them. This will allow hardening of the stem, arrest the growth, stimulate the buds and allow healing of the cut ends which will prevent rotting of cuttings when planted. The vines are treated with 1% Bordeaux mixture before planting as a prophylactic measure to protect against diseases

The length of the cutting used for planting will influence growth and pre-bearing period. Studies have indicated that vines of 90 to 120 cm long were the best. It is therefore recommended to have a vine of at least one metre length for field planting.

Cuttings can be collected from mother vines in the field or nurseries specially prepared as source of cuttings. The limitation in getting cuttings from field plants is that usually it will be available only during the harvesting season of September-October when generally pruning is done. In nurseries meant for production of cuttings, they will be available throughout the year. For rooting of stem cuttings, net houses are made with irrigation facility and vines are planted closely in row and the new growth is allowed to trail on plastic netting, coir mats or bamboo supports and is removed when sufficient length is reached. During the period, intensive manuring and irrigation are done to get good vegetative growth. Vines also can be planted around tall trees such as areca palms, coconut, jack etc. and allowed to grow upwards to sufficient length and these vines are also good source of cuttings for planting.

A rapid multiplication nursery also can be raised by forming trenches of 60 cm x 60 cm of any length which is filled with a mixture of soil: sand and cow dung (3:1:1 proportion). Cuttings are planted with a spacing of one metre on supports and intensively manured and watered. Shade to the extent of 50% is necessary. This method would result a vine growth of seven meters per year and one hectare of such nursery may produce 40 to 50, 000 cuttings annually.

3.1.2. Rooted cuttings in bags

In this method, vines are divided in to small cuttings (with two nodes and leaves retained) and rooted in poly bags. The basal one node is inserted in to a suitable rooting medium in poly bags under nursery condition in a protected shed. The bag size can be 25 cm x 15 cm with bottom holes for drainage. Black or white polythene bags are suitable. Rooting medium is normally a mixture of garden soil, FYM and sand in 3:1:1 proportion. If the soil is clayey more sand is to be added to provide drainage. Good top soil alone may be sufficient if water drains easily. Solarization of soil mixture by exposure to sun for 40 days and incorporation of biocontrol agent such as *Trichoderma* may be followed as this would give protection against root diseases. Watering should be done as and when necessary. Excessive watering should be avoided as it would lead to rotting of stem. Extending the base of the stub below the node beyond the poly bag outwards by making a hole is also practiced in some areas to prevent rotting of the cut end while rooting takes place. The cuttings can be drenched with Bordeaux mixture to prevent root diseases if biocontrol agents are not used. The best time for rooting would be during the month of August. The cuttings will root within a week and new shoots will emerge from the upper node. The new growth is to be supported with a long bamboo splinter or sticks of about 75-100 cm length and once the vine reaches a maximum of 60 cm (will take about six to seven months), the rooted cuttings can be field planted. If cuttings are raised in nursery during January-February, they will be ready for planting during rainy season.

Instead of poly bags, split coconut husk can also be used to root the cuttings. In this case, split coconut husk is filled with a mixture of soil: sand: cow dung (1:1:1) and cuttings are planted with one node inside the husk. Tying of the husk is needed to hold them together. After rooting the planting is done with the husk intact and transplanting shock is avoided. The husk can be placed in horizontal or erect position.

Another variation practiced by few farmers for rooting of cuttings is as follows. Bamboo splinters of two metre length are taken and vines of one metre length are tied to this. The lowest three nodes are buried under soil in the nursery. The cuttings are planted close to each other. Over head shade is provided with plastic netting. After rooting, these vines are uprooted and planted along with bamboo intact in the field and allowed to lean on the support tree.

3.1.3. Tissue culture derived plants

Micro propagation technique through tissue culture has been standardized in vanilla and mass multiplication of vanilla plantlets are taken up by Spices Board and a few private laboratories. This method is ideal for production of very large number of plantlets. However, special training is to be given to farmers on hardening the plantlets before field planting. It is advisable to grow plantlets to a minimum length of 45 cm in poly bags before planting in the field.

4.0. SOIL AND CLIMATE

4.1. Soil

A light and porous soil rich in humus, well drained and covered with a lot of dry mulch on a slope is ideal for vanilla. The soil has to be slightly acidic than neutral. A pH of 6.5 is optimum. Water logging, marshy or salty conditions are not good. The presence of loose mulch helps in proliferation and ramification of its roots that encourage good growth.

4.2. Climate

Vanilla prefers a warm humid climate with a well distributed rainfall of 150-300 cm. per year. Uncleared jungle lands are ideal for establishing vanilla plantation. Extremely hot periods, exposures to sun dry hot winds, heavy and continuous rainfall are not suitable. High humidity coupled with high temperature is conducive for occurrence of diseases. It requires a warm day period during the flowering and maturity periods of the beans. It is shade loving and 50 % shade is ideal. The filtered shade available under tree canopies is the most ideal for the crop. It grows up to 1500 metre from MSL.

5.0. PLANTING AND AFTER CARE

Vanilla may be raised as a pure crop or as mixed crop with perennials or agro-forestry species or in home steads. Pure crop is possible only in areas where enough land is available. Where land is a problem as in Kerala, it is preferable to grow vanilla as a mixed crop with other perennials, such as coconut, arecanut, etc.

Apart from clearing weeds and bushes and taking pits not much work is involved in land preparation. In sloppy lands, contour terracing will be helpful for conservation of soil and water. The width of the terrace may be about 1.3 m (4 feet).

5.1. Planting

5.1.1. Standards

Being a climber, vanilla requires live or non living supports for its successful growth and productivity. Since it needs shade, living supports cum shade trees are provided in pure gardens whereas under mixed cropping, the perennial crops provide the needed shade. An ideal support tree must be short statured with plenty of branches, are amenable for coppicing, leaves must be small and narrow, the stem bark should not be smooth, but rough to allow easy clinging of the velamen roots. If the support selected is a legume, it will be able to enrich the soil also. The most common tree used is *Glyricidia sepium* world wide. Other trees suitable are *Jatropha curcas* (Physicnut), *Plumeria alba* (frangipani), *Casuarina* sp., *Erythrina* sp., *Pandanus* sp., *Ficus* sp. Vanilla can also be grown on coconut, arecanut, oilpalm, cocoa, coffee, rubber or cashew. When grown under coconut or other palms, wires tied above the vanilla rows are necessary to prevent damage to the vines from falling leaves. With cocoa, a few branches above vanilla may have to be removed to allow more light for vanilla. Under high-tech farming system with plastic netting as shade (50%) and concrete or wooden poles, asbestos or PVC pipes, strips of plastic netting etc are used as supports. Even walls of the compound or house also are utilized as supports for growing vanilla by enterprising homestead gardens. Under the canopy of miscellaneous trees, farmers use even simple wooden poles across temporary supports for training vanilla with good success.

In the telephone system of planting the 'T' shaped pole is planted three or four meters apart and wires are tied length wise on both end of the 'T' (at top) and vines are allowed to hang on both sides of the pole.

The live supports are to be established at least three months in advance of planting vanilla. Since glyricidia is commonly used, limb cuttings of 5.0 cm thickness and a length of 1.5-2.0 metre are collected during summer and allowed to stand in a leaning position for rooting. With the onset of rains these stumps are planted in pits for establishment. As it starts sprouting a group of branches all around the stem, 1.5 metre above ground level is developed into an umbrella like fashion to facilitate looping of the vines. Generally it is pruned close to the main stem in June when rains are in full swing while a light pruning is done to branches by removing 1/3rd length in September to allow for retention of leaves during summer. If no pruning is done the branches will shed the leaves in summer exposing vines to the hot sun. Under agroforestry or other tall trees shade regulation in rainy season is necessary. The ideal system to get the best yields is yet to be standardized.

5.1.2. *Spacing*

Though farmers practice different spacing, too close spacing is not ideal for vanilla because overcrowding may result in severe incidence of diseases and pests. As a pure crop with single supports a spacing of 2.5 to 3.0 metre between rows and 2 metre between plants in a row is ideal that would accommodate 1600 to 2000 plants per hectare. Few farmers follow a spacing of 2.5m X 1.5m to accommodate 2500 plants per hectare. This is applicable for live standards such as glyricidia. In systems where nonliving standards are used, a spacing of 2m X 2m is sufficient. If trailing on walls, a spacing of 1.5 metre between plants may be sufficient. In certain high tech systems even one metre spacing between plants is adopted. What ever may be the case, adequate aeration, enough light penetration easy management and better disease control should be taken into account while selecting the appropriate spacing.

When intercropped with coconut, arecanut or oil palm, only the interspaces should be used for planting vanilla.

5.1.3. *Pits*

Vanilla being a surface feeder, a small pit of 40 cm x 40cm x 40cm is sufficient for planting. The pit can be filled with good top soil and well decomposed FYM and allowed to settle for a week before planting. The filled earth should form a small mound above the pit to facilitate planting and also to avoid depressions in the pit. Otherwise rain water will accumulate in the pit resulting in rotting of the vine. Bio control agent (*Trichoderma* @50g per pit) can be incorporated to the soil with sufficient moisture when pits are filled to ward off potential diseases.

5.1.4. *Planting season*

Considering the fleshy nature of the vines, it is generally recommended to plant vanilla in the months of August-September when heavy rains are over and good humidity and light prevails. In low rainfall areas, it may be planted at any time with irrigation. So also is true for summer, provided necessary shade is given.

5.1.5. *Planting*

The method of planting depends on the type of planting material used. If cuttings are used, the leaves from the lower three nodes are removed, before planting. The defoliated part of the vine is laid on the loose soil surface and covered with a thin layer of about two to three cm soil. The basal end of the cutting would be kept just above the soil to prevent rotting. The growing end is gently tied to the support for clamping by aerial roots . If the sun is hot the cuttings are shaded with tall dry grass, palm fronds or with other suitable materials. In dry soil, a light sprinkling of water helps for early establishment of cuttings. It takes about four to eight weeks for the cuttings to strike roots and show initial signs of growth. In some areas where diseases are a problem another planting technique is adopted. Here the vine is tied to the support in such a way that the lower cut end of the vine is 10 to 15 cm above the ground level. The vine gradually puts down roots which reach the ground and help establish the plants. In this case spraying with nutrient solutions once in a fortnight may be necessary to stimulate sprouting and root formation. In summer planting, shading of the vines are needed.

When rooted cuttings are planted, a small hole is made in the filled pit to accommodate the root ball, the polybag is removed and planting is done by covering with soil. The growing end is tied to the support. The same method is applicable for planting of tissue culture derived plants also.

It is recommended to plant only one cutting per standard though many farmers do plant three or more plants to get quick canopy coverage and high yield. More plants (up to three) may be planted per support if the spacing adopted is wider. When planting is done in coconut, arecanut etc. 3 or 6 or even 10 vines are planted depending on the girth of the palm. Same is the case when non living supports such as asbestos pipes, concrete poles etc. are used.

In homesteads, planting closer to the walls of compounds or house in a large size pots, can be taken up. In all the above cases planting has to be done as discussed above. For pots a good potting mixture of sand, soil and FYM in 3:1:1 proportion may be used.

5.2. Training or looping

Vanilla plant if allowed to grow up on a tree it will rarely blossom so long as it is growing upward. Hence in order to induce flowering vines after reaching a convenient height of about 1.5 metre are trained to grow horizontally. Bending of vines in this manner helps to accumulate carbohydrate and other flower-forming materials beyond the bend and to induce flower production at this portion of the vine. The general practice involve where vine is allowed to grow to a height of 1.5 meter and then it is looped over a branch of the support tree such as glyricidia and allowed to grow downwards. Once the shoot touches the ground it is again tied to the support, allowed to grow vertically and after reaching the height of 1.5 metre it is again looped over another branch and allowed to grow downwards. Thus six to seven looping are done for each vine and after wards it is pruned to induce flowering .Similar method is followed when vanilla are grown in pots also. In some cases farmers allow the vine to trail over the ground after several looping to get vigorous growth and in other cases the down ward growing tip when it reaches the ground is buried under the soil before allowing to grow vertically. Once the vine grows to about seven metres of length, it can be pruned for flower induction.

When arecanut or coconut is used as support, the vines are trained by providing hooks to the palms or trellis is provided between the palms and trained on the trellis. In order to prevent breakage of the vine at the bend while looping in the wire trellis system, the wires can be enclosed in polytubes of 16 mm diameter or wrapped with areca nut spathe.

5.3. After care

After care involves regular weeding either by slashing or hand removal, manuring, mulching, tying the vines to the support, and looping of the vines, irrigation, etc. Weeds are not a problem since most of the area under vanilla is mulched. As the vines grow, it has to be tied to the support if needed and the vines are looped according to the system of planting adopted. Any operation done in the plantation should not disturb the roots, which are mainly confined to the mulch and surface layer of the soil.

5.3.1. Irrigation and mulching

Irrigation is needed during the summer months only after flowering is over. Mulching and irrigating once in two days was found to increase vanilla yield. Thirty minutes of mist irrigation during morning and evening each day was reported to be good. If the vines are irrigated continually after stoppage of rains no flowering will take place. An interval of about a month is needed for flowering. For fruit development irrigation is essential when rains are not enough.

Mulching is very important for vanilla for profuse root development which in turn will induce vigorous growth. Mulching from planting onwards is needed and the base of the vine must be covered with mulches. Dry leaves, rotten wooden logs, coconut husk, coir waste, wood shavings etc. are good for mulching. Sawdust should not be used as mulch, as it thickens like cake preventing aeration and drainage. Some farmers have obtained excellent results with chopped pieces of bamboo (1" or 2") where ramification of roots is excellent. Coconut husk is also very good mulch as it provides potassium and retains moisture.

5.3.2. Shade regulation

When the support trees grow up, they are pruned early to induce branching. It is desirable to develop an umbrella shape for the trees to give better shade and protection to the growing vines. If the trees do not drop off leaves they are pruned before the commencement of heavy rains to allow in more sunlight. The pruned vegetation may be chopped and applied as mulch.

5.3.3. Pruning of vines

One or two months prior to flowering, pruning or pinching of hanging shoots is to be done to arrest growth of the vine to induce flowering. This involves removal of 10-15 cm tip of the hanging shoots in October. No irrigation is given till flowers appear. One problem encountered after pruning or pinching is that the bud immediately behind the pinched area may start sprouting and the buds behind this bud may not flower at all or only a few buds develop into inflorescences. In order to make most of the buds in the hanging shoot to put forth flowers, hanging shoot is rearranged in the branches of the support in such a way that a bud is vertically exposed on top of the bend (from where the shoot hangs down) and the leaf subtending it is slightly pulled back to stimulate the erect bud to sprout. After 15-20 days, the tip of the hanging shoot is pinched off. This will prevent sprouting of vegetative buds of the hanging shoot and turn most of them into flowers. The top stimulated bud will form a vegetative shoot and will hang down and will be the one to be used for the subsequent year's crop. After the beans are harvested, that particular length of shoot will be removed to prevent overcrowding of shoots.

5.3.4. *Hand pollination*

Due to the peculiarity of the flower structure self pollination is prevented in vanilla. Hence flowers are to be hand pollinated to achieve fruit set .The flowers have to be hand pollinated between 6 AM to 1 PM. Hand pollination is done with a splinter of bamboo or other material about the size of a tooth pick. The flower is held in one hand and the labellum is pushed down with the thumb releasing the column. The anther cap is removed by the stick which is held in the other hand which exposes the pollen mass. Then the flap-like rostellum is pushed up under the anther, with the stick and, by pressing with the thumb and the finger, the pollinia are brought into contact with the sticky stigma to which the pollen mass adheres. Studies have shown that complete transfer of pollen results in maximum fruit growth and with less than 50% pollen, the fruit size gets reduced considerably. A skilled worker can pollinate about 1000 flowers per day. While pollinating care should be taken to see that the ovary (bean) is not scratched as these scratches are seen later on mature beans affecting in quality. For the production of better quality fruits, 8-10 flowers located on the lower side of the inflorescence are pollinated and number of inflorescence are restricted to 10-12 per vine. The remaining flower buds are nipped off to reduce the strain over the vine. Now, practically all vanilla is produced by hand pollination which accounts for 40 percent of the total labour cost in vanilla production.

5.3.5. *Maturity*

The beans take seven to nine months to reach maturity which is indicated by the presence of radiating yellowish streaks starting from the tip of the bean. At this stage the beans are in a rounded shape, olive green in colour, the petiole will be thick and snaps easily when bend backwards. If the yellowing has progressed too much it is likely that the beans my split while being processed. Immature beans give a product with low aroma. To get good quality beans, with good vanilla content only mature beans are to be harvested. Therefore, periodical visit to the plantation is needed and the harvested beans may be processed within three days if possible and in any case should not exceed seven days.

5.3.6. *Yield*

Vanilla plants will start flowering by third year. It is considered that an average yield of 1500 kg green beans per hectre is normal that will yield 300 kg of processed beans from sixth year onwards. About 70-80 beans of 18-20 cm in length will make one kilogram of fresh beans which on processing yield about 200 g of cured beans. The yield will gradually increase from fourth or fifth year and continue up to 14th year and then starts declining.

5.4. Standards and production guidelines for organic vanilla

(Source: Production of Organic Spices 1998, Published By Spices Board, India)

As demand for organically produced vanilla in increasing in international market, it is wise to produce organic vanilla, following appropriate regulations. Spices Board, India formulated certain guidelines to produce organic vanilla right from site selection to packaging and handling of final produce.

5.4.1. Site selection

Vanilla can be cultivated either as a pure crop or as an inter- crop with coffee, coconut, arecanut, pepper etc. under such cases all the crops should be grown by following organic methods. An isolation distance of 25m wide should be provided. A period of three years is required as conversion period for existing plantations. For new planting, if vanilla is cultivated in virgin land or in farm where records are available that no chemical inputs are used, this conversion period can be relaxed.

5.4.2. Source of planting material

Vanilla to be propagated by using cuttings from healthy and vigorously growing plants, which are grown organically. However, to begin with they can be obtained from conventional plantations. Tissue culture plants should not be used as planting materials in order to keep integrity with the methods of propagation.

5.4.3. Preparation of land and planting standards

As vanilla requires a support tree for climbing, live standards having low branching habit with rough bark and small leaves may be planted at least six months ahead of planting vanilla cuttings. As many recommended species as possible may be planted to keep biodiversity.

5.4.4. Vanilla cuttings

Basal three–four leaves of cuttings may be stripped off and kept under shade for one week to loose moisture. The defoliated portion of the vine is laid on the loose soil surface and covered with a thin layer of soil. The basal tip is to be kept just above the soil to prevent rotting. The other end is to be tied gently to the support. The plant basin is to be mulched and the plants shaded if necessary.

5.4.5. Cultural practices

The plantation is to be visited regularly to train the vines to grow at a convenient level to regulate the growth of vines and supports and keep watch for pests and disease incidence, if any. Always keep leaf mulch around the vanilla vines. Any operation done in the plantation should not disturb the roots, which are mainly confined to the surface layer. Weeding may be carried out if necessary and the cut weeds are to be used for mulching.

The support trees are to be pruned lightly at a height of 125 t o 150 cm to induce branching and to develop an umbrella shape for providing adequate light and shade (50%). Pruning is to be done before the commencement of heavy rains and the pruned vegetation is used for mulching

For convenience of cultural operations, the vines are to be allowed to grow only up to a height of 1.2 to 1.5m and then trained horizontally on the branches of support trees. Pollinate the recommended umber of inflorescence and the flowers during the flowering season.

5.4.6. *Manuring*

Vanilla, being an orchid plant, prefers organic manures. Decomposed organic materials may be applied two to three times a year. Bone meal, well rotten cow-dung, compost or vermicompost @ 4-5 kg/ plant/ year may be used

5.4.7. *Plant protection*

Diseases

Some of the disease affecting vanilla is rotting of leaf, stem, root, shoot tip and pods and blight caused by *Fusarium oxysporum* as well as brown spots or anthracnose caused by *Colletotrichum gloeosporioides*. Regular surveillance and plant sanitation are required for managing the diseases. The disease- affected portions are to be removed and burnt. Any injury to roots and other plant parts should be avoided. The plant basins should be kept under mulching. Restricted use of Bordeaux mixture (1%) may be made if necessary.

Pests

No serous pest attacking vanilla is noticed. However, a few caterpillars, earwigs, snails and slugs damage the tender parts of the plant. They may be controlled mechanically.

Harvest and post harvest operations

Immature bean is dark green in colour. When ripe, yellowing commences from the distal end of the bean. This is the optimum time for harvesting the bean. If left on the vine the bean turns yellow on the remaining portion and starts splitting. To avoid this, it is essential that the plantation is visited frequently and beans, which are in the right stage of ripening, are harvested. Beans at this stage do not have aroma, as free vanillin is not formed in them.

Method for curing involves the following four stages; (i) Killing the vegetative life of the beans to allow the onset of enzymatic action (Vanillin is developed as the action on the glycosides during curing). (ii) Rising temperature to promote this action and to achieve rapid drying to prevent harmful fermentation. (iii) Slower drying for the development of different fragrant substances. (iv) Conditioning the product by storing for a few months.

Curing of Bourbon vanilla (produced in Madagascar, Comoro and Reunion), which contributes more than 70 per cent of the world production, is very simple compared to the method practiced in Mexico.

The beans are immersed in hot water of 63 to 65° C for the three minutes for the cessation of vegetative life. After rapid drying, when the beans are still very hot, they are rolled in flannel of woolen blanket and kept in chest lined with same material to retain the heat. The beans will acquire chocolate brown colour by the following day. They are then spread out in the sun on dark coloured cotton covers for three to four hours and latter rolled up to retain the heat. Usage of raised black net for spreading the beans in sunlight has been observed to give better results.

Sunning and keeping in chest is repeated for six to eight days during which the beans loose some weight and become very supple. Later, beans are dried by spreading out in trays under shade, in an airy location. The duration of drying varies according to the beans, which usually last for two months. Properly dried beans are kept in trunks where the fragrance is fully developed. Finally they are graded according to size, bundled and placed in iron boxes line with paraffin paper. The vanillin content of properly cured beans will not be less than 2.5 per cent.

6.0. MANURING

The best way to manure vanilla has not been scientifically evaluated and only ad hoc recommendations are given. Being a terrestrial orchid deriving nourishment from the decaying vegetative matter, organic sources of nutrients, may be the best. It is therefore advisable to give plenty of mulching materials that slowly decompose and supply nutrients including organic manures. Studies have shown that plenty of dry leaves and dry cow dung were the best and fertilizers were not advised. Nevertheless the Spices Board recommends fertilizers @ 40-60g N, 30g P_2O_5 and 60-100g of K_2O per plant applied in 3 to 4 split doses for a year. Animal manures are not be used for vanilla as they are not favoured by orchids. Farmers have been using fermented cow dung slurry, oil cake etc. Slurry is diluted with water and applied either in the basin or sprayed on the foliage. Spraying verminwash every 15 days and applying ½ kg of vermicompost every month during the growing period are beneficial in boosting growth and productivity. The manuring should be restricted to the period May to September. All the manures should be applied without disturbing the root system and covered with mulch. Foliar application is also good for vanilla for which an NPK mixture of 17:17:17 may be given @1% at bi-monthly intervals.

7.0. DISEASES AND THEIR MANAGEMENT

The crop suffers from various diseases The symptoms and management strategies of important diseases are described below.

7.1. Fungal diseases

7.1.1. Bean rot

The fruits are called as beans and it takes about 8 months to mature from the date of pollination. Two kinds of rot caused by two different fungi are recorded.

Phytophthora induced rot develops at the tip of beans, slowly extend towards the pedicel and the affected beans show water soaked lesion which become dark green leading to rotting of the beans. The rotting extends to whole bunch of beans exhibiting abundant external growth of fungal mycelium. In later stages of infection the rotting advances to the stem, leaves, aerial roots and extend towards the basal portions. If favorable whether condition such as continuous rains prevails, the infection extends to the whole plant.

Another fungus, *Sclerotium* induced rot is characterized by the rotting of bean tips and affected portions show white thick mats of fungal mycelium forming a mantle around the bunch of beans and leaves.

Predisposing factors: Both types of bean rot is noticed in gardens having excess shade, continuous heavy rains, overcrowding of vines, waterlogged conditions and presence of pathogen inoculum in the field.

Management

1. Remove and destroy infected plant parts and mulch during rainy season.
2. Regulate shade during monsoon period in order to prevent excess shade.
3. Allow at least 30-50 % light to fall on the vines.
4. Spray Bordeaux mixture (1%) and soil drench with 0.25% copper oxy chloride 2-3 times depending on the severity of infection and as prophylactic measure.
5. If rotting is due to *Sclerotium* carbendazim-mancozeb mixture at 0.25% can be sprayed twice at 15 day interval.

7.1.2. Premature yellowing and bean shedding

The disease is of relatively recent origin and is noticed in all vanilla plantations of Karnataka and Kerala especially during summer months.

Symptoms

The disease initiates as dropping off dried corolla from the tip of immature beans which otherwise remain attached to the beans till half way through maturity. As the dried corolla drop off, exudates from the beans accumulate as a drop at the tip, the beans turn yellow followed by brown discoloration of the beans from the tip upwards leading to falling of beans

Pre-disposing Factors

Warm moist conditions with well distributed rain fall of 150-300 cm with a temperature range of 25-32° C is found to be ideal for the growth of vanilla. High temperature (more than 32°C) and very low relative humidity (less than 70%) prevailing during the months of February-May predisposes the plants to infection. Over crowding of the beans may also play a key role in the immature bean shedding. Intensity of the disease is low under conditions of high altitudes where temperature and humidity are maintained under forest cover. Constant association of *Colletotrichum gloeosporiodes* and insect larvae inside the flowers were noticed.

Management

1. Provide 50% shade in the plantation.
2. Provide mist irrigation for at least 4-6 h during pollination till the onset of pre monsoon showers in order to maintain a relative humidity more than 70%.
3. Restrict the pollination to 15-18 flowers /inflorescence
4. Spray dimethoate or quinalphos 0.05% during flowering period thrice at 15-20 day interval and fungicides such as thiophanate methyl 0.2% or carbendazim -mancozeb (0.25%) at 15-20 day interval thrice from February up to May.

7.1.3. Stem rot

The disease usually appears during the post monsoon periods of November-February.

Symptoms

The disease appears as yellowing and shriveling of the inter nodal area extending to both sides of the stem. When the basal or middle portions of the vines decay and shrivel, the remaining distal portions of the vines show wilting symptoms. Stem rot and drying are generally observed at the basal portions above the ground level. The disease is caused by *Fusarium oxysporum f.sp.vanillae*.

7.1.4. Root rot / wilt

Symptoms

Initially the disease appears in the form of browning and death of underground and aerial roots. Aerial roots die before entering the soil resulting in flaccidity and shriveling of the stem and finally the vine droops. The disease is caused by *Fusarium batatis* Wollen var. *vanillae*.

Management of stem and root rot/wilt

1. Remove and destroy infected plant parts (Phytosanitation)
2. Foliar spray with carbendazim 0.2%
3. Soil drenching with carbendazim (0.2%), copper oxychloride (0.25%) or a mixture of carbendazim -mancozeb (0.25%)
4. Apply biocontrol agents such as *Trichoderma harzianum* and *Pseudomonas fluorescence* (having a cfu of 10^8/g) @ 50g/vine in carrier media.

7.1.5. Tip rot and die back

Symptoms

Visible symptom is the brown discoloration of the growing tip of the vine. The symptom starts at the collar region of the funnel like tip which extends to inter nodal regions resulting in the rotting of the tip. Disease may be caused either by *Phytophthora meadii* or *F. oxysporum*. In case of *Phytophthora* rot, the fungus forms thick white mycelial cover along the water soaked black lesion. But if the infection is due to *Fusarium*, the lesion is grayish in colour with large number of pin-head like encrustations of mycelial aggregation on the lesion. Such aggregation contains a large number of conidia.

Management

1. Nip of the infected tip below the next node.
2. Spray Bordeaux mixture (1%) or mancozeb or carbendazim at 0.25% as prophylactic measure.

7.2. Viral diseases

Two important viral diseases infecting vanilla include mosaic and stem necrosis.

7.2.1. Mosaic disease

Various kinds of mosaic such as mild mottle, mild mosaic and mild chlorotic streak (could be seen when the leaf is held against light) were observed. In a few cases such mosaic is also associated with leaf distortion giving wavy margin. The size of the leaves also gets reduced and in advanced stages, leaves become brittle and show severe crinkling.

7.2.2. Stem necrosis

The disease is characterized by the appearance of brown necrotic patches on the stem region with shriveled appearance. The affected stem shows distinct necrotic lesions of varying length (few mm to several cm) This disease is different from the fungal induced stem rot. Stem necrosis can be distinguished from stem rot caused by fungi by the following:

1. Stem rot affected region will be totally blighted and very soft that can be easily felt by touching the affected region by fingers, while stem necrosis (caused by viruses) affected region when touched by hand appear very dry and hard and gives cracking sound when attempted

to bend at this region. Fungal diseases are commonly seen during the wet monsoon period whereas stem necrosis is seen all through the year.

2. A close look at the stem rot affected region show a white cottony growth on the upper surface of the affected region while no such growth is seen with stem necrosis affected region.

3. In the case of stem rot the portion above the lesion often wilts with yellowing of leaves whereas in stem necrosis no wilting would be seen

In a few cases necrosis is also seen on the leaves at the lower surface in the form of scab. This often gives an appearance of sun scorch. The disease initially starts as a necrotic spot on the stem and slowly gets enlarged and encircles the stem. In an affected plant, necrosis may be seen only at one or few regions on the stem. Rest of the stem region looks apparently healthy without any visual symptoms. A few of the necrosis affected plants also show mosaic symptoms on leaves.

Transmission and spread

The major means of spread of the virus is through the use of infected stem cuttings. Insects like aphids and sucking pests may also play an important role in the transmission and spread of the disease in nature.

Management

1. Use of virus-free planting material is the primary requirement to check spread of the virus. Apparently healthy looking plant should not be used for any new planting as this would carry the virus which eventually would show the disease symptoms after planting. If tissue culture raised plants are used, it is important to check for the presence of virus in the mother plant. If the mother plant is infected with the virus, the plantlets derived from this also will carry the virus thus contributing for the spread of the virus.

2. Regular inspection and removal of infected plants and replanting with healthy plants

3. Weed and crop hosts (especially pea, pumpkin and watermelon and other hosts) which might act, as reservoir for the virus also needs to be removed. The removed plants may be burnt or buried deep in the soil.

4. Insects such as aphids and others may act as vectors for the different viruses. These insects whenever noticed on vanilla plants may be controlled with insecticide spray. Insecticides like dimethoate or monocrotophos @0.05% can control aphids, and other sucking insects.

5. Movement of planting materials from infected regions to disease free regions should be avoided.

8.0. PESTS AND THEIR MANAGEMENT

Vanilla cultivation in India is of recent one and hence pest problem is not very severe. Incidence of a few pests infesting vine, shoot tip, flower buds and roots are reported (Table.3). Among these insect pests that damages vanilla, a hemipteran bug, a lepidopteran caterpillar and a coleopteran weevil cause considerable damage. They cause *shoot tip rot, which may look similar* to fungal rot but a close observation indicates the difference in the symptom. Besides there are a few non-insect pests damaging vanilla in the country.

8.1. Insect pests

8.1.1. Hemipteran bugs

Vanilla bug (Halyomorpha picus)

The bug is reported to occur in Karnataka and Kerala, particularly where vanilla is intercropped in arecanut plantation. It causes serious damage by sucking the sap from shoot tip and inflorescence. Pin-prick-like punctures at the site of feeding and subsequent necrosis and rotting is the typical symptom of bug feeding. The affected vegetative buds drop off within 3-5 days and affected inflorescence become rotten. Incidence of the pest is high during inflorescence initiation period i.e. January-February. The pest activity was observed throughout the day but the intensity was high during morning and evening hours.

Female bugs lay spherical eggs in clusters on the lower surface of leaf. After hatching (within 5-6 days), the first instar nymphs do not feed while second to fifth instar nymphs actively feed on the shoot tip. The nymphal duration lasts for about 60 days. The pest causes about 40% damage by way of feeding on the inflorescence.

Management

(i) Monitoring for the bug during November to February and removal of egg mass and first instar nymphs which are seen on the lower surface of leaves.

(ii) Spray on dimethoate @ 0.05% a.i. when infestation is very high.

Scale Insects

The scale insect sucks sap from the leaves, vine and inflorescence Black ants are found to be associated with this sucking insect and the incidence is recorded during January-February.

Management

Spray dimethoate at 0.05% a.i. only if the pest is serious.

8.1.2. Coleopteran beetles and weevil

Of the different species of coleopteran insect pests are recorded, vanilla weevil (*Sipalus* sp.) is causing considerable damage in India.

Vanilla vine weevil (sipalus sp.)

The pest is reported to cause serious damage to young shoots, vines and leaves of vanilla. The adult weevil feeds on vegetative shoot leading to necrosis. Since the weevil lays eggs singly along the length of vine and the emerging grubs feeds the inner core of the stem by making tunnel, the entire length of vine become pieces, rot and fall down.

The adult weevil is about one cm long with two wavy white cross bands on the elytra. Adults mainly feed on shoots by inserting the snout, the injured area become necrotic within a day, leading to rotting of shoot tip/vine. The weevil also feeds on leaves by scrapping upper or lower epidermis with mesophyll tissue, leaving a thin transparent epidermis on the surface of leaves.

Females lay eggs singly, 2-4 mm below the epidermis on vine or shoot tip. The site of egg deposition develops necrosis. The emerging larvae feed on the necrotic tissue by making tunnel in the vine. Larval period lasts for 35-40 days. The larvae tunnel the vine by feeding and the entire length of the affected vine becomes necrotic. The mature larvae pupates inside the tunnel with fibrous material which lasts for 19-20 days. Adult weevil emerges from the vine by making a small slit in the dried vine.

Extensive damages by the larave and the adult weevil on the vine is observed mostly in open area where shade is less. The adult weevils are seen in the field from November-January, and can easily be located. The weevils are not very active, and hence they may be hand picked and destroyed to reduce the damage on crop.

Saula ferruginea

This beetle cut through the leaf from the lower surface eating the entire leaf tissue except for the thick translucent cuticle of upper epidermis. Attacked leaf rots as a result of secondary infection by fungi. The pest may be managed by keeping the garden weed-free and in severe case by application of malathion 0.1% .

White grub

Root damage by white grubs is reported in certain pockets of Kerala. Drenching chlorpyriphos 0.05% a.i, at plant base during the month of May controls the pest.

8.1.3. Lepidopteran pests

Plusia sp.

The pale green caterpillar of this moth feeds on the vegetative shoots between the shoot bud and the first leaf leading to rotting of the terminal bud. Incidence of the caterpillar was recorded during January and February. The adult moth is reddish-brown with a broad bright yellow band across forewings and grey hind wings. The pest can be managed by spraying dimethoate at 0.05% if the incidence is high.

Other lepidopteran pests such as *Spilosoma casigneta* and *Pericalia ricini* are found to feed on leaves, tender shoots and flower buds. The pest can be managed by spraying dimethoate at 0.05% if the incidence is high.

8.2. Non insect pests

Among this, snails, slugs and avian pest cause considerable damage to vanilla.

8.2.1. Snails and slugs (Achatina Sp.)

The snails feed on the chlorophyll tissue from the base of the vine and leaves. The incidence of the snail is more in places where coconut fronds are used as mulch on the plant base. The snails hid in the mulch during day time, and come out during night to feed on vanilla. The management of these pests includes avoiding mulching with coconut fronds or any other materials that do not decompose fast. The snails may be collected from the mulch and destroyed.

8.2.2. Avian pests

Chickens cause much damage by scratching among the mulch and thus exposing and damaging the roots.

8.2.3. Vanilla scab

Longitudinal corky formation on the beans of vanilla is commonly referred to as 'vanilla scab'. It was found that the mechanical injury at the early stage of bean caused scab. Close observation on bean, leaves and internodes showed that wherever the early stage of plant parts come in contact with hard object like bamboo or dry twig or even mature leaf lamina, scab information was observed on the point of contact. Apart from the scab caused due to mechanical injury, scab of unknown etiology was also recorded.

Table 3. Pests of vanilla (*Vanilla planifolia*) reported from India.

Name of the pest	Systematic position	Nature of damage
Insect Pests		
A. Hemiptera		
Vanilla bug (*Halyomorpha picus*)	Pentatmoidae	Suck sap from vegetative bud and inflorescence leading to rot.
Scale insect	Coccidae	Suck sap from leaves, vine and inflorescence
B. Coleoptera		
Vanilla vine weevil (*Sipalus* sp).	Curculionidae	Adult damage the leaves and vegetative buds, and grub tunnel the vine
Saula ferruginea	Endomychidae	Adult cut through the leaf from lower surface eating entire leaf tissue
C. Lepidoptera		
Plusia sp	Noctuidae	Caterpillar feeds on shoot forming a web in between the bud and first leaf
Spilosoma casigneta		Feed on leaves, tender shoots and flower buds
Pericalia ricini		Feed on leaves, tender shoots and flower buds
Non-Insect Pests		
Snails and slugs (*Achatina* sp)	Gastropoda	Feed on vines and leaves
Avian Pest Chickens	Aves	Damage caused by exposing the roots
Scab	-	Scab formation due to mechanical injury

9.0. POST HARVEST PROCESSING AND VALUE ADDITION

9.1. Harvesting

Immature bean is dark green in colour. Although the pods reach their greatest size six weeks after pollination, it is eight to nine months before they are ripe for picking. The beans are to be harvested when they are fully grown and at a stage when they begin to yellow at the lower end. It is necessary to harvest the bean at the right time as the immature ones produce the inferior product and if picked too late they will split while curing and such beans are considered inferior. In more heavily shaded areas, beans may take up longer time to mature than where there is more light or less shade. The vanilla plantation should be visited every day so that the beans can be harvested as soon as they are ready. They may be harvested by side ways pressure of thumb at the base or by cutting with a sharp knife. Twisting should not be done as it may lead to breaking of bean. Around 75 to 80 beans of 18-20 cm in length will make one kilogram of fresh beans. Since the pollination of flowers in a vanillery last for three to four weeks, completion of harvesting of beans may also take this much time. Blossom-end yellow cured beans is known to give a good product with a pleasing vanilla bouquet, whereas, blossom-end brown beans produced a fruity aroma which was agreeable but lacking in true vanilla character. It was found that vanillin content reached maximum when the pods were tending to turn brown.

9.2. Curing

The fresh vanilla beans do not have any flavour or aroma because vanillin and other chemical substances responsible for imparting the particular fragrance and flavour are not present in free form at the time of harvesting. During the process of curing, free vanillin is developed in the beans as a result of a series of enzymatic action on several glucosides. These compounds together give the fragrance of natural vanilla well distinguishable from synthetic vanillin. Many curing processes have bean developed in various vanilla growing countries to meet the quality requirements of the vanilla market.

The curing is a process of alternatively sweating and drying of pods until they have lost most of their moisture as much as 80 per cent. It is extremely important stage in production since during curing they undergo the enzymatic reaction responsible for the characteristic flavour of vanilla.

9.2.1. *Curing methods*

Different procedures have been developed for curing of vanilla. All methods are based on same principles and are characterized by the four phases

Killing or *wilting*: This stops further vegetative development in the fresh bean and initiates the onset of enzymatic reactions responsible for the production of aroma and flavour. Killing is indicated by the development of a brown colouration of the bean.

Sweating: This involves raising the temperature of the killed beans to promote the desired enzymatic reactions and to achieve rapid drying, to prevent harmful fermentations. During this operation, the beans acquire a deeper brown colouration and become quite supple, and the development of an aroma becomes perceptible.

Slow Drying: This is done at ambient temperature (usually in the shade) for the development of various minor flavour contributing components

Conditioning: In this final stage, the beans are stored in closed boxes for a period of three months or longer to permit the full development of the desired aroma and flavour.

Of the various traditional procedures for curing vanilla beans, the most important one is called the 'Bourbon' method, the details of which are given below.

The bourbon method

In this method the beans are immersed in hot water at 63–65°C for three minutes for the cessation of metabolic activity. After rapid draining, when the beans are still very hot, they are kept in chests lined with blankets. The beans will be chocolate brown colour by the following day. They are then spread out in the sun or dark coloured cotton covers for three to four hours and later rolled up to retain the heat This is repeated for six to eight days during which time the beans loose some weight and become every supple. Later, the beans are spread preferably on wooden trays in open and ventilated room and subject to slow drying. Usually it takes 15-20 days for completion of slow drying. Properly dried beans are kept in trunks/boxes where the fragrance is fully developed. Finally they are graded according to size, bundled and placed in cartons lined with paraffin paper. Vanillin content of properly cured beans will be more than 2.0 per cent.

Method followed in India

Attempts were made to cure vanilla beans by suitably modifying the bourbon method of processing to suit condition prevailing in different vanilla growing regions of south India. It was found that irrespective of locations, optimum conditions for killing beans was 65°C hot water dipping for three minutes. As there will be a sudden drop in temperature by about 3-5°C, when the beans are dipped, it is necessary to maintain the temperature at the required level by heating of water. After killing, any left out moisture was wiped off and the killed beans were wrapped in woolen cloth and stored in airtight wooden boxes lined with black cloth or woolen cloth. It was found that techniques for sweating and slow drying needed alterations to suit the climatic condition prevailing in various locations. In general for retaining higher moisture and pliability of cured beans, it was observed that the sweating and slow drying periods should be longer with only gradual loss of moisture. To achieve this, the following techniques have been found to be useful. (i) During the process of sweating, exposing killed beans to sun on raised platform erected about 75-100 cm above the ground (ii) Providing a layer of agro-shade net over the beans kept in the raised platform to prevent excessive build up of heat on the beans. Exposing the beans to filtered light through the agro-shade net on raised platform is of much more importance while processing the beans at lower elevation.

The period of sweating will be around 10-12 days depending on the time and period of exposing beans to sun. At the end of this period, weight of beans become around half the initial weight. Subsequently the beans are subjected to slow drying in a room by spreading them on wooden racks. The period of slow drying would be for 20-25 days wherein the beans loose further moisture very slowly and become more supple. While slow drying the relative humidity of the room is increased by hanging moistened cloths and keeping water in trays below the racks. Maintenance of higher relative humidity while slow drying is essential under all processing conditions in South India. The beans are inspected regularly to prevent any mould growth and turned upside down for uniform drying. The slow dried beans are sorted out and bundled into 50 or 100 numbers depending on length and tied at both ends. They are properly packed using suitable material such as butter paper, cellophane paper or polypropylene bags and stored in airtight containers for conditioning, the period which lasts for three to four months. Development of vanillin crystals was noticed after a period of three to four months in properly cured and conditioned beans.

9.3. Quality requirements

Vanilla is by far the most popular flavour at the present time in the ice cream, baking and chocolate industries in the United States. It is chiefly used as flavouring of chocolate beverages, confections, cakes, custards, puddings and ice creams and in the manufacture of soaps, perfumes and sachet powders. Vanilla is commonly used in the form of an extract from the beans. In the manufacture of chocolates, however the beans are usually ground finely with the sugar and included with chocolates. The bean is also sometimes used directly in the manufacture of ice creams and other confectioneries. The preliminary quality requirement for cured vanilla beans is the aroma/ flavour character. Other factors in quality assessment include the general appearance, flexibility, the length and vanillin content. The relative importance of these various quality attributes depends upon the intended end use of the cured beans.

Traditionally, the appearance, flexibility and size characteristic have been of importance since there is a fairly close relationship between these factors and the aroma or flavour. Top quality beans are long, fleshy, supple, very dark brown to black in colour, somewhat oily in appearance, strongly aromatic and free from scars and blemishes. Law quality beans are usually hard, dry, thin, brown or reddish-brown in colour and posses poor aroma. The moisture content of top grade beans is high (30-40%) while it may be as little as 10% per cent in the lower grades.

10.0. ECONOMICS AND MARKETING

10.1. Cost of cultivation

Economic aspects of vanilla production is analysed under three headings:

i) *Establishment Cost*: includes costs of all inputs and operational expenditure during establishment period (till bearing stage of the crop) i.e. up to 3 years.

ii) *Maintenance Cost:* includes operational expenditure and material costs involved in a year for maintaining the plantation during its bearing stage i.e. 4-15 years

iii) *Output and Returns:* quantitative yield and money value per unit.

Table 4. Cost of cultivation of vanilla (Rs./acre)

S.No.	Particulars	Cost (Rs.)
Establishment cost per acre (700 vines)		
1	Labour	10050
2	Planting material	4560
3	Manures	28000
4	Chemicals	1548
5	Standards for support	2280
	Total establishment cost	46438
Maintenance cost		
6	Labour usage for all operations	4350
7	Compost	14000
8	Chemicals	645
9	Interest on working capital @11% per annum	2089
	Total	***21084***
Apportioned establishment cost @11%		6458
Output and returns per acre		
10	Total cost of production (Rs./acre)	27542
	Cost of production (Rs/kg)	230
	Average annual production (kg/acre) (green)	120
	Gross returns @Rs.300/kg	36000
	Net returns (Rs/acre)	8458
	Net returns (Rs/kg)	70
	Benefit Cost Ratio (BCR)	1.31

Note: 1. Recommended package of practice is combined with the actual survey information to work out the present cost.

The estimated maintenance cost per acre per year was Rs.21084. Here, the incurred cost towards compost forms the major component (66%) followed by labour charges (21%). On an average the estimated total cost of production was Rs.27542/acre. The average yield per acre (700 vines) obtained was 120 kg of green beans. Thus an average net return per acre was Rs.36000 (@ Rs.300/kg) with the benefit cost ratio of 1.31. The grower would make some additional earnings also by way of selling the cuttings from the second year onwards. Productivity per acre is expected to go up (more than 360kgs) when the plantation reaches the full maturity stage of 6-9 years of age.

10.2. Marketing

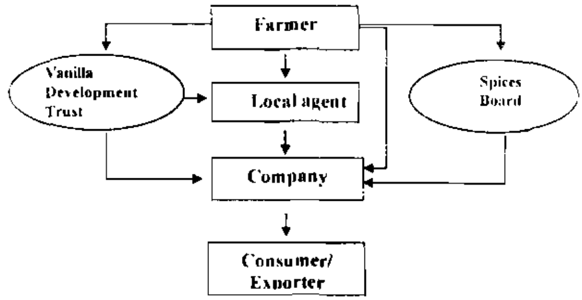
There exists two marketing seasons for vanilla depending on the type of produce and place of sale:

1. *October-November:* During this harvesting season the green beans are sold as and when they are harvested.
2. *March onwards:* Second season starts when the cured beans are ready for sale.

The sequence of stages involved in moving the produce from the farm to the consumer is generally referred to as a marketing chain/channel. There exist four marketing channels for vanilla as shown in Fig. 1.

In the first channel harvested green beans are sold to local agent or trader. The local trader who has developed contact with processing and exporting companies sell the produce to them without adding any value to the produce. The company will process (cure) the bulk purchased green beans before export or further processing into vanilla concentrate.

Fig 1. Marketing channel for vanilla



The channel II of the marketing system is being followed both by sellers of fresh and processed beans, where the produce is directly sold to the procurement wing of the processing company either at the farm gate or at the factory gate during October - November harvesting season.

Fourth way of marketing is through Vanilla Development Trust (VDT) in Karnataka and Vanilla Growers Association in Kerala and other non-governmental co-operative organisations.

In the second season, which starts from the month of March representatives of the company meet the farmers directly to procure cured beans. In the third channel, Spice Board on request from the vanilla growers and depending on the availability of vanilla beans, facilitate the meeting of both buyer and seller at a convenient common place. Spice Board does this as a service to farming community and then there exists a direct contact between the seller and the purchaser for further transaction. Once the company comes to know about the whereabouts of the potential seller (farmer), in subsequent years they directly contact the farmer as in the second channel.

10.3. Trade and commerce

Major importers of vanilla in the world market are USA, Germany and France accounting for 64% of the total world imports. The share of USA alone comes to around 43 per cent. These three countries are also major exporters of value added products. In USA, over 95 per cent of vanilla beans are processed into extracts while in France at least 20 per cent are consumed directly. As it can be seen from Table 5, there has been a steady increase in volume of vanilla imported over the eight years period commencing from 1991 and there was a decline in import from 1998 onwards. This decline was mainly due to short supply rather than fall in demand.

10.4. Indian scenario

Apart from the global demand, unlike other producing countries, India has huge domestic market, which can acts as a cushion for vanilla economy of the country in the event of adverse situation in the world market. An average import of vanillin and ethyl vanillin together to India from 1995-96 to 2000-01 was 265 Mt. Even if 10% import of these synthetic substitutes are to be replaced with natural vanillin, the requirement of vanilla beans would be 1325 tones at 2% vanillin content, against the present Indian production of hardly 92 tones. This indicates the great potential for vanilla development in India even if a part of the consumption of synthetic vanillin is to be met by natural source both in domestic and international market. Thus, the opportunity awaiting the country is immense.

Table 5. Import of vanilla beans by major importing countries (1996-2000)

Country	1996	1997	1998	1999	2000	Average
USA	1524	2198	1941	1361	1304	1666
France	420	460	490	565	491	485
Gennany	291	332	320	326	312	316
Canada	95	204	110	119	66	119
Japan	79	95	69	9.1	115	90
Netherlands	222	106	182	102	NA	153
UK	92	225	290	385	395	277
Spain	139	292	125	94	14	133
Others	357	648	390	671	1012	616
World	3496	4651	4564	4320	3719	4150

Over the years price of cured vanilla has been increasing tremendously from mere Rs.800/- per kg to Rs.9600/- per kg. However, for the last two to three years the price is much below the Rs.500 mark. The observed parallel movement of Indian and International price for cured vanilla indicates that Indian vanilla is gaining importance and is on par with the produce from other major producing countries.

Indian export has increased from mere 0.03 tones of cured beans during 1997-98 to 26.0 tones valued at Rs.3606 lakhs during 2003-04 (Table 4.). The target set for the current fiscal year is 50 tones, while the target set for the Tenth plan is 1,000 tones of cured vanilla beans. The total value of exports including concentrates has jumped to many fold increase during this period owing to high unit price. Though the country is yet to earn an important position among the major suppliers of natural vanilla to the world market, the level of growth indicates its potential. Looking to the above potential many steps were taken by the governmental agencies for the development of the vanilla industry.

10.5. Development related activities

- Spice Board has fixed the target to bring 15,000 hectares under vanilla by the year 2008
- In a bid to promote the crop, the board has also entered into a tie-up with the Kudumbasree Project of the Kerala State Government, under which women are given training in nursing the vanilla plants developed through tissue culture method. They are also trained in artificial pollination methods and processing of the beans.
- Large scale multiplication of planting materials is being supported both in government and private sector nurseries for distribution at reasonable price.
- Farmers are also being trained to cure the beans and are provided with a curing kit by the Board. During the 9th Plan, processing units were given a subsidy of Rs 5,000 each. In the current Plan, subsidy at the rate of Rs 2,500 per unit, i.e., 25 per cent of the investment for setting up a facility is being given.
- Vanilla Growers Associations in the vanilla growing States provide technical guidance in production and processing to the member growers and assist the farmers in marketing their produce at a reasonable price.

It can be concluded, that the overall analysis of vanilla industry in India in particular and global as a general shows that there is huge potential for further development of the vanilla economy to earn foreign exchange, create direct and indirect employment to rural mass in the plantation sector. Finally, the nature of the crop can allow the

Table 6. Export of vanilla from India

Year.	Cured Beans		Concentrate	
	Qty, (Mt)	Value (Rs. Lakhs)	Qty. (Mt)	Value (Rs. Lakhs)
1997-98	0.03	0.72	0.55	12.97
1998-99	2.55	12.66	0.52	21.60
1999-00	11.17	97.72	.0.83	31.56
2000-01	12.65	161.62	0.39	30.78
2001-02	19.87	1212.37	0.25	35.71
2002-03	25.00	2226.0	Na	Na
2003-04	26.00	3606.0	Na	Na

sustainable eco system in growing region. The Indian Vanilla farmer is well informed, progressive and financially capable of producing high quality Vanilla even at lower rational prices.

As vanilla is being cultivated by a large *number of small growers with holdings* less than one ha area, in varied agro-climatic conditions, the quality of the end product varies very much even if they followed common curing process. Hence, it was essential to set up common processing facilities to get uniform good quality produce.

Vanilla beans during curing and after curing has to be stored properly. Otherwise, the quality will be affected. Growth of moulds during slow drying and conditioning is a major problem faced by the growers. Research on the storage, handling and packaging is lacking. Only a limited number of personnel who had some knowledge on the culture and processing of vanilla were available in the country.

Organic vanilla is now a new product range much in demand in so many countries.

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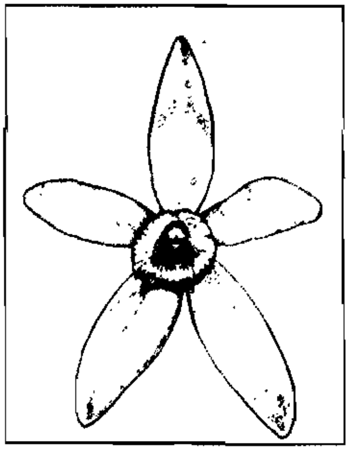
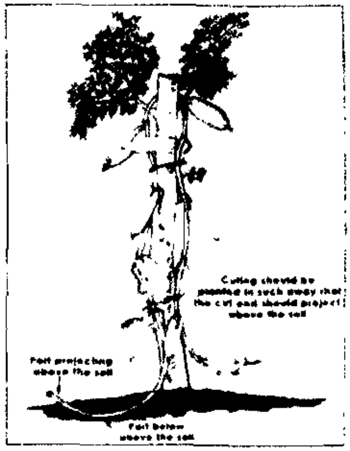
A vanilla plant

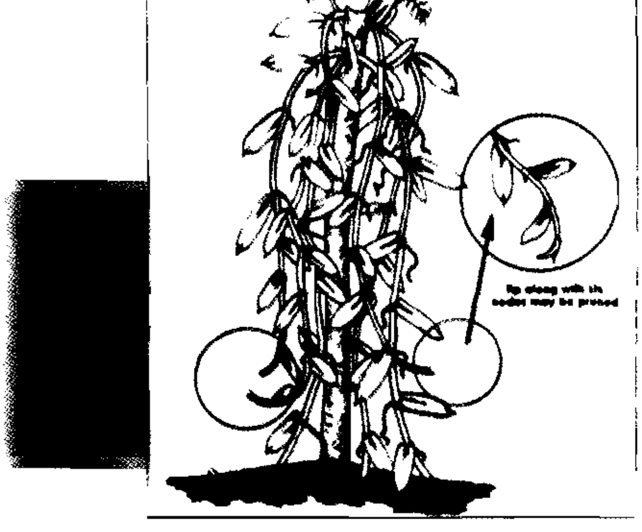


Vanilla flower

Flower parts

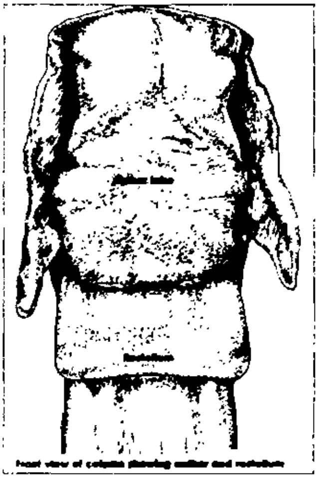


Planting method of vanilla



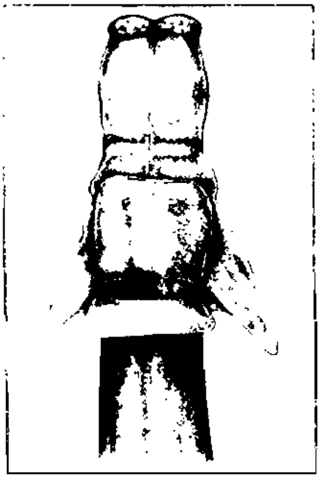
Training and pruning of vanilla

Hand pollination technique in Vanilla.

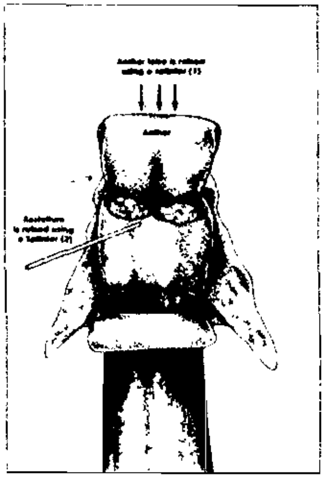


Column showing Anther lobe and Rostellum (front view)

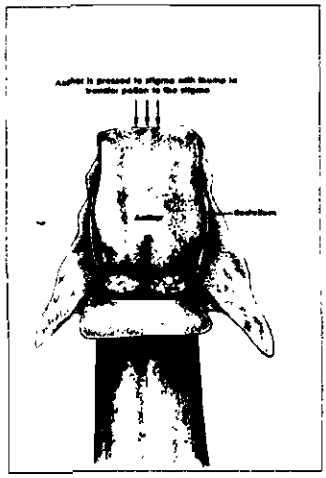
Column showing Anther lobe and Rostellum (side view)



Column with Anther lobe and ostellum raised to show stigma

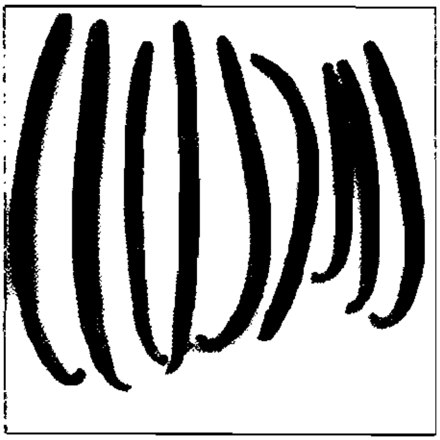


Pollination stage I



Pollination stage II

Fungal diseases of Vanilla



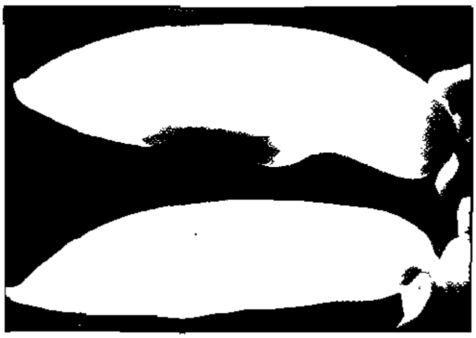
Bean rot induced by Phytophthora

Sclerotium induced rot on leaves

Premature yellowing
and bean shedding

Stem rot induced
by Fusarium

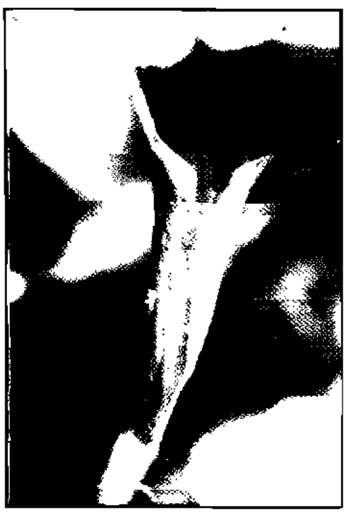
Viral diseases of Vanilla



Infected leave showing
mosaic symptoms

Necrosis affected plant
showing necrosis of stem

Pests of Vanilla

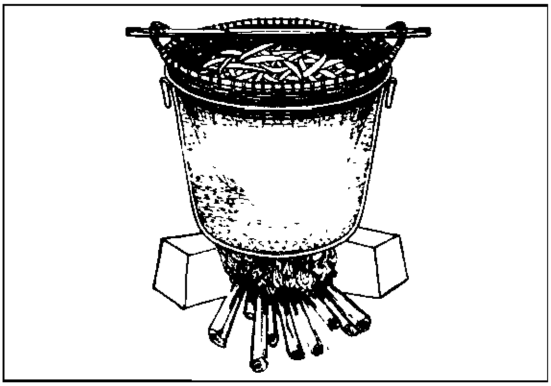


Shoot tip rot
caused by bug, Halyomorpha picus

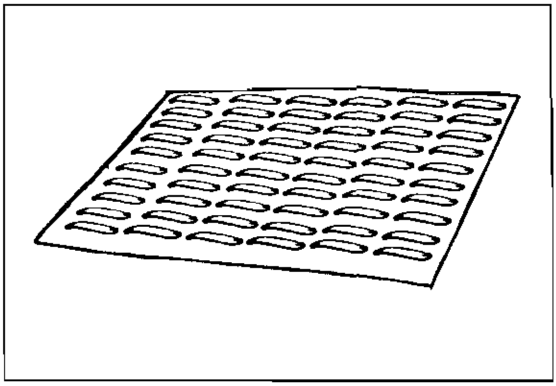
Shoot tip necrosis and not
caused by weevil, Sipalus sp

Vanila scab due
mechanical injury

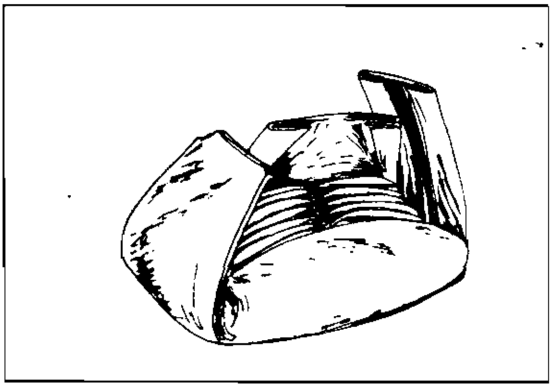
Viral diseases of Vanilla



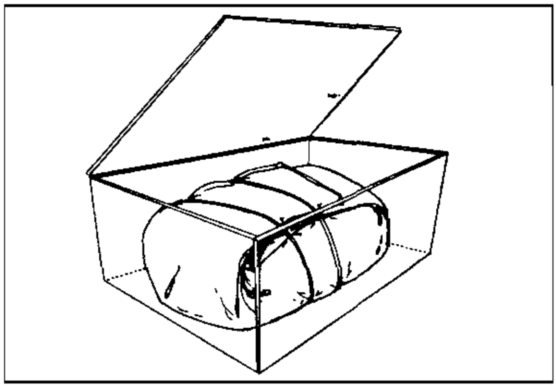
Killing the beans in hot water (65°C)
for three minutes



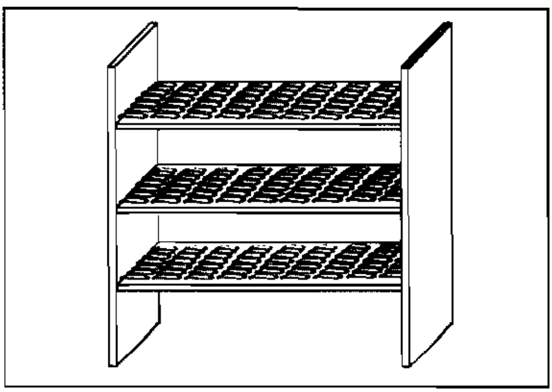
Drying of beans on black cloth



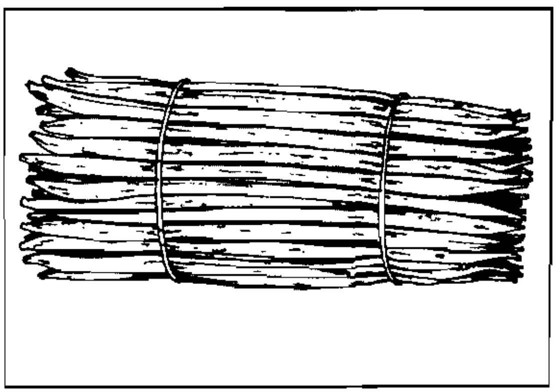
Wrapping in the cloth by
folding from sides after two hours of drying



The beans wrapped in the
blanket in sweating box



Slow drying on racks



Bundle of processed beans

CHILLI AND PAPRIKA

K.N. Shiva, D. Prasath, T. John Zachariah, V. A. Parthasarathy

1.0. INTRODUCTION

Capsicum or chilli (*Capsicum annuum* L.), including paprika, is a native of new world tropics and sub tropics. The word *Capsicum* is possibly derived from the Greek word 'Kapso' meaning 'to bite' referring to its pungency. The genus *Capsicum* belongs to family Solanaceae, having five major cultivated species *viz*., *Capsicum annuum, C. baccatum*, *C. chinense*, *C. frutescens* and *C. pubescens*. Most of the commercially cultivated chilli cultivars as well as paprika belong to the species *C. annuum*. 'Paprika' means plants of the genus *Capsicum*, in the Hungarian language.

Both chilli and paprika are largely consumed as vegetable and spice all over the world. The majority of cultivars grown in Asian countries are pungent, while less and non-pungent are more common in European countries. Three major products traded in the world market for use in food processing are: paprika, oleoresin and dried chilli (both in whole and in powdered form). They are widely used in curry powder, paste, pickles, sauces and ketchups for being its characteristics pungency, colour and aroma. The countries mainly producing this crop are Egypt, Ghana, Nigeria, Tunisia, India, Mexico, USA, Argentina, Indonesia, Korea, Pakistan, Srilanka, Turkey, Bulgaria, Hungary, Italy, Romania and Spain.

The cultivated *Capsicum* belonging to America, are known from prehistoric remains in Peru and Bolivian regions of America. It was introduced to India and Southeastern Asia in the 17th century by the Portuguese.

'Paprika', the term used by the International Spice traders for non-pungent (sweet) red *Capsicum* powder, is used primarily for its colour and flavour in processed foods. Paprika is one of the most widely used spices worldwide. In Spanish cuisine, paprika is valued for its flavouring and colouring attributes. Even though different kinds of paprika are cultivated world wide, genuine sweet paprika is mostly cultivated in Spain, particularly in the provinces of Caceres, Murcia and Alicante, where most of its related industries are located. Apart from Spain, paprika is produced in Morocco, Southwestern states of the USA, Mexico, Chile, India, Israel, Hungary, China and South Africa. In the United States, paprika is made from the New Mexican type chilli, whereas in Europe, paprika is made from two principal fruit types (i) a round fruit about the size of a peach called as Spanish or Moroccan paprika and (ii) a longer one, more conical and pointed type grown in the Balkan countries called 'Hungarian paprika'. This may be pungent or non-pungent depending on the cultivar.

1.1. Area and production

India is the largest producer of chillies in the world. Among the various spices produced in India, per capita consumption is the highest for chillies. Contribution of chillies in world pool of vegetables is nearly 3%. According to FAO estimate, the percent change in area and production of chilli at world level is increasing with 5.5 and 15.7, respectively. The world chilli production over the past five years has increased not only due to increase in cultivated area, but also due to the increase in productivity from 13.2 mt/ha in 2000 to 14.5 mt/ha in 2004.

Chilli is cultivated in almost all the States and Union Territories of the country. During 2003-04, it was grown in an area of 7.69 lakh hectares with an annual production of 12.39 lakh tonnes and recording the highest productivity of 1611 kg/ha. Trends in area, production and productivity (1990-91 to 2001-02) reveal that area exhibited a fluctuation recording a maximum area of 9.77 lakh hectares during 1999-2000. However, production showed more or less increasing trend with maximum production of 11.13 lakh tonnes during 2001-02. However, productivity remained more or less static (about 1 t/ha) up to 1995-96 and an increasing trend thereafter (Table 1). Though India leads in area, the productivity remains low (1t/ha), as compared to 3-4 tonnes in other countries (USA, South Korea and Taiwan).

Table 1. Area and production of chillies in India (1990-91 to 2002-03)

Year	Area ('000 ha)	Production ('000 mt)	Productivity (kg/ha)
1990-91	816.20	719.00	881
1991-92	846.30	617.50	730
1992-93	962.10	862.10	896
1993-94	930.00	800.10	860
1994-95	829.20	794.70	958
1995-96	883.70	809.70	916
1996-97	944.20	1066.00	1129
1997-98	840.60	870.10	1035
1998-99	891.20	1043.20	1171
1999-2000	977.53	1056.00	1080
2000-01	884.04	1046.22	1183
2001-02	881.29	1113.09	1263
2002-03 (Provisional)	831.63	846.16	1017

Source: Spices Board, Cochin (2004)

The major chilli growing states in India are Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu, which together contribute about 75% of the total area. Andhra Pradesh ranks first in dry chilli production, followed by Tamil Nadu, Maharashtra, Orissa and Karnataka. Even though, chilli is grown in all over India, Andhra Pradesh tops the list in area (224830 ha) and production (591410 t), followed by Karnataka (197160 ha and 167030 t) and Maharashtra (106800 ha and 58700 t). The other states leading in area and production are Tamil Nadu, Orissa, West Bengal, Madhya Pradesh and Rajasthan. With respect to productivity, Andhra Pradesh (2630 kg/ha) ranks first (table 2).

In each major chilli growing state, some districts are contributing significantly for the production, which are given in table 3.

1.2. Composition and uses

1.2.1. Chemical composition

As with most plants, chilli/paprika contain thousands of chemicals including water, fixed (fatty) oils, steam-volatile oil, carotenoids, capsaicinoids, resin, protein, fibre and mineral elements. The numerous chemicals have importance for nutritional value, taste, colour and aroma. The two most important groups of chemicals found in chillies

Table 2. State-wise area, production and productivity of chillies in India (2001-2002)

State	Area ('000 ha)	Production ('000 mt)	Productivity (kg/ha)
Andhra Pradesh	224.83	591.41	2630
Andaman & Nicobar	0.25	0.40	1600
Arunachal Pradesh	1.53	2.13	1392
Assam	14.73	9.65	655
Bihar	3.56	3.55	997
Chattisgarh	6.45*	1.54*	239*
Gujarat	13.60	12.10	890
Jammu & Kashmir	0.93	0.93	1000
Karnataka	197.16	167.03	847
Kerala	0.69	0.69	1000
Madhya Pradesh	39.69	22.15	558
Maharashtra	106.80	58.70	550
Manipur	7.45	4.47	600
Meghalaya	1.83	1.16	634
Mizoram	1.53	2.06	1346
Orissa	70.03	59.18	845
Punjab	8.90	14.13	1588
Rajasthan	32.42	48.74	1503
Tamil Nadu	72.86	41.52	570
Uttar Pradesh	19.09	14.50	759
Uttaranchal	2.41	4.06	1685
West Bengal	61.00	54.53	894
Total	881.29	1113.09	1263

* (2002-03) Provisional

Source: Spices Board, Cochin (2004).

are carotenoids and the capsaicinoids. The carotenoids contribute to chilli colour and its nutritional value. The capsaicinoids are the alkaloids that give hot Chilli their characteristic pungency. The proximate chemical composition of chillies and paprika is given in table 4.

Water: Water is the major constituent in chilli/paprika. In pepper fruits, the amount of water is dependent on the age and type of pod harvested. Green mature pods contain the larger amount, about 90%, while spice varieties, allowed to dry on the plant may contain about 70%. Dehydrated product prepared for storage or shipping will contain to 15-20% water. The rapid lose of water after harvest is a major quality problem when shipping fresh chilli pods. New Mexican-type Chilli loses water twice as fast as bell or *jalapeno* types.

Table 3. Major chilli producing states and its districts in India

State	Major chilli producing Districts
Andhra Pradesh	Guntur, Warangal, Khammam, Krishna, Hyderabad, Pundur, Nizamabad, Cuddapah, Rajamundry and Nellore
Karnataka	Dharwad, Haveri, Belgaum, Shimoga, Bellary, Chitradurga, Hubli, Gadag, Mysore, Hassan and Bangalore
Tamil Nadu	Perambalur, Ramanathapuram, Virudhunagar, Sivagangai, Thirunelveli and Thoothukudi
Maharashtra	Nasik, Ahmednagar, Sholapur, Aurangabad, Nanded, Amravati and Lasalgaon
Uttar Pradesh	Bareily and Khurja
Punjab	Amritsar, Nabha and Patiala
Haryana	Sunam and Samma
Jammu & Kashmir	Srinagar, Budgam, Baramulla and Pulwama

Table 4. Proximate chemical composition of paprika & chillies

Composition	Hungarian paprika (%) Dry	Indian chillies (%) Dry
Moisture	7.0 – 9.5	10.0
Carbohydrate	58 – 60	31.6
Protein	13.8-17.5	15.9
Crude fibre	14-20	30.2
Ash, total	5.6-7.6	6.1
Ascorbic acid (mg/100g)	48.6-58.8	50.0

Carbohydrates: Chilli fruits contain sugar, pentosans and raw fibre. Glucose accounts for 90-98% of the sugar content of red mature paprika pods. The amount of sugar in pods varies by cultivar and pod type. Some add an appreciable 'sweetness' to the fruits, while other types completely lack the sensation of sweetness. Total and reducing sugars are at maximum levels in red succulent fruits.

Cellulose and other fibrous material may account for up to 20% of the dry weight of pericarp tissue. The skins contain 77% soluble fibre and 80% total dietary fibre. This amount of fibre is greater than in either rice or oats.

Lipids: Chilli contains lipids that are qualitatively similar to lipids found in plants in general. The total lipid content of fresh, green, bell chilli pods are 400 mg /100 g (wet wt), a relatively low level. When the lipids were examined for composition, they were found to contain 82% neutral lipids (fats), 2 % phospholipids and 16% glycolipids. The triglycerides make up 60% of the total lipids with palmitic acid, linoleic acid and linolenic acid being the major fatty acids. The phospholipids were 76% phosphatidylcholine. The linoleic acid account for 70% of the fatty acid composition.

In addition, the amount of unsaturated fatty acids in the mitochondria relates to the sensitivity of a species to chilling injury. Plants with higher amounts of unsaturated fatty acids are more resistant to chilling temperatures than those with more saturated fatty acids. Chilli is sensitive to chilling temperatures and the ratios of unsaturated/saturated fatty acids are those expected for a chilling-sensitive species.

Amino Acids, Proteins, Microelements: Several studies list lysine, arginine, proline, tyrosine, tryptophan, methionine, valine, phenylalanine, leucine, glutamic acid, glycine, asparagine, threonine, and alanine as major amino acids being found in chilli fruits. Studies show that the pericarp has 16-17% protein and the seeds contain 18% protein. When the micro elements were investigated, it was found that iron was present in the largest concentration, followed by bromide and manganese. Other microelements found were cadmium, calcium, cobalt, copper, magnesium, phosphorus, potassium, sodium and zinc.

Vitamins: Chilli is good sources of several vitamins. They produce high concentrations of vitamin C, provitamin A, E, P (citrin), thiamine (B_1), riboflavin (B_2), and niacin (B_3). A wide range of vitamin levels have been reported and this phenomenon has been attributed to differences in cultivars, maturity, growing practices, climates, post harvest handling and analytical methods. The content of thiamine, riboflavin and niacin vary depending upon pod type examined. Thiamine amounts range from 0.60 to 0.40 mg $100g^{-1}$. Riboflavin had a range from 0.93 to $1.66100g^{-1}$, and niacin amounts were 13.6-15.4 mg $100g^{-1}$. Chillies are rich sources of vitamin E with the tocopherols being the source of vitamin E. Red, dry chilli powder has a-tocopherol levels comparable with those of spinach and asparagus, and on a dry weight basis has four times more than tomatoes.

Carotenoids: The diverse and brilliant colours of chilli fruit originate from the carotenoid pigments present in the thylakoid membranes of the chromoplasts. In plants, carotenoids are synthesized in both the chloroplasts of photosynthetic tissues and the chromoplasts of flowers, fruit and roots. Chemically, carotenoids are lipid-soluble, symmetrical hydrocarbons with a series of conjugated double bonds. The double bond structure is responsible for the absorption of visible light. Carotenoids function as accessory pigments for photosynthesis, but more importantly, as photoprotectants in the plant. The primary function of b-carotene and other carotenoids is to protect the chloroplasts from photooxidative damage. However, carotenoids are unstable when exposed to light, oxygen or high temperatures. The carotenoids in the fruit are important for attracting seed dispersers (birds).

The green, yellow, orange and red colours originate from the carotenoid pigments produced in the fruit during ripening. More than 30 different pigments have been identified in chilli/paprika fruits. These pigments include the green chlorophylls (a and b); the yellow-orange lutein, zeaxanthin, violaxanthin, antheraxanthin, p-cryptoxanthin and p-carotene; and the red pigments, capsanthin, capsorubin and cryptocapsin, which are found only in chilli fruits. The red colour in chilli comes from the carotenoids capsanthin and capsorubin, while the yellow-orange colour is from p-carotene and violaxanthin. Capsanthin, the major carotenoid in ripe fruits, contributes up to 60% of the total carotenoids. Capsanthin and capsorubin increase proportionally with advanced stages of ripeness, with capsanthin being the more stable of the two. The amount of carotenoids in fruit tissue depends on factors such as cultivar, maturity stage and growing conditions.

In chillies, 95% of the total provitamin-A in green pods and 93% in mature red pods is â-carotene. When red mature pods were measured, the cultivars with the highest and the lowest provitamin A activity were both yellow wax pod types.

Anti-oxidative properties: *Capsicum* has a strong anti-oxidative property, and the binding of free radicals may be the mechanism. Several mechanisms for the possible protective action of â-carotene have been suggested. More than 20 carotenoids have been isolated from chillies. Recent evidence for antitumour activity of carotenoids in humans has renewed interest in foods containing these compounds, especially because diet supplements do not provide the same nutritional and medicinal benefits as fresh fruits and vegetables. The mode of action for the carotenoids appears to be that they are radical scavengers, effectively binding the singlet or excited oxygen and the free radicals, which may cause damage in humans under physiological conditions of oxygen tension, a characteristic not shared by retinol.

1.2.2. Uses

Chilli: Chilli is the most popular and widely consumed condiment all over the world. Fruits are consumed in fresh, dried or processed form as table vegetable or spice. Fruits are extensively pickled in salt and vinegar. Colour and flavour extracts are used in both the food and feed industries, as well as for some pharmaceutical products. The fruits of the genus *Capsicum* have as many diverse uses as its versatility. Some of the innovative uses of chilli are summarized below:

Fresh uses: Immature –green, mature-red fruits and leaves are used in South Asian vegetable curries, Chinese cuisines, salad in Europe and America, leaves in Philippines.

Fresh processing: Sauce, paste, pickles, beer.

Dried spice: Mature whole fruits and powder.

Colouring and flavouring agents: Oleoresins (carotenoids) extracts or powder (meat/ food industries, cosmetic industries, poultry feed).

Ethno- botanical/ traditional medicine: Fruit extracts and powder (consumed to stimulate digestion, improves the complexion and increase passion, to relieve toothaches, to relieve hangover).

Modern medicine/ pharmaceuticals: Capsaicinoids and carotenoids as liniments used for sore muscles, arthritis, improve the cytotoxic action of anticancer chemotherapy.

Insecticide/ repellent: Capsaicinoids (effective repellent against mice damaging the underground cables).

Spiritual: Whole fruits (belief that it will keep evil away, as a symbol of hospitality).

Ornamental: Whole plants or fruits.

Defense: Capsaicin extracts/ fruit powder.

Paprika: Paprika oleoresins are used in colouring and seasoning poultry products, snack foods, fats and oils, pasts and the remaining in all other food categories such as baked food, cheese, condiments, fish and fish products, gravies, juices, meat with gravy, nuts and toppings/ creams/soups.

In comparison to above, ground paprika is used in confectionary, meat and meat products, snack foods, processed foods and vegetables, fish products and the remaining in other like bakery, beverages, cereals, dairy, fats and oils.

Advantages of using oleoresin are:

i) Hygienic, avoid bacteria and moulds.

ii) Spice flavour-with no bacteria is particularly crucial for the producers of canned and preserved foods.

iii) The producers of finished products can maintain the same standards by use of specific oleoresins which otherwise is not possible by using ground spice.

2.0. BOTANY AND CROP IMPROVEMENT

2.1. Botany

Capsicum annuum (2n=2x=24) is a highly branched herbaceous plant with height varying from 50 to 100 cm. Leaves are simple, alternate, exstipulate, elliptic, lanceolate, glabrous with unequal margin. Root system is highly branched with a taproot at the center and is restricted to upper soil layer of 30 cm depth. The flowers of *Capsicum* species are solitary, extra axillary and sometimes occurs in pairs. Flower is ebracteate, actinomorphic, pedicellate, bisexual and hypogynous. Sepals are five and gamosepalous. Corolla is bell shaped, rotate 5 to 6 lobed. The stamens are 5 and alternate with petals, anthers dehisce longitudinally by lateral sutures. Ovary is superior, 2 or 4 celled. Style is slender, terminal, and linear. Majority of the flowers open at 5 am and the stigma receptivity vary from a day earlier to anthesis and continues to 2 days after anthesis. The pollen grains are fertile a day before anthesis with maximum fertility on the day of anthesis. The extent of natural crossing in peppers has been reported to vary from 7.6 to 36.8 per cent in the field. Fruit attains full maturity around 35 days after anthesis and then fruit colour turns green to red or purple depend on variety. The fruit is a berry and it varies in size (1 to 30 cm in length) and shape (thin long to conical) and includes pungent and non-pungent types. The major fruit components are seeds, pericarp, placenta and pedicel. Pericarp contains almost all the pungency whereas seeds contain only traces of pungency. Chilli seeds are compressed orbicular and minutely pitted. Viability of seeds commences 35 days after anthesis and increases up to 50 days after anthesis.

2.1.1. Horticultural classification of varieties

Older classification grouped *Capsicum annuum* L. into four groups depending upon the shape of the fruits as below :

Capsicum annuum L var *accuminatum*	Bright red colour, slender, thin walled
Capsicum annuum L var *grossum*	Non pungent, round or bell shaped
Capsicum annuum L var *cerasiforme*	Very small, round, highly pungent
Capsicum annuum L var *longum*	Thin long and stout with broad base

The modified classification is based on grouping of cultivars that are horticulturally similar in major characteristics such as fruit shape, size, colour, texture, flavour and pungency. The classification has following 7 groups:

I. Fruit large, smooth, thick fleshed

Bell group

Pimento group

II. Fruit broad, smooth, thin walled

Ancho group

III. Pods long, slender

Anaheim chilli group (long chilli)

Cayenne group

Cuban group

IV. Fruit elongated to 7.5 cm long, green when immature

Jalapeno group

Serrano group

Small hot group

V. Fruit small (to 5 cm) globular to oblate, thick flesh

Cherry group

VI. Fruit yellow when immature

Short wax group

Long wax group

VII. Fruit slender, yellow, turning red at maturity (belongs to *Capsicum frutescens*)

Tobasco group

2.2. Varieties/hybrids/landraces

2.2.1. *Chilli types/landraces*

There are several chilli types/cultivars, which traditionally grown in chilli growing areas; Bird's eye chilli (Dhani) (Assam, Mizoram and some areas of Manipur), Byadagi dabbi / kaddi (Dharwad, Karnataka), Ellachipur Sannam - S4 type (Maharashtra), Guntur Sannam – S4 type (Guntur, Warangal, Khammam Districts of Andhra Pradesh), Hindpur-S7 (Hindpur in Andhra Pradesh), S7 (Hindpur in Andhra Pradesh), Jwala (Kheda, Mehsana in South Gujarat), Kanthari white (Kerala and some parts of Tamil Nadu), Kashmir chilli (Temperate region such as Himachal Pradesh, Jammu & Kashmir and in subtropical regions of North India), Madhya Pradesh – G.T. Sannam (Indore, Malkapur chikli and Elachpur areas of Madhya Pradesh), Madras Pari (Nellore District of Andhra Pradesh), Nagpur and Nalchetti (Nagpur District of Maharashtra), Ramanad Munda (Ramanad and Virudhunagar District of Tamil Nadu), Sangli Sannam – S4 type (Kolhapur District of Maharashtra), Sattur-S4 (Dindigal, Sattur, Rajapalayam Sankarankoil and Theni areas of Tamil Nadu), S9 Munda (Ananthapur District of Andhra Pradesh), Tadapally Biglong (Tadapally in Andhra Pradesh), Tomato chilli or Warangal Chappatta (Warangal, Khammaam, East and west Godavari Districts of Andhra Pradesh). Some popular types/cultivars of chilli are given in Table 5.

Table 5. Commercially known chillies that cultivated in different states of India

State	Commercial / local name
Punjab	Serhindi, Sanauri Red, Sanuari yellow, Patna Red, Rajpura long red, Jullundur, Shokati, Longi
Andhra Pradesh	Mundu, Sadasivpet, Shivai, Nallapadu, Warangal, Lanka chilli, Seema Mirapa
Maharashtra	Dondicha, Achalpur, Malkapuri
Tamil Nadu	Salem, Ramanad, Samba Kodakal, Sattur samba Elichup, NP 34
Karnataka	Javari, Javageal, Coilbel danur, Gouridnur, Byadgi type, Sankeshwar type, Chincholi, Kollegal type, Arsikere, Madhugiri
Bihar	Rahuri, sity patna red, Sobour
Gujarat	Gholar, Patta
Assam	Suryamukhi, Latabh, Tiger
Uttar Pradesh	Kalianpur
Kerala	Kandhari

Source: Johny and Ravindran (2004)

2.2.2. Chilli varieties/hybrids

In India, so far 16 open pollinated improved populations and 5 hybrids have been identified and released in chillies for cultivation under specific agro-climatic zones. These improved varieties and hybrids are cultivated for the specific market types with few exceptions, wherein a variety/hybrid may be grown for both green fruits and/or red-ripe dry fruits.

In India, many varieties and hybrids have been released by ICAR institutes and State Agricultural Universities for cultivation to various agro-climatic regions (tables 6 and 7).

Besides these hybrids, many private seed companies including Multi National Companies and Indian firms have developed and introduced a number of hybrids in India, which are also getting popular among growers (Table 8).

Among the hybrids, BSS-188, BSS-141 and HOE-818 at Varanasi, HOE-888, MHP-59 and ARCH-236 at Bangalore, Kiran at Coimbatore, and Kiran, Tejaswini are promising hybrids at various locations.

In recent years, the occurrence of leaf curl disease caused by white fly transmitted (WFT), Pepper Leaf Curl Virus (PepLCV) and infestations of thrips and mites have been threatening chilli cultivation throughout India. In certain major chilli growing states of India, the severe impact of leaf curl disease coupled with infestations of thrips and mite forces the growers to withdraw their chilli cultivation. Several reports on the identification of tolerant genotypes against PepLCV based on germplasm screening under open filed conditions are available, especially from India like Pusa Jwala and Pant C-1. However, these field tolerant lines are often show susceptible reactions. The dry fruit production of chilli is severely damaged by frequent occurrence of anthracnose. So far no real resistant variety against these biotic stresses has been developed, although resistant sources of some of these biotic stresses are known (table 9).

Table 6. Improved varieties of chillies and their important characters

S. No	Variety	Source	Yield potential (kg/ha) Green	Dry	Important characteristics
1	Pusa Jwala	Indian Agriculture Research Institute, New Delhi	7500	610	Plants dwarf, tolerant to thrips, mites and aphids
2	Pusa Sadabahar	"		2000	Plants tall, fruits erect in clusters, resistant to CMV, TMV and leaf curl, has perennial tendency
3	K 1	TNAU, Agriculture Experiment Station, Kovilpatti, Tamil Nadu		1700	210 days duration, suitable for rainfed cultivation in Southern districts of Tamil Nadu, high pungent type
4	K2	"		1800	Tolerant to thrips, 210 days duration
5	Co.1	TNAU, Horticultural College and Research Institute, Coimbatore, Tamil Nadu		2100	Fruits bright red in colour, 210 days duration, high pungent type
6	Co. 2	"	11000	2200	200-210 days duration and suitable for both green and dry chillies
7	Co. 3	"		3000-3500	165 days duration, dual purpose chilli, high oleoresin content, suitable for high density planting
8	Co. 4	"	23000	-	Dwarf plants, Suitable for vegetable purpose, 165 days duration
9	PKM 1	TNAU, Horticultural College and Research Institute, Periyakulam, Tamil Nadu		2300	Dwarf plants, suitable for irrigated conditions, 180 days duration
10	MDU 1	TNAU, Agricultural College and Research Institute, Madurai		1900	Plants dwarf and suitable for high density planting, 205-215 days duration, cluster bearing
11	PLR 1	TNAU, Vegetable Research Station, Palur, Tamil Nadu		1800	'gundu' type , suitable for green chilli, 210 days duration
12	PMK 1	TNAU, Agricultural Research Station, Paramakudi, Tamil Nadu		2300	'gundu' type , suitable for rainfed cultivation, 200 days duration
13	G3	ANGRAU, RARS, Lam Guntur, Andhra Pradesh		3000	Suitable for rainfed and irrigated conditions
14	G4 (Bhagyalakshmi)	"		1100 (rainfed) 4000 (irrigated)	Fairly tolerant to pest and disease, wider adaptability
15	G5 Andhra Jyothi	"		5000 (irrigated)	Plants tall, tolerant to thrips, wider adaptability
16	Sindhur	"		5000 (irrigated)	Dual purpose chilli variety, plants tall, suitable for summer cultivation

17	Aparna	"		3500	Highly pungent, moderately tolerant to major pests and diseases under field conditions
18	Bhaskar	"		5000 6000	Early maturing, highly pungent, tolerant to thrips and mites, suitable for pickles
19	Jwalasakhi	KAU, Vellanikkara, Trichur	20000	-	Dwarf plants, less pungent, suitable for Southern districts of Kerala
20	Jwalamukhi	"	22500	-	Pods dark green, less pungent, suitable for Southern districts of Kerala
21	Ujwala	"	22170	-	Resistant to bacterial wilt, mosaic and leaf roll
22	*Anugraha*	"	27000	-	*Early in flowering, resistant to bacterial blight*
23	Phule Jyoti	MPKV, Rahuri, Maharashtra	-	3000	Dual purpose chilli, tolerant to leaf curl and powdery mildew disease, resistant to lodging, suitable for both *Kharif* and summer
24	Phule Suryamukhi	"		2800	Tolerant to leaf curl and powdery mildew disease, suitable for both *Kharif* and summer
25	Punjab Lal	PAU, Ludhiana, Punjab		1200	Resistant to TMV, CMV, leaf curl viruses, moderately tolerant to fruit rot and dieback
26	Pant C-1	GBPUAT, Pant Nagar, Uttaranchal		1200	Highly pungent. Tolerant to mosaic and leaf curl virus
27	Pant C-2	"		1400	Tolerant to mosaic and leaf curl virus
28	NP 46A	IARI, Pusa, New Delhi	7500	-	Tolerant to thrips but susceptible to viral diseases

2.2.3. Paprika and paprika like chillies

Spice paprika is only a recent introduction to our country. In India, there is no spice paprika variety grown commercially. Hence spice paprika work was taken up at Indian Agricultural Research Institute - Regional Station, Katrain, Himachal Pradesh, which ultimately developed a variety 'Kt-Pl-19' with high color value and oleoresin content of international standards. Later research was taken up at other institutes.

Kt-Pl-19: The plants are upright with profuse branching. Fruits are pendent bearing two-celled dark green when immature, turns to dark red on maturity. Fruits are long, conical, mostly tapering to slightly curve with pointed tips. On an average, it produces about 60 fruits with a yield of 25 – 35 tonnes/ha and colour value of 233 ASTA units. It yields 4.0-4.8 tonnes of dry fruit with 60-66% skin recovery and around 2.77 tonnes dry basic product for processing into ground paprika or oleoresin. A seed yield of 0.7-0.8 t/ha can be realized, which will be an additional income.

There is immense potential for export of paprika. The varieties *viz.*, Byadagi kaddi, Byadagi dubba and variants of these grown in Dharwad, Gadag and Haveri Districts of Karnataka have got the highest colour values of 200000-250000 CU. and are red in color and negligible in capsaicin. The pesticide usage is very low being a rain fed crop. Hence, the produce from these areas is the most preferred, even though the yield is very low (200-300 kg/acre). In Bellary, Raichur and Gulburga Districts of Karnataka, variant of Byadagi kaddi or Byadag dubba locally known, as 'Thumps up' is cultivated, which gives medium color (1,25,000-

Table 7. Hybrids developed in chillies for cultivation in India

Hybrid	Source	Yield (dry, kg/ha)	Important characteristics
CH - 1	Punjab Agricultural University Ludhiana	2500	Less incidence of fruit borer and sun scald, Longer fruit span due to its tolerance to diseases and viruses. High pungency (0.83 %) and red color (88.75 ASTA units)
CH - 3	"	2750	Tolerant to fruit rot, wet rot, die back, wilt, mosaic and leaf curl. High colour (145 ASTA units), low pungency (0.52 %) type.
CH-9646	ARS (chilli), Devihosur, Haveri, UAS, Dharwad, Karnataka	2500	Fruits medium long (10.11 cm), thick walled, pendulous and medium pungent. Tolerant to leaf curl complex. Dual purpose hybrid, can be grown during Kharif and summer season

Table 8. Hybrids developed in chillies by private sectors

Company	Hybrids
Ankur Seeds	ARCH 006, ARCH 236, ARCH 226, ARCH 112
Hoechest	HOE 888, HOE 808, HOE 818
Novartis	SHPH-54, SHPH-35, SHPH-47, Picador
Namdhari	NS 101, NS 1420, NS 1101
Nath	NATH 70, NATH 120
Sungrow	Sungrow No.16, Sungrow 86235
Bejo Seethal	BSS 138, BSS 141, BSS 273
Korean Hybrid Co.	Kiran, Surya.
Indo American	No. 5
Pro-Agro	PROH 01, PROH 02, PROH 03, NPCH 004, NPCH 005, NPCH 006
Century	Hybrid 3, Hybrid 4
Seminis	Guntur, Hope Picabello
Mahyco	MHP 5, MHP 58, MHP 59, MHP 1 (Tejaswini), MHP 62, MHP 63, MHP 155, MHP 157, MHP 159 (Tejaswini.2)
Zuagri Agro	ZCH-2
Nagarjuna	NARDI –712
Sandoz	Agni, SHPH - 35, SHPH - 47

Source: Johny and Ravindran (2004)

1,60,000 CU.) and medium yield level (1500-1800 kg/acre). The pungency is negligible, but the use of pesticide is very high, being irrigated crop. The variety grown in Warangal District of Andhra Pradesh is known as 'tomato chilli' which is sometimes used for color extraction. It gives high color value (1,75,000-2,00,000 CU.). Its fruits are ob-

Table 9. Resistant/tolerant sources against pest and diseases in chilli

Pest / Disease/ Nematode	Resistant/tolerant source
Leaf curl virus / Mosaic virus	Phule Jyothi, Phule, Suryamukhi, Pusa Jwala, Pusa Sadabahar, PantC-1, Pant-C-2, Punjab Lal, Jawahar-218, HC -1, HC- 15, HC - 22, HC - 28, HC – 44, NP46 A, Musalwadi
Mosaic, wilt & dieback	Punjab Surkh, LCA – 235, LCA - 305
Leaf curl complex	KDC-1, GPC-82, GPC 69, GPC 80, Jwala, LCA – 235
Virus complex	LCA – 235
TMV	Kranti, Krishna (Hybrids)
Bacterial wilt	Ujwala, Anugraha, Manjari, BC-21-2 (Utkal Rashmi), AAUM-1 & AAUM-2
Bacterial leaf spot	G-5
Die back /Anthracnose	Musalwadi, Pusa Sadabahar, Vardan (Hybrid), HC – 28, HC – 44, Achar
Powdery mildew	Musalwadi, Phule Jyothi, Phule Suryamukhi, Arka Lohit, HC -28
Fruit rot	Jawahar-218, PBC 36, HC – 28, HC -44, K-2
Thrips, mites	Andhra Jyothi, Bhaskar
Thrips	K-2, Chamatkar,Guchedar
Root knot nematode	K 2, G-2
Mites	LCA - 235, LCA - 230, LIC - 13, LIC - 45, Yellow anther mutant
Multiple resistance	Punjab Lal, Lorai, LS - 111,CH - 1

long shaped and glossy with less seeds. It is highly red coloured with very low pungency. The pesticides used are very low and the yield also very low. However, this variety is not homogeneous; prone to powdery mildew, fruit rot & viruses; susceptible to sucking pests and the adoption is region and season specific. Moreover, the released variety 'Kt-pl-19 from India and introduced varieties like Bola and Negral have failed to have wider adaptability.

Arka Abhir: A pure line selection from Dyavanur dubba (a local variety grown in Kundgol taluk, Dharwad District) has been released from IIHR, Bangalore, Karnataka, which gives a yield of 2.0 tonnes of dry chilli per hectare. Fruits are light green, wrinkled turning to deep red on maturity. It has high colour value (1,65,541 cu) and low pungency (0.05% capsaicin). It is suitable for oleoresin extraction, oleoresin yield (5.78%) and is without seed.

KDC –1: A cultivar cross between Byadagi and *C. frutescens* was released from UAS, Dharwad, Karnataka, which is tolerant to leaf curl virus. It bears semi-wrinkled red

Table 10. Varieties of paprika like chilies

Paprika like chilli	Location	Color value (ASTA units)	Capsaicin (%)
Tomato Chilli (Warangal Chappatta)	Warangal, Khammam, East and West Godavari Districts of Andhra Pradesh	125.26	0.17
Byadagi chilli	Dharwad, Haveri, Gadag and Hubli Districts of Karnataka	156.90	Negligible

fruits with more capsaicin than Byadagi type with high color and low pungency. It is suitable for intercropping with cotton and for cultivation in black cotton soil.

3.0. SOIL AND CLIMATE

3.1. Soil

Well-drained, well-aerated loamy soil rich in organic matter with pH range of 6.5-7.5 is highly suitable for chilli and paprika cultivation. The crop is widely cultivated in black cotton soils (rainfed) and red sandy soils (irrigated) and to a certain extent in coastal alluvial soils. Though chilli comes up well in black cotton soil, sandy loam is best suitable for its growth and yield, if provided with adequate irrigation and manure. Light loamy or sandy loam soils rich in organic matter are ideal for chilli crop. It is suitable from the Himalayan range in the north to coastal sandy soils of Kerala, Tamil Nadu and Karnataka. Crop is highly sensitive to water logging and thus drainage is important. The crop is not very sensitive to soil acidity but saline and sodic soils are not suitable, as it hinders fruit development. In saline soils, the germination and early vigour of plants are affected. In India, most of the chilli growing area for dry chillies lies in deep black cotton soils (Vertisols) and medium deep soils (Vertic integrades) occurring in transitional belt of Dharwad (Karnataka), Nagpur, Nanded and Kolhapur (Maharastra), Guntur (Andhra Pradesh) and Coimbaotre (Tamil Nadu). It is grown in soils having pH from 5.0 in coastal areas to pH 9.0 in vertisols of the country.

3.2. Climate

The *Capsicum* (chilli and paprika) is a plant of tropical and sub-tropical regions requiring a warm humid climate. It is suitable to varying altitudes ranging from sea level (Coastal Karnataka, Kerala and Tamil Nadu) to 2000 m MSL (Himachal Pradesh). Crop can tolerate extremes of temperature but long frost and freezing temperature is not suitable. A soil temperature about 17°C favours normal development. Even though high temperature favours shoot growth, soil temperature above 30°C affects the root development. Fruit coloring is delayed considerably below 15°C. At high temperature, fruit drop and poor fruit set is a problem. Maximum temperature of 20-30°C and minimum temperature not below 10°C is optimum for growth and development. However, performance of paprika types is better under low temperature conditions. It thrives well in areas having a moderate rainfall within the range of 60 – 120 cm. Excessive rainfall associated with high humidity causes defoliation and root rot. It is mostly grown as rainfed crop both for green and dry chilli purpose in Dharwad belt of Karnataka and certain pockets of Andhra Pradesh and Tamil Nadu. Peppers are photoperiod-insensitive (day length does not affect flowering or fruit set).

4.0. NURSERY MANAGEMENT

4.1. Raising of seedlings

Chilli (and paprika) is grown from seeds, which are very light and remain viable for 2-3 years. Successful production of chilli depends on quality of seeds i.e., maximum germinability and vigour. Larger seeds have better growth, early emergence and higher germination. Maximum percentage of viable seeds may be achieved by harvesting the fruits in reddening stage. One kilogram of chilli seeds may contain 123-170 thousand seeds depending upon size and weight.

Time of sowing and transplanting depends upon temperature, rainfall and availability of irrigation facilities. Normally, chilli is raised by transplanting of seedlings but in some regions direct sowing is also practiced. The advantages of transplanting are better care for seedlings, better establishment and growth, optimum plant protection measures compared to direct seeding.

Treat the seeds with *Trichoderma viride* @ 4 g/kg or Thiram or Dithane M-45 @ 3 g/kg seed and sow thinly 5 cm apart in lines spaced at 10 cm in raised nursery beds and cover with sand. Mulching with paddy straw or dry grass helps to maintain optimum moisture and soil temperature required for better and uniform germination and the mulch material should be removed once germination is noticed. Under normal conditions, seeds germinate in 6 – 10 days. Regular light watering with rose can in morning and evening is advisable. Drench the nursery with Copper oxychloride at 15 days interval against damping off disease. Apply Carbofuran 3 G at 10 g/sq.m. at the time of sowing to control sucking pest and nematode infestations.

	Varieties	F_1 hybrids
For transplanting crop	0.5 - 1.0 kg/ha	100 - 250 g / ha
For direct sowing crop	6.25 kg/ha	

Well-drained, fertile and elevated areas in partial shade is preferred for raising nursery and the selected area is ploughed to a fine tilth and the stones and other debris are removed. Raised beds are preferred compared to flat beds. Raised beds of 90 – 100 cm width and of convenient length are prepared to which well-decomposed organic matter at the rate of 20-25 kg/bed is incorporated. The nursery beds should be surrounded by 30 cm width drainage channels. The nursery area required for planting one hectare is 100 m^2. Around 1,250 g of seeds would be required to raise the seedlings for one hectare.

The nursery area earmarked may be subjected to sterilization or fumigation to control pathogenic fungi and bacteria. Solarization is done by covering the area with plastic or polythene sheet and sealing the sides so that heat generated kills the pathogen or the dug up portion is treated with 0.5 lit of 40 % formalin/m^2 and immediately covered with plastic sheet for about 48 hours. After a gap of 5-6 days sowing can be undertaken.

Commercially available plastic trays filled with sterilized premixed media can be used to raise quality seedlings of paprika. The advantage includes uniformity in germination to transplant, height and growth, ease in management, strong and healthy root system, less risk with soil borne pathogens and ease in transporting to long distances. Trays with cell size of 1.5" X 1.5" are adequate. The trays may be arranged under shade net or green house for proper germination and growth. Fertilizer application is done through a mixture of calcium nitrate and potassium nitrate @ 2 g each / litre of water applied twice during 25^{th} and 35^{th} day and two applications of single super phosphate @ 10g /liter. Seeds take about 10 days to germinate depending upon the favourable temperature and moisture content in the soil.

4.2. Integrated pest management practices in nursery

- Provide proper drainage to nursery site
- Use solarized soil for raising nursery
- Apply neem cake 300 –350 g per 100 m^2 as basal dose before preparation of raised beds
- Use tolerant varieties
- Apply Cardendazim 3G @ 80 – 100 g or Phorate 10G @ 400 g / 100 m^2 at sowing
- Seed treatment with Carbendazim @ 2 g or thiram @ 3 g /kg of seed or *Trichoderma* @ 4-6 g /kg of seed
- Protect nursery with 100 mesh nylon net
- Spray methyl demeton 0.025% or acephate 0.05% on 2-3 week old seedlings

5.0. PLANTING AND AFTER CARE

Successful crop management is primarily based on the soil type, climate, variety/hybrid, availability of adequate nutrients in the soil, good quality seed materials free from seed borne diseases, cultural practices, etc. The cultivation of paprika is almost the same as that of chilli.

5.1. Land preparation and planting / transplanting

The land is ploughed 3-4 times to a fine tilth and farm yard manure is incorporated in the last ploughing. For irrigated crop, ridges and furrows are formed in South India, while bed system is adopted in North India.

5.1.1. Season

In South India it is cultivated throughout the year for green fruits under irrigated condition and during *Kharif* season (June – July) for ripe dry fruits. In West Coast of India, chillies are mostly cultivated during *Rabi* season (October – November). In North India, it is mostly grown during *Kharif* and summer since the crop does not withstand low temperature. Sowing and transplanting seasons of different Indian states are given in Table 11.

Soil type influences the time of planting under rainfed cultivation. In light soils, transplanting may be taken up in earlier part of monsoon than heavy soils, as the moisture retention is low in light soils.

The seedlings are subjected to hardening prior to transplanting so that it can withstand the transplant shock. This is done by reducing the frequency and quantity of watering during the last week in the nursery. Age of the seedlings for transplanting depends on variety, soil and weather conditions. Early maturing varieties need to be transplanted early compared to late varieties. Young seedlings establish better in cloudy days than in sunny days. Age of the seedling influences the growth and yield of the crop and while planting it should be in active growth stage and young. Generally, 40-45 day old seedlings, when they are about 15 cm height are preferable for transplanting. Optimum number of seedlings per hill is 2 –3 for varieties and 1-2 in case of hybrids .Later it is thinned to one per hill and gap filling is completed 30 days after sowing.

Starter solution consisting of urea, single super phosphate and muriate of potash

Table 11. Sowing and transplanting seasons for chilli/paprika in different states

Region/State	Direct sowing	Nursery sowing	Transplanting
Andhra Pradesh	June (*Kharif*) September (*Rabi*)	May – July	August – September
Karnataka	June – July (*Kharif*)	August	September
Tamil Nadu	-	January – February (*Rabi*) June – July (*Kharif*)	March – April (*Rabi*) September - October (*Kharif*)
Maharashtra	-	September – October (*Rabi*) June – July (*Kharif*)	November –December (*Rabi*) August – September (*Kharif*)
Punjab & Rajasthan	-	April – May	June – July
Jammu and Kashmir	-	March – April or January – February (*Rabi*)	May – June or July – August
Kerala	-	April – May (rainfed) August – September (irrigated)	June – July October – November
Gangetic valleys	-	June – July	August – September
North-eastern region / Hill areas	-	March – April	May – June
Paprika types	-	August (Autumn winter crop) November (Spring summer crop)	September – October December - January

(2:1:1) applied at 300 ml/hill soon after transplanting boosts the yield. To enhance establishment and growth of seedlings, *Azospirillum* @ 2 kg/10 liters of water is used for dipping the root of the seedlings for about 30 minutes.

Chilli is transplanted mainly in June-July, if grown under rainfed conditions and throughout the year under irrigated conditions in South India. However, main planting seasons for the crop are June-July, November and March. In North India, summer crop is raised by transplanting in February – March in hills, while it is mainly during *Kharif* season in plains. However, crop cannot be raised successfully in *Rabi* season due to low temperature The season of sowing and transplanting for different regions/states are given in table 12.

In red soils of Bangalore, Karnataka, transplanting in July is recommended, since late planting attracts more insect-pests and diseases, while it is in August for Hyderabad, Andhra Pradesh.

5.1.2. *Spacing*

Plant density per unit area is decided by the spacing adopted for the crop. Distance between two ridges depends upon the row spacing of the crop. Healthy, disease free, vigorous and 40-45 days old seedlings are transplanted to the field at proper spacing.

Water is given immediately for better establishment of seedlings. In India, different spacings *viz.*, 30 x 30 cm , 30 x 20 cm (when applied with nitrogen at 120 kg/ha for cv. MDU-1), 45 x 30 cm (cv. Pusa Jwala), 45 x 20 cm (cv. Dharwad 7-6-6), 45 x 30 cm (cv. NP-46A), 30 x 30 cm (cv. K-1), 60 x 30 cm, 45 x 60 cm, 90 x 20 cm (cv. Byadagi in rainfed with 125 kg N/ha) are being adopted to obtain maximum yield in chilli. In Karnataka and Maharasthra, spacing of 75 x 75 cm or 90 x 90 cm is generally practiced, while in Andhra Pradesh and Tamil Nadu, narrow spacing of 45 x 45 cm or even closer is followed.

Increase in plant density results in less lateral branching, which makes the fruits easier to be harvested. When the crop is raised in light soils, narrow spacing is followed. In black cotton soils, wider spacing facilitates inter-cultivation operation. In Karnataka and Maharashtra, growing cotton and onion as intercrops along with chilli is a common practice. In these states, under rain fed cultivation, wider spacing (90 x 90 cm) is followed for widely grown, tall stature and wide spread cvs. Byadagi, Guntur selections and Sankeshwar type of chillies, while narrow spacing (60 x 60 cm) is adopted for short stature, low branching and short duration type of cvs. Jwala and NP 46 A. A Spacing of 30 x 15 cm in flat beds suits to cv. CO-3 at Coimbatore, Tamil Nadu. However, the general recommendation is of 60 x 45 cm for varieties and 50 x 45 cm for hybrids.

5.2. Intercultural operations

Intercultural operations such as weeding, earthing up and mulching are performed in chilli. In order to keep the field free from weeds and to facilitate soil aeration and proper root development, shallow cultivation should be followed at regular intervals.

5.2.1. Weed management

In chillies, weed intensity is generally high in red soils than in black cotton soil; higher weed intensity is noticed in *Kharif* season than in *Rabi* and summer seasons. In Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra, perennial weeds are predominant in clayey soils while it is annual weeds in red soils. Common perennial weeds associated with chilli crop are *Cynadon dactylon*, *Cyperus rotundus* and *Convolvulus arvensis*. Among annual grasses, *Dianebra retroflexa*, *Panicum isachne* in red soils and *Digetaria marginata*, *Dactylocatinum aegyptinum* in black soils are common. Other dicot weeds commonly observed are *Commelina benghalensis*, *Cynotis* spp, *Phyllanthus amarus*, *Sida* spp. Weeds associated with chilli in Tamil Nadu are *Trianthema portulacotrum*, *Gynandropsis phenotophylla*, *Gynadon dactylon* and *Cyperus rotundus*. In north regions, *Cyperus rotundus*, *Tribulus terretris*, *Celosia argentia*, *Digera arvensis*, *Digiteria sanguinalis*, *Eragrostis* spp, *Eleusine aegyptiacum*, *Eleusine indica* and *Amaranthus viridis* are noticed.

Weeding is done either by hand hoeing or by the application of herbicides. In irrigated crop, 3-4 hoeing and in rain fed crop, 2-3 hoeing are given. Among the herbicides, application of trifluralin and pendimethalin each at 1.0 kg/ha at the time of transplanting checks the weeds effectively and increases the yield. Soil application of EPTC 10 days prior to transplanting, followed by nitrogen and Alachlor controls weeds in chilli field .

Spraying Tok-E 25 @ 2.0 litres/ha with one hand weeding, lasso@ 1.5 litres/ha with one weeding was reported to increase the yield of dry pods per hectare.

5.2.2. Mulching

Mulching may be practiced with black polythene film with rice husk in order to conserve soil moisture and to add organic matter to the soil over a period.

5.2.3. Earthing up

Earthing up is done, sometimes, along with hoeing to drain the surplus rain water under rain fed cultivation, which also helps in soil aeration, checking weeds and mixing the fertilizer with soil.

5.2.4. Crop rotation, mixed and inter-cropping

Chilli is rotated with jowar, ragi, cotton, groundnut and castor under rain fed conditions and with sugar cane, turmeric, beans, maize or with vegetables avoiding brinjal and potato exclusively. Chillies are also grown as mixed crop under irrigated conditions in some pockets. In Tamil Nadu, onion, brinjal and coriander are grown as intercrops under rain fed conditions. Barrier crops such as castor and agathi are grown on bunds in chilli field. In Karnataka and Maharashtra, it is a common practice to grow cotton and onion as intercrops alongwith chilli. These crops provide additional income to the farmers.

5.3. Irrigation

Chilli crop is raised as a rain fed crop, where the amount of annual rainfall received is around 80-100 cm and well distributed. In northern parts of Karnataka and southern parts of Maharashtra, where the rainfall received is around 80 cm, it is extensively cultivated as a rain fed crop during *Kharif* season. Chilli crop is also raised in *Rabi* and summer mainly under irrigated conditions for green chillies. In Andhra Pradesh and Tamil Nadu, the crop is raised under irrigation for ripened dry fruit, where the amount of rainfall received is not sufficient for the crop. Irrigation reduces the fruit yield in the first picking but increases in the second and subsequent pickings. First irrigation is given just after transplanting and a life saving (light) irrigation on third day of transplanting and at weekly interval thereafter. Gap filling may be done after 10 days of transplanting during the second irrigation. In India, generally 8 to 9 irrigations are given depending on the rainfall, soil type and humidity and prevailing climatic conditions.

Spray of anti-transpirants on foliage helps to reduce the transpiration rate of leaves in the arid and semi-arid regions, where the irrigation water is scarce. Irrigation at 12 day interval alongwith spraying of 20 ppm Alachlor solution as anti-transpirant is recommended for the variety 'Pusa Jwala' in Andhra Pradesh. Chillies could be grown near pitcher for effective utilization of saline and high residue sodium carbonate water in sandy loam soil of arid and semi-arid regions.

5.4. Growth regulators

Growth regulators in chilli crop are used for production of male sterile flowers, to induce early flowering, for preventing flower and fruit drop, for uniform ripening of fruits, for improving fruit set and yield of chilli and to increase or decrease seed content in fruits. Some of the commonly used growth regulators are naphthalene acetic acid (NAA), Gibberallic acid (GA), Tri-iodo benzoic acid (TIBA), Kinetin, Ethylene, Phenoxy acetic acid sterols and long chain aliphatic fatty acids. Naphthalene acetic acid is mainly used to prevent flower and fruit drop and ethrel for uniform maturity of fruits. Various growth substances used in chilli along with actions are given in Table 12. Based on the experiments conducted at TNAU, Coimbatore, it is reported that spray of NAA 10 ppm (10 mg/l of water) on 60 and 90 days after planting increased fruit set. Spraying of Tricontanol at 1.25 ml/10 on 20, 40 and 80th day of planting is highly effective against fruit drop.

6.0. MANURING

Chilli crop responds well to application of manures and fertilizers both under rain fed and irrigated conditions. Chilli crop uptakes about 100 kg of nitrogen from one hectare

6.1. Organics

In general, chilli fruit yields are fairly high, when fertilizers are applied with organic manures rather than either fertilizers or organic manures alone. Fertile soils with adequate humus are most desirable for the crop. Chilli crop demands heavy application of organic manures under irrigated conditions. In general, FYM 25-30 t/ha is incorporated in soil before transplanting. Under rain fed conditions, spot manuring is practiced before transplanting. The amount of organic manure applied under rain fed conditions varies from 5 to 10 t/ha. Sheep penning is a common practice in transitional belt of Karnataka, Maharashtra and Rajasthan.

Azospirillum, a biofertilizer is more effective as seed treatment. Soil application of *Azospirillum* @ 2kg/ha, mixed with 20 kg FYM/compost as carrier along with 75% dose of NPK is recommended. *Azospirillum* @40 g in 2 litres of water is recommended for root dipping of seedlings to boost the growth and vigour of the plant.

Table 12. Effect of growth regulators on chilli

Growth regulator	Concentration (ppm)	Stage of application	Response
NAA (Naphthalene acetic acid)	50	Full bloom	Checks fruit drop and increases yield
	20	First at flower opening and 2 sprays at monthly interval	Increases yield, capsaicin content, ascorbic acid, carbohydrate, protein and fat
	10	First at flowering, second at 5 weeks later	Increase in fruit set
	60	Bloom stage	Increase in yield
Ethrel (Ethephon)	200	Pre-flowering	Improved flowering and fruit set
	500	At maturity stage	Turn in color and increase in yield
Cycocel (CCC)	1000	30 days after planting	Increases fruit set and yield
GA (Gibberellic acid)	50	At the time of fruit setting	Decrease in flower drop and increase in fruit set
Paclobutrazol	300	First at flower bud initiation and 2nd at 20 days later	Increases fruit set, no. and wt. of seeds, seed weight and yield
Tricontanol	2	First spray at 30 days after transplanting and 2nd at bloom stage	Reduction in flower drop and increase in yield
MH (Maleic Hydrazide)	3000	Pre-flowering	Suppresses flowering

Source: Rajput and Parulekar (1996); Muthukrishnan *et al*. (2002)

6.2. Inorganic fertilizers

Being a long duration crop, chilli/paprika needs judicious application of manures and fertilizers. Sub-optimal levels of major nutrients often lead to deficiency symptoms in chilli as detailed below:

Nitrogen: Stunted appearance leaves pale green, older leaves are small and uniformly pale green bleaching from margin towards leads to bleaching of entire leaf and to pale white

Phosphorus: Leaves small and bluish green in the beginning, which turns to dirty greyish green, later

Potassium: Retarded plant growth to a lesser extent, leaves normal green but smaller in size with crinkled surface. *Foliar symptoms*: appearance of very small whitish necrotic spots dispersed over the entire *lamina in* older leaves

Nitrogen deficiency causes pale yellow colour on older leaves, phosphorus, bluish green colour on older leaves, potassium, marginal necrosis, and subsequently marginal scorching, magnesium, interveinal chlorosis of matured leaves and zinc, smaller leaves in shorter internodes. Nitrogen deficiency reduces plant growth and fruit yield considerably but the crop is only slightly affected by calcium deficiency.

In chillies, a wide range of fertilizer recommendations have been reported. The recommendation varies based on soil type, type of cultivation (*rain* fed/*irrigated*), climatic conditions and variety to be grown. Chilli crop responds well to nitrogen and potash application rather than phosphorus. In rain fed crop, half N dose along with full dose of P and K are applied usually after two weeks of transplanting and the remaining half dose of nitrogen top dressed one month after the first application, while in irrigated areas, N is applied in two or three split doses at an interval of three weeks. The nitrogen should be applied in two to three doses, if the amount to be applied is more than 100 kg/ha and may be applied as single dose, if the quantity is less than 50 kg/ha.

In general, about 240:300:350 kg/ha NPK is recommended along with FYM @ 25t/ha. However, fertilizer recommendations developed by different states for chilli crop along with its response is given in Tables 13 and 14 .

6.3. Foliar application

Chilli/paprika crop responds to foliar application of nutrients, especially to nitrogen and potassium. In Tamil Nadu, spray of 75 kg N as 1.5% urea on 30th day and subsequently at fortnightly interval accelerated flowering in cv. G-4. At Dharwad, Karnataka, spraying urea @5 kg/ha is reported to increase yield of dry chilli (2.53 t/ha) and also spraying for three times *viz*., 45, 78 and 108 days after transplanting.

Besides macronutrients, spraying of Zn, Fe and B @ 0.1 % either alone or in combination at 30, 50 and 70 days after transplanting increases the yield and quality of chillies.

7.0. DISEASES AND THEIR MANAGEMENT

Chilli/paprika crop is attacked by a number of diseases caused by fungi, bacteria and viruses. The loss due to diseases was estimated to be in the range of 15-50 % depending upon location and season. Oc-

Table 13. Fertilizer recommendations made by different states for chilli crop in India

Centre/State	Variety	Recommendation	Response
Faizabad (UP)	Pant C-1	120-150 kg N/ha. Split into 60 kg as basal and rest in 2-3 equal quantities or Application of 90 kg N/ha long with basal doses of 60 kg P_2O_5 and 40 kg K_2O/ha	High yield
Tamil Nadu (Coimbatore)	Local	100 kg N/ha. Split into 50 kg as basal and 50 kg as top dressing after one month of planting	High yield
	G-3	100 kg N in 4 equal splits	High yield and quality
	Co.1	70 kg N/ha	High yield and dry chilli
Tamil Nadu	K-1 and local cultivar	50:25:25 kg NPK/ha with 30 x 30 cm spacing	High yield
		80:0:35 kg NPK/ha	High capsaicin content
		0:35:0 & 120:0:0 kg NPK/ha	Low capsaicin content
	-	50 kg N as soil application and 25 kg N as foliar spray	High yield of pods
Haryana (Karnal)	-	90:90:0 kg NP/ha	High yield
Haryana (light soil)	-	Organic manure 23-34 t/ha; 57 kg each of N & P and 27 kg K/ha	High yield
Semi-arid	-	100:90:50 kg NPK/ha (optimum) 150:120:60 kg NPK/ha (irrigated)	High yield of green chilli
Punjab	-	FYM 20 cartloads; 56:56:28 kg NPK/ha. P and K at transplanting, N in two splits – one as side dressing at establishment and another at the time of flowering	High yield
Karnataka	-	34 kg each of NPK/ha	High yield
	-	VAM (*Glomus macrocarpum*) 50 g/10 kg of black clayey and 60 g/10 kg of red sandy loam soils	Higher P-nutrition and yield
Maharashtra	-	45 kg N and 22.5 kg P/ha	High yield
Delhi	-	FYM 50 cartloads; 350 kg ammonium sulphate, 175 kg single super phosphate and 100 kg potassium sulphate/ha	High yield

Source: Muthukrishnan *et al.* (2002)

Table 14. Fertilizer recommended for chilli in different states of India

Region	State	N/ha	P_2O_5/ha	K_2O/ha
Northern India	Haryana	60	30	30
	Himachal Pradesh	75	75	50
	Punjab	62	30	30
	Uttar Pradesh	80-100	40-60	40-60
Southern India	Andhra Pradesh	60-160	30-90	60-75
	Karnataka			
	Irrigated	150	75	75
	Rainfed	100	75	50
	Kerala	75	40	25
	Tamil Nadu	75	35	35
Eastern India	Assam	70	40	60
	Bihar	140	80	90
	Orissa	110	70	75
Western India	Madhya Pradesh	150	60	40
	Maharashtra	60-150	30-60	50
	Rajasthan	70	48	50

Source: Indira *et al.* (2001)

currence of these diseases is endemic in certain tracts except mosaic, which is universal nature. Some of the important diseases infecting the crop along with control measures are discussed.

7.1. Fungal diseases

7.1.1. Damping off

Damping off is a common disease of seedlings in solanaceous vegetable crops. It occurs in almost all chilli growing tracts of India. The disease is caused by *Pythium aphanidermatum* (Edson) Fitzp and *Rhizoctonia solani* Kuhn.

Symptoms: Seeds may rot or the seedlings may be killed before they emerge from the soil. Water soaked lesion and shriveling of stem may occur in the young seedlings after emergence which may lead to fall over and death of seedlings. The disease may start in patches in the nursery and in the course of two to four days, the entire lot of seedlings may be destroyed. The disease severity is more in moist soils with poor drainage. The fungus is mainly a soil-borne pathogen and the fungus is capable of living for many years in the soil.

Management

- Partial sterilization of soil by burning trash in the surface
- Providing better drainage by improving soil texture with addition of sand
- Raising seedlings in the raised beds with free drainage around the bed
- Sterilization of soil by drenching the soil to a depth of 4 inches with formaldehyde diluted 50 times with water or some other effective chemical soil sterilant

- Spraying with 0.5 – 1.0% Bordeaux mixture or drenching any effective copper fungicide like blue copper or fytolan commencing from 10-15 days after seed sowing
- The seedlings after 15-20 days of sowing should be sprayed with Thiram 3g/ litre of water
- The soil or nursery should be treated with Thiram $3g/m^2$ before sowing
- Seed should be treated with Carbendazim / Thiram 2g/kg of seed before sowing
- Biocontrol agents *viz.*, *Trichoderma viride* and *Pseudomonas fluorescens* are also found effective

7.1.2. Anthracnose and fruit rot

This is one of the serious diseases of chilli in India, which occurs in severe form in all the Southern states of India and also reported from several other countries. The disease is caused by *Colletotrichum capsici* (Syd) Butler and Bisby.

Symptoms: Appear mostly on ripened fruits and hence the name 'fruit rot'. The spots usually appear as circular and sunken with black margins. As the disease advances, the sunken spots covered with a pinkish mass of fungal spores forming concentric markings with dark fructifications (acervuli). The fruits with many spots drop off prematurely resulting in heavy loss of yield. The fungus may also progress to fruit-stalk and spread along the stem causing die-back symptoms. The fungus is externally seed borne and the secondary spread is through air borne inoculums. The disease spreads rapidly with wind rains during the rainy seasons. The fungus may not survive long in the soil but may survive on the dead twigs stored under dry conditions.

Management

- Seed borne infection may be controlled by treating the seeds with bavistin (Carbendazim) at 0.1%
- Spraying Difolatan 80% W.P. (captafol) at 0.2% at monthly intervals after transplanting against anthracnose and dithane M-45, 75% W.P. (Mancozeb) against ripe fruit rot is recommended
- Die-back could be controlled effectively by spraying with 1.0% Bordeaux mixture
- Spraying Blitox + captafol (0.3%) four times after 20 days of transplanting at 15 day interval
- Shoot die-back may be checked by dipping the seedlings in the suspension of *Azospirillum* sp.
- Cultivating resistant/tolerant varieties such as Pant C-1 (anthracnose and fruit rot), HC-44 (fruit rot and die-back), HC-28 (fruit rot & die-back) and K-2 (fruit rot)

7.1.3. Frog-eye leaf spot

The disease is caused by *Cercospora capsici* Haeld and Wolf, which is a seed borne nature but does not live in the soil.

Symptoms: The disease is characterised by chlorotic lesions angular to irregular in shape, which in later stage turning to grayish brown with profuse sporulation at the centre of the spot. The severely infected leaves drop off prematurely resulting in reduced yield.

Management

- Spray of 1.0% Bordeaux mixture
- Spraying bavistin 0.1%, 5-6 times at fortnightly interval
- Foliar spray of Benlate 0.1% or Dithane M-45 (0.2%) or Bayleton 0.1% or Difolatan 0.2%

7.1.4. Fusarium wilt

This disease is caused by *Fusarium annuum*.

Symptoms: The disease is characterised by wilting of the plant upward and inward rolling of leaves. The leaves turn yellow and die. The fungus can live for several years in the soil.

Management

- Drenching with 1.0% Bordeaux mixture or blue copper or fytolan
- Seed treatment with Bavistin @ 2g/kg of seed
- Crop rotation of three to four years should be adopted

7.1.5 Powdery mildew

It is caused by *Oidiopsis taurica* Salmon (syn. *Leveillula taurica*). The disease is reported from India, Mauritius, Hungary, Libya and elsewhere.

Symptoms: The leaves and stems are covered by white powdery dust resulting in rapid defoliation of leaves and wilting of the plant, ultimately.

Management

- Spraying wettable sulphur at 0.3% or karathane (dinocap) at 0.05%, thrice at fortnightly interval
- Spray of karathane, 3-4 times at 0.1% at 10 day interval or aureofungin 50 ppm
- Spraying Topsin – M (0.05%) or Sulfex (0.3%), twice at 15 day interval
- Growing powdery mildew resistant/tolerant varieties *viz.*, HC-44 and HC-28

7.2. Bacterial diseases

7.2.1. Bacterial leaf spot

This disease is caused by *Xanthomonas vesicatoria* (Doidge).

Symptoms: It can cause damage to both leaves and fruits. On young leaves, the spots are yellowish green and on older leaves, they are dark and water soaked. Later, they appear with straw-coloured centres and dark margins. On the fruits, small blister-like spots occur at early stages becoming warty in appearance later. The bacteria are seed as well as soil-borne.

Management

- Use of copper oxychloride, 3g/litre of water and Stroptocycline, 100 mg/litre of water together as spray in nursery and field at 15 day interval
- Growing resistant/tolerant varieties namely, G-5, CA 960, CAP (63), Co.1 and X 197 (highly resistant) and G-4 and X 206 (resistant)
- Following suitable crop rotation since the bacteria are soil-borne

7.3. Viral diseases

As many as 36 viruses have been reported to infect chilli. Among these, only the leaf curl virus and chilli mosaic virus are reported in India. Leaf curl is the most serious disease, among the viral diseases affecting the chilli crop. If the virus infection takes place at the seedling stage or in the early stage of plant growth, the reduction in yield is enormous and as high as 70-80% ,particularly in the case of mixed infections. In case of Phytoplasma infection (little leaf of chilli), the loss is cent per cent.

7.3.1. Leaf curl virus (Gemini virus)

Symptoms: the leaves curl towards the midrib and become deformed. As a result, the plants become stunted in growth. Flower buds abscise before attaining full size and anther appear devoid of pollen grains.

Vector: Chilli leaf curl Gemini virus is transmitted by White fly, *Bemisia tabaci*

Management

There are no definite control measures available yet. However, the following management practices may be adopted:

- The infected plants should be uprooted and burnt or buried immediately to avoid further spread
- The incidence and intensity of the disease may be delayed /reduced by controlling insect –vectors, as follows:
- Soil application of Carbofuran or disulfoton @ 1.5 kg a.i./ha at 10 day interval
- Application of Thimet (phorate) at 0.1% after the establishment of seedlings and twice more at 15 day interval
- Use of systemic insecticides such as Imidachloprid @ 1ml/3 litres of water
- Seed treatment with raw cow's milk (50% of dilution with water for 24 h) with *Trichoderma viride* (0.6%) and application of *T. viride* (10g/m2) in the nursery soil
- Spray of viricide, Pre-vental B.V. (2g/ litre of water) along with Imidachloprid (1ml/3 litres of water), once in seedling stage (20 days after sowing) and twice in the main field (50 and 70 days after planting)
- Cultivation of resistant/tolerant varieties *viz.*, Pusa Jwala, HC-28, HC-44, Musalwadi, Pant C-1 & C-2 and NP 46-A

7.3.2. Chilli mosaic virus

The virus of chilli mosaic is a strain of Cucumber mosaic virus (CMV) - Cucumovirus.

Symptoms: Appearance of yellow and dark green areas on the leaf surface, shrunken or raised (puckering)is the major symptom.. Sometimes, the size of the leaves get reduced greatly and become filamentous. Infected plant assumes busy appearance. The diseased plants produce less flowers and fruits. Usually, the affected fruits become small and malformed.

Management

- Spraying 0.05% dimethoate or orxydemeton methyl (0.02%) or monocrotophos, 6 times at fortnightly interval starting from 21 days after transplanting or by spot application of Carbofuran or phorate granules at 1.5 kg a.i./ha twice, 15 and 60 days after transplanting
- Use of nylon-net and soil application of carbofuran granules 3G @ 1kg a.i./ha in the nursery, followed by three foliar application with monocrotophos and sulfex in the main field to check the insect-borne viral diseases.

- Growing non-host barrier trap crops such as sesame and wheat for summer and winter crops, respectively. The border crops like maize, jowar or bajra should be sown around the field at least 50-60 days in advance.
- Mineral oil @ 1.5 – 3.0% at weekly intervals are effective in checking vector-borne viruses.

7.4. Other (minor) diseases and physiological disorders

The other minor important diseases that attacking the chilli crop are: stem rot caused by *Macrophomina phaseoli,* dry rot caused by *Sclerotium rolfsii* , fruit rot caused by *Phomopsis* sp. and fruit and stem rot caused by *Glomerella* sp.

Some of the physiological disorders such as excessive development of lenticels, corkiness and necrosis at the base of the stalk, collar and main roots, decay of secondary roots and shoot wilt due to water logging have been reported in chilli.

Blossom end rot, sun scald and salt injury are non-parasitic disorders of chilli. Decaying with respect to discoloration and breaking of the pericarp, detachment of pedicel and spore dust formation within fruit was observed in chilli fruits that stored in humid regions. *Aspergillus, Fusarium, Syncephalastrum, Paecilomyces* and *Pencillium* were commonly associated with decaying chilli fruits. The capsaicin content was also reduced due to fungal infection.

8.0. PESTS AND THEIR MANAGEMENT

There are many insects and pests, causing severe damage to chillies and paprika/ paprika like chillies. They are major limiting factors for profitable cultivation of these crops. Regular monitoring of pests along with natural enemies is essential and helps to take up the control measures at the appropriate time. Economic Threshold Level (ETL) for various important pests is as follows and control measure has to be taken up once it reaches ETL.

Pest	Economic Threshold Level
· Thrips	6 thrips / leaf or 10 % infested plants
· Mites	5 – 10 mites / leaf
· Aphids	10 – 15 % infested plants
· Fruit borers	1 egg mass or 1 larva or 1 d amaged fruit / plant

8.1. Thrips

Thrips (*Scirtothrips dorsalis* Hood. *Thrips palmae*) is a polyphagus pest having wide range of host plants. Both nymphs and adults damage the crop. Adults are tiny, slender, fragile and yellowish straw colour and have grey-coloured heavily fringed wings.

Symptoms: They lacerate the leaf tissue and suck the sap. The infested leaves develop crinkles and curl upwards. The severely infested plants develop bronze colour. If the plants are infected at early stage, plants remain stunted in growth and flower production and pod set are arrested causing severe loss in yield. Pest will become very serious during dry months and is a vector for leaf curl virus.

Management: Spray dimethoate 30 EC 2 ml/lit or Carbaryl 0.15% @ or Phosalone 0.1% @ 3 ml or Methyl demeton 0.05% @ 2 ml or Acephate 0.075% I g/I of water at fortnightly intervals.

8.2. Mites

Mites [*Polyphagotarsonemus latus* (Banks), *Tarsonemus translucens* (Green), *Tetranychus cinnabarinus* (Boisduval)] are tiny accarids found in large numbers on the ventral surface of the leaves under protective cover of fine webs.

Symptoms: Both nymphs and adults suck the cell sap. The affected leaves curl downward along the margins of the leaf and attains on inverted boat shape. The pedicels of the leaves get elongated and the young leaves at the tip of the branch cluster. The affected plants develop dark green clour. In the infested plants, the vegetative growth is inhibited and flower production is ceased and yields are considerably reduced.

Management: Spray Phosalone 0.1% @ 3 ml or Dicofol 0.09% @ 5 ml of water or Ethion 50 EC @ 4 ml/litre or Wettable sulphur 50 WP @ 6 g/litre.

8.3. Aphids

Nymphs of aphids (*Aphis gossypii* Glover) are small, ovate, and soft bodied and adults appear on the tender shoots, leaves and on the lower surface of the old leaves.

Symptoms: They suck the sap and reduce the vigour of the plant. They secrete sweet substance, which attract ants and develop sooty moulds. The pods that develop black colour due to sooty moulds loose quality and fetch low price. The yield levels are also reduced by aphid infestation directly and more through the spread of virus diseases as vectors.

Management: Spray 0.1% Dimethoate @ 3 ml/1 or Methyl demeton 0.05% @ 2ml/1 or phosalone 35 EC 2 ml/litre or Acephate 0.075% @ 1 g/1 litre of water. Spray alternating the chemicals at 10 days interval till the aphids population is checked. Avoid spraying when predatory beetles are seen in sufficient numbers.

The winged forms of aphids migrate rapidly from one field to another. Hence, spraying is to be undertaken as far as possible within a day or two by all the cultivators on a community basis.

8.4. Pod borers

Helicoverpa armigera Hubner : Larvae are yellowish green in colour and adults are grey in colour

Larvae *Spodoptera litura* (Fabricius) are brownish with three strips and adults are grayish brown.

Symptoms: Pod bores are polyphagaous and appear on both in vegetative and reproductive phase (at the time of pod formation). Borers enter chilli pods by second and third instars by making a hole near calyx and feed on chilli seed. The affected pods drop off or develop white colour on drying. The fully grown caterpillars enter the soil for pupation.

Management: Spray Carbaryl 0.15% @ 3 g/1itre or Chloropyriphos 0.05% @ 2.5 ml/litre or Monocrotophos 0.07% @ 2 ml/litre or Quinaphos @ 2.5 ml/l of water can be sprayed. The dosage of these chemicals should not be increased as they cause flower drop.

8.4.1. Integrated pest management of fruit borer

1. Set up pheromone traps for *Helicoverpa armigera / Spodoptera litura* at 12 no./ha.

2. Collection and destruction of damaged fruits and grown up caterpillars.
3. Spray *Bacillus thuringiensis* at 2 g/litre
4. Provide poison bait with Carbaryl 1.25 kg, Rice bran 12.5 kg, Jaggery 1.25 kg and water 7.5 litre/ha
5. Spray Carbaryl 50 WP @ 3 g/litre or Chlorpyriphos 20 EC @ 3 ml/litre or Quinalphos 25 EC @ 2 ml/litre.

8.5. Root grubs

Roots grubs (*Anomala bengalensis, Holotrichia consanguinea, Holotrichia reynaudi*) damage the plants by feeding the root system. The affected plants die and can be easily identified. Its damage can be seen in the field up to the end of October.

Management: To prevent root grubs, use only well-rotten farmyard manure. Apply 250 kg Neem cake/ha by mixing with farmyard manure. Apply Carbaryl 5% @ 50 kg dust/ha in July-August before planting.

8.6. Nematodes

Root-knot nematodes (*Meloidogyne* spp.) are polyphagus pests with a wide range of host plants. In general, nematodes infest the roots and produce tiny galls and infested plants show symptoms of withering and wilting of leaves. The growth of the plant is stunted and fruiting is adversely affected.

Management: Exposure of soil to the sun by several ploughings reduces the infestation of nematodes. Application of neem cake @ 500 g/m2 helps to reduce the infestation and crop rotation with cereals or intercropping with marigold may be effective. Use of granular insecticides Aldicarb 10G (20 kg/ha) or Furadan 3G (35 kg/ha) during transplanting considerably reduce the nematode infestation.

8.7. Organic pest management

To avoid infestation of root grub, only well rotten farmyard manure should be applied in the field. Application of neem cake @ 250 kg/ha is also advisable for control of root grubs. Change in the agronomic practices to disturb the life cycle of the grub is also found useful.

Application of neem seed kernel extract (NSKE 3%) can be done for control of thrips, aphids and mites. Release of larvae of *Chrysoperla cornea*, a biocontrol agent, once in 15 days is also helpful in controlling thrips and mites.

Fruit (pod) borers are the major pests, which cause considerable damage to the crop. They can be managed to a certain extent by adoption of biocontrol measures. Restricted installation of pheromone traps in the field @ 5 nos. per acre helps to monitor the adult moths. Ten days after spotting the moths in the traps, spraying with Nuclear Polyhedrosis Virus (NPV) @ 500 LE (larval Equivalent)/ha @ 4-5 rounds is beneficial to control the early larval stage of the pod borers. The egg masses of *Spodoptera* borer can be mechanically collected and destroyed. *Trichogramma* an egg parasite, may be released two days after appearance of moths. Spraying of neem products like neem oil, neem seed kernel extracts and restricted use of *Bacillus thuringiensis* @ 1 kg/ha is beneficial. All the shed fruits and inflorescence parts should be collected and destroyed at regular intervals.

9.0. SEED PRODUCTION

Even though chilli is a self-pollinated crop, cross pollination takes place to some extent. Hence, to obtain pure seeds, the two cultivars (parents) may be kept in an isolation distance of 250-400 m to avoid any cross-pollination. Good, healthy, well-developed and true to type fruits should be collected from plants for producing seeds.

Chilli fruits should be harvested at the breaker stage for early seed crop, without affecting its quality. Paprika fruits could be harvested at 60 days after flowering for high yield and better quality of seeds. A simple mechanical seed extractor may be used for extraction of seeds. Curry powder grinder after suitably adjusting the grinding plate can be advantageously put to use to break the pods into pieces, while the seeds are completely shed. A winnower or sieve shaker may be used for separation of seeds fitted with BSS6 wire mesh. By this method, the cost of extraction is brought down besides, enhancing the germination. The average seed yield varies from 50 to 80 kg/ha. The seeds thus collected are dried to a safer moisture level (10-12% depending upon the cultivar) and packed, after treating with Captan @2g/kg of seeds. For paprika, seeds dried at 40°C air temperature gives better seed quality.

9.1. Hybrid seed production

The successful utilization of male sterility in commercial F_1 seed production involves the following steps:

- Identification of male sterility.
- Transfer of male sterility character into the otherwise desirable variety by repeated back crossings, which will be used as female parent.
- Preparation of male sterile lines by developing maintainer line.
- Development of hybrid seeds in open or by the hand pollination by use of identified restorer lines.

The planting pattern is an important factor for increasing the yield in hybrid seeds. Out of five systems of male sterile to male fertile plant proportion, alternate planting of two rows male sterile plants and one row fertile plants with a ratio of 2:1 in favour of the male sterile component (accommodated approximately 53,000 male sterile plants per hectare) was most suitable because of the high yield of hybrid seeds per hectare due to a higher number of male sterile plants. Approximate cost of hybrid seed production in chilli under Karnataka condition is given in table 15.

Table 15. Cost of hybrid seed production in chilli by conventional method

Planting Details	
Area	10 guntas (=1000 m^2)
Planting pattern	3:1 (Female: Male)
Approximate number of female plants	500
Approximate number of male plants	150
Labour requirements	1 women for very 100 plants

Approximate cost components

Land preparation	Rs. 500/-
Inputs (Fertilizers, pesticides, irrigation etc)	Rs. 2000/-
Labour cost (Emasculation, pollination and other cultivation practices)	Rs. 7000/-
Miscellaneous (Supervisor, drying, seed extraction etc)	Rs. 500
Total cost	**Rs. 10,000**

Benefits

Yield per plant	20g (F_1) seed per plant
Total yield per 10 guntas	10,000g (10kg)
Sale price	Rs. 2,500/- per kg
Gross returns (for 10 kg F_1 seeds)	Rs. 25,000/-
Less cost	Rs. 10,000/-
Net profit	**Rs. 15, 000/- per 10 guntas**

Note: (40 guntas = 1 acre)
Source: Madalageri and Chandrakala (2005).

The hybrid seed production cost by use of cytoplasmic genetic male sterility will be much cheaper by eliminating labour cost of around Rs. 7,000/-.

10.0. POST HARVEST PROCESSING AND VALUE ADDITION

10.1. Harvesting and yield

The stage of harvest is dependent on the final use. Most fresh chillies are harvested at the physiologically immature (horticulturally mature) stage, while the dehydrated and mash industries prefer physiologically mature fruits. For the canning of green New Mexican type chilli, a processor demands that all pods are free of any red colouring because as the pod matures the 'skin' begins to stick and peeling of the pod is hampered. In addition, if the fruits are to be shipped long distances, care must be taken to reduce the 'field heat', so that respiration is reduced and the fruit will be saleable at its destination. Therefore, yield is dependent not only on the growing environment and cultivar but also on the time of harvest.

In chilli, flowering begins 1-2 months after transplanting depending upon the variety, climate, nutritional status of soil and it takes another month for green fruits. First harvesting is done at the green stage to stimulate further flush of flowering and fruit set. Chillies used for drying are picked at fully ripened red stage and it takes another month for dry chillies. Thereafter, ripe fruits are harvested at an interval of 1-2 weeks and it continues over a period of about 3 months with 6-10 pickings depending upon the season, cultivar and cultural practices adopted. The ripe chillies are generally dried under sun for 8-15 days depending upon weather conditions, while commercially it is dried at about 54.4°C in 2-3 days. One hundred kg of fresh ripe fruits yield 25-40 kg dry chilli depending upon the variety and thickness of inner wall. Normally, chilli crop yields 7.5 – 10.0 mt green chilli and 2.0

2.5 mt dry chilli from a hectare. Under rain fed conditions, commercial chilli varieties yield 1.0 – 1.5 mt/ha dry pods, while it is 2.0 – 2.5 mt/ha under irrigated conditions. A maximum yield potential of 5.0 mt/ha dry chilli was reported in cv. Karan. Fully ripened fruits of paprika/paprika like chillies could be harvested at 60 days after flowering. Usually 4-5 pickings are done. Paprika (cv. Kt-Pl-19) gives average yield of 25-30 mt/ha with a dry yield of 4.0 – 4.8 mt/ha with a skin recovery of 66% and dried under shade to a safer moisture level (8-12%). Stage of harvesting of chilli/paprika for various uses / purposes are given in table 16.

Chillies are harvested by hand. The reason that the chilli industry as a whole is still based on hand harvesting is quality. Hand -picked chilli are of a higher quality because human can instantaneously reject mouldy, underripe, overripe or damaged pods. Besides quality of the product with hand harvesting, there is also an increased yield per unit area. The increased yield is associated with less damage to the plants as human pickers move through the field. Machine -harvests cause more damage to plants than human pickers. Machine-harvested plants also take longer to recover and set more fruit.

10.2. Processing

The post-harvest handling of chilli/paprika is as crucial as the growing of the crop. Whether the chilli is used as a fresh commodity or processed, appropriate post-harvest handling is essential for a quality product. Chillies can be fresh, canned, brined/pickled, frozen, fermented, dehydrated and extracted for oleoresin.

Table 16. Commercial cultivation of chilli in India: fruits of various market types

Stage of harvesting	Consumption pattern	Cultivars types	Species	Preferred fruit type/size	Degree of pungency
Red ripe fruits	Intact fruits or grinded (power)	Landraces, improved populations and hybrids	*C. annuum*, *C chinese* *C. frutescens*	Cayenne fruits 10-12 x 2-3 cm	High colour retention and highly pungent
Green fruits	Intact fruits or sauce preparation	Landraces, improved populations and hybrids	*C. annuum*, *C. chinese* *C. frutescens*	Cayenne fruits 6-8 x 2-3 cm	Mild pungent to highly pungent
Red ripe fruits (paprika)	Oleoresin extraction	Landraces (e.g. Tomato, Chilli, Bayadgi Kaddi etc.)	*C. annuum*	Cayenne fruits with very less capsaicin and high oleoresin	High oleoresin with no pungency
Red ripe fruits	Pickle formation	Landraces	*C. annuum*	Jalapeno type fruits, but with thin pericarp	Very mild pungent
Red ripe fruits	Specific flavour	Landraces (e.g. Dello of North-East region)	*C. baccatum*	Typical bell shaped with distinct flavour	Regional preferences

Source: Mathura Rai (2005)

High quality chilli begins with selection of the proper variety and the purchase of quality seed. Before post-harvest handling, good cultural practices such as fertilization, irrigation and disease management in the field must be maintained to produce a high quality crop. The level of stress that the crop endures in the field will influence yield, pungency, fruit colour and diseases. In general, chillies harvested from poorly managed fields will have inferior post-harvest quality.

Fruits are harvested at ripe stage and are piled on a hillside facing south for 24 hours and then dried in the sun for about four days until they are soft and wrinkled. The fruits are then cut and sectioned and again dried in the sun for about eight days until sufficiently dried. The sun-dried product has high moisture content of 18 per cent and is further dried in the factories in hot air dryers to a moisture level of 8 to 12 percent, which makes them suitable for storing and grinding. On a commercial scale, the freshly harvested fruits are taken directly to factories for rapid drying and grinding. The harvested fruits are first washed by a water spray and then immersed in very dilute hydrochloric acid to completely remove the fungicide and pesticide residues. A second thorough wash with water to remove and acid wash is given before the fruits are cut mechanically in to one cm strips and loaded on the trays or continuous bands of the counter current hot air dryers. Steam-treated radiators, positioned at the centre and exit, control the temperature at 8- and 65 °C. With the control of airflow and humidity, the drying time varies between 2.5 to 4 hr to give a product with a moisture content of 10 to 12 per cent and a yield of 18 per cent of fresh weight. It has been found that by rapid drying the colour loss is less than by prolonged sum drying. After drying the seeds, peduncles and calyxes, the placental tissues are removed by hand or by mechanical means. The pericarp material is separated in to categories according to colour, quality, intensity and absence of blemishes for use in making a wide range of colour strengths and three qualities of paprika powder.

Curing is done by the "netsack method" based on the observation that in freshly harvested fruits stored in cotton meash sacks, the red pigment content increased rapidly up to the 25th day to a high of 4.5 to 4.7g/kg and remained at that level up to 39 days and then slowly decreased. Traditionally the withered and cured fruit is further dried to a safe moisture level by spreading them in the sun for 2 to 3 weeks. The leathery skin slows the rate of loss of moisture. To cope with the increased cultivation, the withered, cured product is quickly dried to a moisture level of 8 to 10 per cent in modern dryers with hot air under 80°C and is further ground in mills. A further development is to directly process the fresh crop after washing and to cut into slices for rapid drying at 70 to 80°C, to reduce moisture from 85 to 8 percent. A special feature of processing (in Hungary) is the preliminary grading of the harvested crop according to quality and the extensive separation of the dissepiment (placenta) carrying the pungency stimulating capsaicinoids ,the seeds, calyxes and peduncles which dilute the colour.

Recovery from the fruits of paprika:

68.7 %	- Skin (pericarp)
25.0 %	- Seed
6.3 %	- Pedicel

Drying percentage/Driage – 15% on an average

Good Processing Practices (GPP) for chilli include the following steps:

1. Selective harvesting
2. Ideal temperature for drying (above 37°C)
3. Drying surface
   - Clean drying yards, cemented/ kadapakal/terracotta tiles/HDPE sheets
   - Mechanical driers – solar driers
4. Chilli thickness for drying should be 10 cm
5. After 2 days turning required (once in two days)
6. Time required 12-15 days for drying
7. Grading – remove fungus effected/ discoloured/insect infested pods and other extraneous matter
8. Packing
   - Use clean dry gunny bags of 30 kgs
   - For export – 25 kgs
   - Packing may be in morning hours
   - Avoid synthetic colour on gunny bags
9. Transportation by load/tractor/lorry

10.3. Storage

After harvesting during hot weather period, the cold storage is recommended which will aid in colour retention and guard against infestation. Storage of chilli in cold store is extensively followed around Guntur as the produce fetches premium price due to excellent colour retention. The use of commercial cold store for chilli storage has now become almost a general practice among farmers. The temperature in a cold store is *maintained in the range of* 5-8°C and relative humidity is kept at 55-60 %. There were great loss of oleoresin and capsanthin when it stored ambient temperature for 20 days after removed from the cold store. Therefore, the chilli produce should be used immediately after termination from cold store for extraction of colour *and oleoresin and* other products.

10.4. Quality parameters

Different aspects of quality standards vary according to uses by growers, shippers, sellers and consumers. A *Capsicum* suitable for the fresh market may be unsatisfactory for paprika use. The quality of red chilli powder and paprika products is based on visual and extractable red colour, pungency level and to a lesser degree the nutrition value.

10.4.1.Colour

Colour is one of the most important attributes of red chilli and paprika. Chilli colour can be evaluated from three different perspectives: surface colour, extractable colour and carotenoid profiles. Surface colour is a measurement of the visual colour perceived by the viewer. It is sometimes referred to as reflective colour. Surface colour varies according to cultivar, growing conditions, dehydration and storage conditions, and the coarseness of ground samples. Surface colour measurements are important when dehydrated chilli is to be used as a retail spice or as a coating on foods. Extractable colour is measured by a spectrophotometric process, and is designated ASTA units (American Spice Trade Association.). Generally, higher the ASTA colour

<u>Model flow diagram for processing of Chilli</u>

Harvesting

↓

Washing and Sorting

(Remove dirt, debris and diseased fruits)

↓

Storage

(Storage at refrigerator temperature below 7°C)

↓

Drying

(Optimum moisture level of 8%)

- Sun drying – 10 to 15 days
- Hot drier- 40-60°C

↓

Grounding

(Stone mill)

(Hammer mill)

↓

Storage & Re-drying

(Moisture content <14%)

(Storage temperature <13°C)

Processing of paprika:

Fresh fruits → **Dried fruits** Shade drying

↓ Separation of pedicel calyx, seeds & placenta and pericarp/skin portion

↓ Powder/Ground form

↓ Oleoresin

Marketing

↓ Whole form (or) Ground /Powder form

↓ Oleoresin

Marketing

value, the greater the effect on the brightness or richness of the final product. A chilli powder with 120 ASTA colour units would give a brighter red to a finished product than an equivalent amount of 80 ASTA colour.

Essentially, the paprika fruit can be portioned into pedicel, seed, placenta and pericarp, where in major portions of pigments occur in the outer pericarp tissues beneath the epidermis. Pigments constituting the color are a complex mixture of carotenoids. Red and yellow components combine to give the total color to paprika. The red color is constituted by two major pigments of capsanthin (30-60%) and capsorubin (6-18%). The inherent characters of the cultivar, which affects the stability of the color are: anti-oxidants present in the pericarp and seeds and oxidizing agents. In the case of ground paprika (Powder), exposure to sunlight for a few hours completely decolorizes the red pigments. The accumulation and retention of patterns of the red pigments and total carotenoids in the fruits are cultivar dependent. Colour, like pungency, is a priced quality characteristic of paprika which is commercially important and exported.

In paprika, the commercial interest lies in exploiting red color, which is constituted by two major pigments of capsanthin and capsorubin. However, the color intensity depends on diverse factors such as varieties, stage of maturity of the fruit harvested, agro-techniques adopted, agro-climatic conditions, and post harvest operations. Paprika produced in Zimbabwe, South Africa and Morocco is sweet and have high color value as that of Spain. Hungary, and other Central and East European countries produce high quality paprika.

10.4.2. Oleoresin

Oleoresin prepared from chillies is popular among food processors and other industries where a concentrated pungency or red colour additive is needed. When pungent chillies are used in the extracting process, the product is called 'oleoresin capsicum'. This product is used in medicinal and food industries. When non-pungent (paprika) chilli is used, the product is called 'oleoresin paprika'. Oleoresins are available in *two* basic forms: oil soluble or water soluble. Oleoresin is obtained from dried chilli pericarp by extraction with a volatile non-aqueous solvent (often hexane), which is subsequently removed from the oleoresin by evaporation at moderate temperatures and under partial vacuum. Oleoresins contain the aroma and flavour of the paprika or other chilli type, in concentrated form, and are usually viscous liquids, or semisolid materials. Oleoresins are used for standardizing the pungency, colour and flavour of food products. . Because of their high concentration, oleoresins cannot be incorporated into food products unless they are diluted. The dilution is usually achieved by dissolving the oleoresin in an appropriate solvent to make an essence. The paprika oleoresin is usually diluted with soybean oil. Oleoresin capsicum is made from the most pungent pod types and where colour content is not important. The oleoresin has a very high pungency and is used where a concentrated pungency is needed. This ranges from pharmaceutical uses to anti-mugger sprays, and has limited use in food products to modify the pungency level of a product.

Oleoresin extractors are located in many countries around the world. However, the facilities for producing high pungency oleoresin are limited to India, Africa and China. Paprika oleoresin is produced in several countries of which Spain, Ethiopia, Morocco, Israel, India, the USA, Mexico and South Africa are the top producers. The Indian oleoresin industries have been using some of the land races such as 'Byadagi kaddi', 'Byadagi, dubba' and 'Warangal tomato chilli', for extraction of oleoresin.

10.4.3.Pungency

Another important typical attribute of *Capsicum* is pungency. Scoville heat units measure the heat of *Capsicum* powder. One part per million concentrations of capsaicinoids is equal to 15 Scoville heat units. The nature of pungency has been established as a mixture of seven homologous branded-chain alkyl vanillylamides, named capsaicinoids. They often are called capsaicin after the most prevalent one, dihydrocapsaicin being the second. They are unique to *Capsicum.*

Generally there is a decrease in pungency from chillies to paprika and a parallel increase in colour pigment concentration and an increase in size and fleshy nature of pericarp. The group paprika contains less than 0.1% of capsaicinoids, the best grade of Spanish paprika having 0 to 0.003% and for the pungent grade, a maximum of 0.5%. But the pungency level of chillies varies from 0.1 to 1.4%.

Dried red *Capsicum* powder is classified into five groups based on pungency level: nonpungent or paprika (0 to 700 Scoville heat units) mildly pungent (700 to 3,000), moderately pungent (3,000 to 25,000), highly pungent (25,000 to 70,000) and very highly pungent (80,000 Scoville heat units). The last group is mainly the product from Asian countries.

Growers can, to some extent, control pungency by the amount of stress to which the plants is subjected. Pungency is increased with increased environmental stress. More specifically, any stress to the chilli plant will increase the amount of capsaicinoid level in the pods. A few hot days can increase the capsaicinoid content significantly. In New Mexico, it has been observed that even after furrow irrigation, the heat level will increase in the pods. If the same cultivar were grown in both a hot semi-arid region and a cool coastal region, the fruit harvested from the hot semi-arid region would be higher in capsaicinoids than the fruits harvested in the cool coastal climate.

10.4.4. Flavour and aroma

Most chillies are used for flavour. Flavour is a complex sensation determined in the mouth. Chilli connoisseurs can readily identify subtle flavours presented by each type. As in wine-tasting, one can distinguish between the subtle flavours of chillies after a few years of experience. One of the most potent volatiles known is found in chilli, the pyrazine 2-methoxy-3-isobutyl-pyrazine which gives the 'green bell pepper' smell. The three main aroma compounds in chillies are 4-methyl-1-pentyl-2-methylbutyrate, 3-methyl-1-pentyl-3-methylbutyrate, and isohexyl-isocaproate.

10.5. Value addition / products

Various products are being prepared from chilli/paprika, which are having high export potential. The product description and its intended usage along with packaging and shelf-life are given in table 17.

10.5.1. Canned chilli

Acidification of the products reduces the pH below 4.6, which decrease the thermal resistance of microorganisms. The pH of fresh chilli has been shown to vary with time of harvest and degree of ripeness. Properly canned chilli fruits generally have maximum shelf-life of two years. Citric acid is most commonly used to preserve chilli. Invariably the pH of processed chilli pods can increase during storage. It may change from an initial 4.37 to 4.59 after twelve

Table 17. Product description and intended use in chilli

1.	Product name(s)	Chillies
2.	Important product characteristics of end product	• Moisture 11.5% • ASTA cleanliness specification • Aflatoxin B1 + B2 2 ppb - EEC G1 + G2 4 ppb – EEC
3.	How the product is to be used	• Whole chilli • Dried chillies • Stemless, chilli flakes, chilli powder • Oil and oleoresin
4.	Packaging	• Clean dry gunny bag, 25 kgs • Multi layer paper bags for export • Cloth bags with inner polylynings for crushed chillies • Consumer packages
5	Shelf-life	• 8 months – whole chilli • 3-4 months – chilli powder • 13 years – oil oleoresin
6	Where the product will be sold	• Domestic and international market

months of storage. The initial pH of canned products should be sufficiently low to compensate for such a pH change during storage.

Fruit softening of canned chilli/paprika can be minimized with calcium treatments. Calcium chloride is the best source for this purpose. The combination of citric acid and 0.02% calcium chloride makes the product firm and improves the drained weight. Canned chilli which is thermally processed at 100°C for 50 minutes contained higher capsaicin levels than fresh samples. The process involves blanching of fruits for 3 minutes at 100°C, rinsing and packing in brine (2% Acetic acid, 2% Vegetable oil, 0.2% sodium chloride- the solution being hot) and thermal processing at 100°C for 50 minutes.

10.5.2. Brined/pickled chilli

The pickling and brining process involves adding sufficient quantities of salt and acetic acid to prevent microbial spoilage. Chilli packed in this manner has superior textural qualities compared with canned products.

The effectiveness of brining for preservations is related to the rate of acid diffusion into all parts of the fruits and the time required reaching an equilibrium pH of 4.6 or below. The primary areas for acid penetration are through the stems and calyxes and into the placentas. The interior of fruit walls is the last area to become acidified, and the entire process can take at least 6 days. Therefore, the first week of brining is the most critical. Exposure to oxygen prior to brining can reduce the time for acid penetration to 1 day. Blanching can also improve the rate of acid penetration into the fruit and therefore reduce the pH variability among fruit parts.

Fresh chilli fruits are placed in a primary brine to firm and to preserve the fruits. After the minimum period of 2-8 weeks (depending on variety and process), the fruits are removed from the first brine, washed, graded a second time, and then repacked whole or sliced in the finishing brine.

In general, the initial brine has a sufficiently high salt and acetic acid concentration to ensure that the fruits retain rigidity and colour, and that microbial growth is prevented. The initial brine should have a maximum pH of 3.8 with 1-1.5% acetic acid by weight, and the solution should be saturated with food or pickle grade salt (24-26% by weight). Saltimeters or specific gravity meters can be used to ensure that the brine is at least 98% saturated. Final packing brines vary according to producer recipe, but are usually formulated for a pH of 4.2 or less.

Sodium bisulphate (0.5-1% by weight) is the most common preservative in pickled chilli. Sodium bisulphate is an effective preservative but imparts an off-flavour which should be leached in the second, packing brine. Brined chilli fruits can be produced without preservatives by using a more costly refrigerated process. Brined fruits without chemical preservatives are then packed in finishing brines with higher vinegar and salt concentration than those with bisulphate. Fruits can be stored in the initial brine for up to 9 months before packing although it is common to store for 2-3 months.

10.5.3. Fermented chilli

Hot chilli varieties of C. annuum, C. *frutescens* and C. *chinense* can be used to produce bottled hot chilli sauce with characteristic flavour and pungency. The chillies are typically ground with 14-20% salt. Depending on the hot sauce recipe, the mash is either used immediately or aged for several months or years. During the process of ageing, fermentation occurs through microbial action and contributes to the unique aged flavour of the mash and, ultimately, the hot sauce. Tabasco sauce, produced by the McIlhenny Company of Louisiana, is one of the best known hot sauces. It is produced from fruits of C. *frutescens*. Hot tabasco chilli mash is aged for a minimum of 3 years in oak barrels before being used in Tabasco sauce production.

10.5.4. Dehydrated chilli

Large quantities of dehydrated chilli are used in prepared meals, seasoning blends and in the canning industry. Dehydration of chilli for storage is an ancient art. The quality of red chilli and paprika products is based on pungency level and extractable red colour and flavour. Chilli must be processed and stored correctly to maintain high quality. Chilli and paprika are dehydrated and sold as whole pods, or ground into flakes or powder.

Traditionally, Chilli is dehydrated by sun-drying. Originally, the fruits were spread on roofs or even on the ground, but damage by birds and rodents caused poor quality for the processors. Controlled artificial drying is now practiced by virtually all commercial processors in the Country. Red colour retention mainly depends on the prevention of an oxidative process that reduces the original colour. Colour can fade rapidly if too much moisture is removed, but mould may grow if moisture content is high. While there is a market for whole dried chilli with good red colour, most of the pods are diced and dried. The diced fruits are dried to 4-6% moisture content. The dried chilli is then ground and rehydrated to 8- 11 % moisture, an optimal level for storage. Cold storage (3° C) is also recommended.

Red colour retention is an important quality consideration for paprika and chilli powder and mainly depends on prevention of oxidation of the powder. Moisture content, storage temperature and atmosphere, light, harvest conditions and timing, variety, and drying conditions all may affect colour retention. Of these, variety and storage temperature have the greatest influence on colour retention. The initial colour of chilli fruits at harvest or after dehydration is not a good indication of the rate of colour loss in storage. Therefore, varieties should be bred and evaluated for both initial colour and colour retention properties.

Defoliants or desiccants, such as sodium chlorate, are often used to accelerate fruit drying during wet weather as well as to aid harvesting.

Table 18. Cost of cultivation of chillies

Sl. No.	Items	Rs./ha
1.	Land preparation	1000.00
2.	Cost of seeds (1.6 kgs)	1250.00
3.	Raising nursery	1000.00
4.	Transplanting	1500.00
5.	Cost of fertilizers Urea – 8 bags DAA – 5 bags Complex – 6 bags	10000.00
6.	Organic manure (FYM 25 MT)	1000.00
7.	Pesticides	10000.00
8.	Weeding and Inter cultural operation	2000.00
9.	Irrigation	2000.00
10.	Harvesting	7500.00
	Total	**37250.00**

10.5.5. Paprika products

The main products of paprika are paprika powder and oleoresin. Paprika powder is obtained by grinding the dried red fruits after removing the seeds and pedicels. Paprika oleoresin is obtained by solvent extraction of the dried ripe fruits with subsequent removal of the solvent. It is a homogenous dark liquid and is dispersible in water and vegetable oils.

11.0 MARKETING AND ECONOMICS

11.1. Economics

11.1.1. Cost of cultivation

The cost of production of chillies is given in tables 18 & 19.

Table 19. Cost of cultivation of chillies

Items	Rs./ha
Human labour	18,740.00
a) Family	13,200.00
b) Hired	6,540.00
Seeds	14,091.00
Manure	4,183.35
Fertilizer	2,328.00
Plant protection chemicals	1,320.60
Interest on working capital	1,631.70
Land revenue	25.00
Total cost Rs./ha	62,059.65

Source : www.indianspices.com

11.1.2. Export

The world export of chilli has increased from 1.36 million mt during 1999 to 1.71 million mt during 2003 and also unit price from 1093.6 $ to 1380.9 $ in the world market. Trend in export of chilli has been increasing over past five years. India is the highest exporter and consumer in chilli, and earned the highest amount of foreign exchange among the spices cultivated. India's export of this commodity to other countries during 1991-92 was 32,603 mt valued at Rs. 8948.5 lakhs, which has reached a record high of 81,500 mt worth Rs. 35511.25 lakhs during 2003-04 (table 20).

In recent years, value-added products like oleoresin, natural red colour (carotenoids) and pungent principle (capsaicin) manufactured for use in food and pharmaceutical industry are also exported. Oleoresin of chilli with low, medium or high pungency is also exported in large quantities. Chilli powder is another important item of export. Other chilli products include: chilli seed, chilli paste, capsicum oleoresin, paprika oleoresin, etc. Among the various items/products exported from India, dry chilli contributed maximum, followed by chilli powder and paprika oleoresin (Table 21).

Table 20. Export of chillies from India (1991-92 to 2003-04)

Year	Quantity (mt)	Value (Rs. Lakh)	Unit Value (Rs./kg)
1991-92	32,603	8948.49	27.45
1992-93	17038	6837.09	40.13
1993-94	30776	7213.56	23.44
1994-95	20096	5711.63	28.42
1995-96	56165	19546.17	34.80
1996-97	50051	20145.15	40.25
1997-98	51779	15890.02	30.69
1998-99	68019	25287.26	37.18
1999-2000	63591	25471.55	40.06
2000-01	62448	22973.30	36.79
2001-02	69998	25244.02	36.06
2002-03	81022	31514.68	38.90
2003-04 (Estimate)	81500	35511.25	43.57

Source: Spices Board, Cochin (2004)

Table 21. Item-wise export of capsicum/chilli/paprika from India (2001-02 to 2002-03)

Items	2001-02		2002-03	
	Quantity (mt)	Value (Rs. Lakhs)	Quantity (mt)	Value (Rs. Lakhs)
Chilli dry	49227.14	15525.97	58379.31	21265.79
Chilli seed	766.14	103.84	477.93	78.29
Chilli fresh	21.00	14.46	103.90	41.45
Chilli powder	19983.22	9599.75	22060.36	10129.15
Chilli oleoresin	89.61	680.38	10.95	178.11
Capsicum oleoresin	485.27	3273.70	618.17	3741.57
Paprika oleoresin	1157.12	12676.60	1305.82	13290.01

Source: Spices Board, Cochin (2004)

Indian chilli and its products are imported by a number of countries. Important among them are: Sri Lanka, Bangladesh, South Korea, and USA for dry chilli; USA, Germany, Japan, UK and France for oleoresin. China and Pakistan are main competitors for India, who offer chillies at low prices in international markets. The varieties of chillies having foreign demand include Byadagi *Guntur, Paprika, Sannam – 4, Indian wrinkled* chillies, Wonder hot, Bird's eye chilli, Kashmiri chilli, and Warangal Chappatta.

India accounts for 60% of the total oleoresins extracted from raw material valued at Rs. 315.48 crores. Of all the oleoresins exported from India, Paprika oleoresins account for 42.13% share and valued at Rs. 132.9 crores. The current market for natural colours accounts for about 65% in Europe and is ever increasing. The red and yellow color hues outweigh all other hues. Moreover, usage rate and replacement of synthetic pigments have also increased the demand for paprika in the world market. Hence, India is having a great export potential. In India paprika like chillies *viz.*, Byadagi chilli in Karnataka and Tomato chilli in Warangal area of Andhra Pradesh are being cultivated by the farmers to meet the huge demand of paprika industry.

11.2. Marketing

Marketing of chilli remains a major constraint. There are several types marketing channels prevailing for chillies depending upon the end use. For produce the channel is; (Producer → wholesaler → retailer → consumer or Producer → commission agent → wholesaler → processing factory → spice

Table 22. Major chilli marketing centers in India

State	Centers
Maharashtra	Nasik, Ahmed Nagar, Sholapur, Aurangabad, Nanded, Amaravathi, Lasalgaon
Andhra Pradesh	Guntur, Warangal, Hyderabad, Guddapah, Vijayawada, Rajamundri, Nellore
Karnataka	Dharwad, Mysore, Hassan, Bangalore, Bellary, Ranibennur, Hubli, Byadgi
Tamil Nadu	Pollachi, Ramanad, Madurai, Trichi, Theni, Dindigul, Virudunagar, Sattur

Table 23. Important market types of chilli and major fruit traits

Market type	Important fruit quality traits
I. Fresh market (green, red, multi colour whole fruits)	Colour, pungency, shape, size, lobe number, flavour, exocarp thickness, endocarp : seed ratio, vitamin A and C
II. Fresh processing (sauce, paste, canning, pickling)	Colour, pungency, shape, size, pericarp thickness, endocarp : seed ratio
III. Dried spice (whole fruits and powder)	Colour, pungency, shape, size, dry weight, low crude fibre, endocarp : seed ratio
IV. Oleoresin extraction	Colour, pungency (essential oils)
V. Ornamental (plants and/or fruits)	Colour, pungency, shape, size, dry weight

Source: Mathura Rai (2005)

Table 24. Agmark grade specifications for commercially known chillies

Grade Designation	Trade Name	Colour	Length, cm	Pods with out stalks %w/w, max.	Broken chillies, %w/w, max.	Loose seeds, %w/w, max.	Damaged & discoloured pods, %w/w, max.	Foreign matter %w/w, max.	Moisture content %w/w, max.
Commercial Name : Sannam									
SS	Sannam Special	Light red shining	5 and above	5	5	2	2	1	12
SG	Sannam General	Light red shining	Above 3 and below 5	10	7	3	4	2	12
SF	Sannam Fair	Blackish dull red	Above 3 and below 5	15	10	5	6	3	12
Commercial Name : Mundu									
M.S	Mundu Special	Deep red shining	Not exceeding 2.5	5.0	1.0	1.0	2.0	1.0	11.50
M.G	Mundu General	Deep red shining	Not exceeding 2.5	10.0	1.0	1.0	4.0	1.0	11.50
Commercial Name : Rari									
RS	Rari Special	Bright red	8 and above	2.0	5.0	1.0	1.0	1.0	11.50
RG	Rari General	Bright red	Below 8	2.0	5.0	1.0	2.0	1.0	11.50
Commercial Name : Gospurea									
GS	Gospurea special	Bright red	5 and above 5	2.0	5.0	1.0	2.0	1.0	11.50
GC	Gospurea special	Bright red	Below 5 and above 3	2.0	5.0	1.0	3.0	1.0	11.50
Varieties not covered above									
Special	-	Characteristic of the variety	-	5.0	5 0	2	2	1	12
General	-	Characteristic of the variety		10	7	3	4	2	12
Fair	-	Characteristic of the variety		15	10	5	6	3	12

Source: Agmark Grade specifications for Spices, Spices Board, 2001 trader → selling agents (within country and abroad) → consumer). For products/value-added products the chain is; [Producer → commission agent → wholesaler → processing factory → spice trader → selling agents (within country and abroad) → consumer or Producer → processor → commission agents (abroad) → retailer → consumer]. The commission agents still take a major share of consumer's price. The major marketing centers located in various states are given in table 22 and important market type of chillies and its quality parameters are given in table 23.

In Andhra Pradesh and Karnataka the most popular system of marketing is through regulated market committees. The Agricultural Produce Marketing Committees are operating market yards in all the major markets. In Tamil Nadu commission agents organise closed auctions. The grower sells the produce at auctions organised by the regulated market committees directly or through the commission agents. Regulated market committees conducts open auctions on a cash and carry basis, ensuring ready payment to growers. The regulated market committees also license dealers and commission agents operating in different market yards.

11.2.1. Grade specifications

Agmark grade specifications for commercially known chillies are given in table 24.

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Paprika variety - Kt-pl-19

Paprika like chilli in the field

Chilli fruits

NUTMEG

B. Krishnamoorthy, J. Rema, N. K. Leela, T. K. Jacob

1.0. INTRODUCTION

Nutmeg (*Myristica fragrans* Houtt.) produces two separate spices, namely nutmeg and mace. Nutmeg is the dried kernel of the seed and mace is the dried aril surrounding it. Nutmeg is indigenous to Moluccas Islands (Indonesia). The species of the genus *Myristica* are distributed from India and South East Asia to North Australia and the Pacific Islands. A total of 72 species are distributed in these areas. The major nutmeg growing areas are Indonesia and Grenada (West Indies). It is also grown on a smaller scale in Sri Lanka, India, China, Malaysia, Western Sumatra, Zanzibar, Mauritius and the Solomon Islands. In India, nutmeg is mainly cultivated in Thrissur, Ernakulam and Kottayam districts of Kerala, parts of Kanyakumari and Tirunelveli districts in Tamil Nadu and in Uthara Kanara, Chikmangalur and Shimoga districts of Karnataka.

Nutmeg and mace are the two major primary products of *Myristica fragrans* and are commercially considered as spice. Both the spices have similar flavour. However, nutmeg is reported to be slightly sweeter than mace and is more preferred in food. Besides nutmeg and mace, a number of other products are commercially important. Oleoresins, nutmeg butter, essential oils are also derived from *M. fragrans* and they find varied use in the food, medicine and perfume industries.

1.1. Area and production

Nutmeg is produced in the tropical areas of Indonesia and the West Indies. World production of nutmeg is about 12,000 tons per year with an annual world demand of 9000 tons. Production of mace is about 2000 tons. Indonesia and Grenada dominate production and export of both the products with a world market share of 75% and 20% respectively. Other producing countries include India, Malaysia, Papua New Guinea, Sri Lanka and a few Caribbean Islands. The area and production of nutmeg in India is given in table 1. The East Indian islands of Siauw, Sangihe, Ternate, Ambon, Banda and Pupua produce highly aromatic nutmeg, traded as East Indian nutmeg. Grenada produces the West Indian nutmeg which is milder in flavour and lighter in colour. International trade in nutmeg is either of the East Indian or the West Indian nutmeg, with a negligible quantity of wild 'Bombay' nutmeg imported by USA. The principal import markets are the European Community, the USA, Japan and India. Singapore and Netherlands are the major re-exporters. USA is the biggest individual market for whole nutmegs. US importers prefer the East Indian type of deep brown, aromatic nutmeg and orange red mace in their whole form. Indonesia has traditionally been the principal supplier of nutmeg and mace to the US market, accounting for an average 65% of total US imports of nutmeg per year in terms of volume. Export of nutmeg and mace from India is given in table 2.

Table 1. Area and production of nutmeg in India

Year	Area (ha)	Production (mt)	Yield (Kg/ha)
2001-02	7,853	1,987	253
2002-03	8,675	2,184	252

Table 2. Export of nutmeg and mace from India

Product	2001-02		2002-03	
	Quantity (mt)	Value (Rs.Lakhs)	Quantity (mt)	Value (Rs.Lakhs)
Nutmeg	1331.82	1936.07	998.05	2130.51
Nutmeg powder	-	-	381.33	710.62
Mace	14.23	54.12	1.19	6.23

1.2. COMPOSTION

The major constituents of both nutmeg and mace oil are monoterpene hydrocarbons, together with smaller amounts of oxygenated monoterpenes and aromatic ethers.

Major constituents of the monoterpene hydrocarbons are pinene and sabinene and the major aromatic ether constituent is myristicin. Aromatic ethers, myristicin, safrole and elemicin determine the flavour and medicinal properties to a great extent. A recent GC analysis of the oils of nutmeg and mace showed 33 constituents in nutmeg oil and 51 in mace oil. Both the oils are qualitatively similar in composition, differing only in their quantity. Nutmeg oil consists of 67.8% monoterpenes, 12.1% oxygenated monoterpenes and 9.8% phenyl propanoid ether whereas, mace oil contains 51.2% monoterpenes 30.3% oxygenated monoterpenes and 18.8% phenyl propanoid ethers and the composition varies with the geographical location. The Indonesian nutmeg contains 2% myristicin compared with 0.13% in *M. argentea*. No myristicin was reported in *M. mulleri*. The safrole content, a suspected carcinogen, was 0.13, 0.51 and 0.245 in *M. fragrans*, *M. argentea* and *M. mulleri*, respectively. The myristicin fraction together with the elimicin is responsible for the hallucinogenic properties of nutmeg seed. The composition of essential oil changes on prolonged storage. Composition of nutmeg and mace, specifications of British Standards Institutions for nutmeg oil and composition of nutmeg oils of different geographical origins are given in tables 3, 4 and 5.

1.3. Main uses

1.3.1. Food

Nutmeg mace, their oleoresins and essential oils are used in the food and beverage industries. Although whole nutmeg is available, ground nutmeg is more popular. The spice in the ground from is mainly used in the food processing industry. In South-East Asia, China and India, both the spices are used sparingly.

Nutmeg is a standard seasoning in many Dutch dishes. Nutmeg and its oleoresin are used in the preparation of meat products,

Table 3. Composition of nutmeg and mace (%)

Composition (%)	Nutmeg	Mace
Moisture	40.00	40.00
Volatile oil	11.00	15.30
Non- Volatile ether extract	33.60	21.98
Starch	30.20	44.05
Sugars		
Glucose	0.10	0.17
Fructose	0.07	0.10
Total reducing sugars	0.17	0.27
Sucrose	0.72	0.39
Total sugars	0.89	0.65
Protein	7.16	9.91
Crude fibre	11.70	3.93
Total ash	2.57	1.56
Ash insoluble in HCL	0.20	0.15
Polyphenoles		
Total tannins	2.50	-
True tannins	1.00	-

soups, sauces, backed food, confectioneries, puddings, seasoning of meat and vegetables, to flavour mild dishes and punches. The fleshy outer cover of the fruit is crystallized or pickled or made into jellies.

Mace is sold either as whole or as ground spice and is used in savory dishes. Mace is used to flavour milk-based sauces and processed meats like sausages, soups, pickles and ketchup. Pickles and chutneys are also seasoned with mace. Because of its aroma, the essential oil is used as a natural flavouring extract and is employed for flavouring food products and liquors. Nutmeg oil and mace oil are used mainly in flavouring soft drinks, canned foods and meat products.

1.3.2. Medicine

Oil of nutmeg is useful in the treatment of inflammation of the bladder and urinary tract, halitosis, dyspepsia, flatulence, impotence, insomnia and skin diseases. It is also used externally as a stimulant and the ointment as a counter-irritant. Essential oil has got several compounds, most of which are valuable in industry. Most of the pharmacological properties of nutmeg are attributed to the compounds in the essential oil. Mace oil possesses almost identical physiological and organoleptic properties as nutmeg oil. Nutmeg butter is a mild external stimulant used in the form of ointments, hair lotions and plaster, and used against rheumatism, paralysis and sprains.

Both nutmeg and mace contain the active ingredient myristicin which possesses nar-

Table 4. Specifications of British Standards Institutions for nutmeg oil

Specification	East Indian Oil	West Indian Oil
Colour	BS 2999/37:1971 Colourless to yellow	BS 2999/38:1971 Colourless to pale yellow
Apparent density (mass per ml) at 20°C	0.885 to 0.915	0.860 to 0.880
Optical rotation at 20°C	8.0° to 25.0°	25.0° to 45 0°
Refractive index at 20°C	1.4750 to 1.4880	1.4720 to 1.4760
Solubility in ethanol (90 per cent (v/v at 20°C)	3.0 volumes	4.0 volumes

Table 5. Composition of nutmeg oils of different geographical origins (%)

Source component	Grenada	St. Vincent	Malay Seedlings	Papua	Indonesia	Penang	Singapore (1)	Singapore (2)
α-Pinene	10.6	12.6	12 8	21.3	18 0	19.9	21.2	19.2
Camphene	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0 4
β - Pinene	7.8	12.1	9.3	14.3	9.7	17.7	12.7	11.0
Sabinene	50.7	49.6	44.1	30.0	27.0	36.3	17.8	15 4
Myrcene	2.5	2.8	2.9	2.4	2.2	2.5	2.6	2 3
α phellandrene	0 4	0.6	0.6	0.5	0.5	0.4	1 0	0.7
α -terpinene	0.8	1.9	1 8	1.1	2.0	0.8	4.0	2 5
Limonene	3.1	3.3	3.1	2.7	2.7	2.8	3.6	3 4
1,8-cineole	2.5	2.3	2.1	1.9	1.8	1.5	3.2	2.7
γ- terpinene	0.4	3.1	2.8	1.9	3.3	1.3	6.8	4.1
p-cymene	0.8	0.7	0.8	0.5	0.7	0.3	1 8	2 7
Terpinolene	1.7	1.2	1.2	1.1	1.1	0.6	2.1	2 6
trans- sabinene hydrate	0.8	0.3	0.5	0.1	0.6	0.2	0.3	0 5
Copaene	0.3	*	*	0.2	0.3	*	0.2	0 2
Linalool	0.9	0.4	0 2	1.0	0.3	0.2	0.8	0.9
cis- sabinene hydrate	0.7	0.2	0.4	0 2	0.6	0 2	0.2	0 4
cis-p- menth-2-en-ol	0.4	0.1	0.1	0 3	0.5	0.1	0.3	0 3
Terpinen-4-ol	6.1	3.5	6.0	3 9	7.3	2 0	9 3	10 9
Cis-piperitol	0.5	0.4	0.4	0.6	0 4	0.3	0.5	0.3
Safrole	0.2	0.1	0.8	1.5	2 1	0.6	1.9	3.2
Methyl eugenol	0.2	0.1	0.5	0 2	1.2	0.6	0.6	*
Eugenol	0.2	*	0.3	0.1	0.7	0.3	*	*
Elemicin	1.4	1.3	1.7	0.4	0.5	4 6	0.3	0.3
Myristicin	0.5	0.8	4.1	10.4	13.5	3.3	6.3	12.4

* Traces detected

cotic properties. Nutmeg butter contains elemicin and myristicin which are also narcotic and cause psychotropic effects. Ingestion in large quantities produces narcosis, delirium, drowsiness, epileptic convulsions and even death. It also causes temporary constipation and difficulty in urination and increased fat deposition in liver. Powdered nutmeg is used occasionally as a hallucinogenic drug, but such use is dangerous as excessive dose of mace has a narcotic effect and symptoms of delirium and epileptic convulsions appear after 1-6 hours of consumption.

1.3.3. *Perfume and other uses*

Nutmeg oil is used in cosmetics, men's perfume and toiletries due to its aromatic properties. Mace oil possesses almost identical physico-chemical and organoleptic properties as nutmeg oil. Mace oil is also used to a limited extent in perfumes and soaps.

The myristicin component which imparts the hallucinogenic properties is also reported to be an effective insecticide. The lignin type of constituents in the nut is anticarcinogenic. Camphene present in the oil is used in the manufacture of camphor and related compounds and has strong antibacterial, antifungal and insecticidal properties. Pinene of the essential oil of nutmeg is used to make camphor, solvent, plasticizers, perfume bases and synthetic pine oil. Dipentene is used in the manufacture of resins and is used as wetting and dispersing agent. Myristic acid is used in the preparation of soaps, liquid detergents, shampoos, shaving creams, perfume, plastics, in compounding rubber, paints and greases, in the synthesis of esters for flavours and perfumes and as a component of food grade additives. Larvicidal properties are also reported in mace.

2.0. BOTANY AND CROP IMPROVEMENT

2.1. Botany

Nutmeg belongs to a small primitive family Myristicaceae with about 18 genera and 300 species. The basic chromosome number of the genus is 7 and the somatic number in *M. fragrans* is $2n = 42$.

The nutmeg is a spreading evergreen tree, 4-10 m high, sometimes attaining 20 m. It is usually dioecious, but sometimes male and female flowers are found on the same tree.

There are numerous spreading branches with the main branches arising low on the trunk. The bark is grayish - black. Leaves are alternate, glabrous and exstipulate. The lamina, 5-15 cm long and 2-7 cm broad, is coriaceous, medium to dark green above and shining, light green or subglaucous beneath, with lower midrib yellowish green, and elliptic or oblong-lanceolate, with an acute base and the apex acute or slightly acuminate. The petiole is about 1 cm long. The male and female inflorescence are similar, glabrous and axillary, with the flowers in umbellate cymes in which there are 3- 10 flowers in the male inflorescence and 1-3 in the female. The main axis is 1-1.5 cm long, not branched, or rarely branched more than twice. The pedicels are pale green. 1-1.5 cm long, with a minute caduceus bracteole at the base of the flower. The flowers, up to 1 cm long, are fragrant, creamy-yellow in colour, waxy and fleshy. The calyx is bell –shaped, with 3 reflexes triangular lobes, and petals are absent. In the male flowers, which are rather smaller than the female, the androecium is up to 7 mm long glabrous, with a stalk 2 mm long, and acute at the apex, with 8-12 stamens with their anthers adnate to a central column and attached to each other by their sides. The female flowers, up to 1 cm long, have a puberulous, superior, sessile, one-celled ovary, 7 mm long, surmounted by a very short, white, two lipped stigma. Male and female flowers take 80 and 148 days respectively, for anthesis from the date of emergence of flower bud.

The fleshy drupe, resembling a large apricot, is usually pendulous, broadly pyriform, yellow, smooth, 6-9 cm long when ripe, as one of the most beautiful fruits in nature. There is a circumferential 'longitudinal' ridge, with the persistent remains of the stigma, and it is one-seeded. When ripe, the succulent, aromatic yellow pericarp, about 1.3 cm thick, splits into two halves along the suture to expose the purplish-brown, shiny testa, surrounded by a much-lacinate red aril attached to the base of the seed. The stout brittle testa encloses a broadly ovoid, grayish-brown kernel, about 2-3 cm long and 1.5-2 cm broad. The exterior of the kernel is longitudinally wrinkled and consists of convoluted dark-brown perisperm, a lighter-coloured endosperm and a small embryo.

2.2. Improvement

Among 100 accessions studied for sex segregation, a ratio of 50:45:5 was observed for male, female and bisexual types, respectively. Analysis of genetic variability in nutmeg progeny population, derived from 16 mother trees, collected from Kerala and Tamil Nadu, revealed lack of exploitable genetic variability for many characters like canopy shape, number of erect shoots, girth of main trunk at the base and number of fruits per tree. The ratio of seed weight and mace weight showed high heritability and genetic advance. Hence selection for this trait has to be given importance in selection programmes.

2.2.1. *Varieties*

As nutmeg is an obligatory cross-pollinated crop, the variation observed in the crop is considerable. The plants differ not only for all aspects of growth and vigour, but also for sex expression, size and shape of nutmeg, quantity and quality of mace. A good tree yields about 2000 fruits annually on an average, but the yield may vary from a few hundreds to about 10,000 fruits. Two varieties of nutmeg namely, Kokan Sugandha and IISR Viswashree are available for cultivation. IISR Viswashree has a very high yield potential (Table 6). This clonal selection yields 100 fruits at 5th year after planting, 600 fruits (6th year), 800 fruits (7th year) and 1000 fruits (8th year). At 8th year after planting @ 360 plants/ha, an average yield of approximately 3122 kg dry nut (with shell) and 480 kg dry mace per hectare could be obtained. 'Viswasree' gives 70% dry recovery in nut and 35% dry recovery in mace, while the nut has 7.1% essential oil, 2.5% oleoresin and 30.9% butter, the mace has 7.1% essential oil and 13.8% oleoresin.' Konkan Sugandha' was released in 1997 for Konkan region from the Regional Fruit Research Station, Vengurala. It is a single plant selection with an average yield of 200 fruits (average of 8 years) and a potential yield of 526 fruits (2.6 kg dry nut)

3.0. SOIL AND CLIMATE

Nutmeg thrives well in warm humid conditions in locations with an annual rainfall of 150 cm and more. It grows well from sea level up to about 1300 m above MSL. Areas with clay loam, sandy loam and red laterite soils are ideal for its growth. Both dry climate and water logged conditions are not good for nutmeg.

4.0. NURSERY MANAGEMENT

An important problem in nutmeg cultivation is the segregation of seedlings into male and female plants resulting in about 50% of unproductive male trees. Though, there have been several claims that sex could be determined at seedling stage on the basis of leaf form and venation, colour of young sprouts, vigour of seedlings and shape of calcium oxalate crystals on leaf epidermis, none of them is sufficiently reliable.

4.1. Vegetative propagation

The only alternative at present is to adopt vegetative propagation either to top-work male plants or to use budded or grafted plants. Nutmeg is commercially propagated

Table 6: Description of IISR Viswashree

a) Description of variety / hybrid.	:	Height of tree at 9 years (m): 3-5; Time taken for flowering:4 years; Yield per tree, 8th year :1000 fruits (1.33 kg mace, 9 kg dry nut); Width of the canopy (m):3-3.5; Trunk girth at 9 years (cm):45; Leaf length and breadth (cm) :18/5; Nature of flowering:2-3 flowers in every axil ; Colour of mace:Dark red; Colour of seed :Shining black; Size of seed: Bold
b) Distinguishing morphological characters	:	A high yielding, high quality variety with bushy and *compact plant type*.
(c) Maturity (range in number of days) Seedling/Transplanting to flowering, seed to seed.	:	Nutmeg is a perennial tree and takes about 9 months for fruit harvest from date of flowering
(d) Maturity group (early, medium and late-wherever such classification exists).	:	NA
(e) Reaction to major diseases under field and controlled condition (reaction to physiological strains/races/bio-types to be indicated wherever possible)	:	Relatively free from diseases. Low incidence of fruit rot caused by *Diplodia* spp.
(f) Reactions to major pests (Under field and controlled conditions including storage pests)	:	Relatively free from pests.
(g) Agronomic features (e.g. resistance to lodging, shattering, fertilizer responsiveness; suitability for early or late sown conditions, seed rate, etc.)	:	Spacing : 4.5m x 4.5 m: One male graft to be planted for every 10 female grafts for effective pollination; Short statured spreading tree being a graft;
(h) Quality of produce of grain, forage/fibre including nutritive value, where relevant	:	**QUALITY CHARACTERS** Nut oil (%):7.14 Mace oil (%):7.13 Nut recovery (%):70 Mace recovery (%):35 Oleoresin in nut (%):2.48 Oleoresin in mace (%):13.8 *Butter in nut* (%):30.9 Myristicin in nut oil (%):12.48 Myristicin in mace oil (%):22 Elemicin in nut oil (%):13.65 Elemicin in mace oil (%):20.8
(i) Reaction to stresses		Cannot withstand dry spell for a long period Requires irrigation and shading during dry periods.

through epicotyl grafts. For raising rootstocks, naturally split healthy fruits are harvested during June-July. The seeds are extracted from the pericarp and sown immediately in sand beds of convenient length, 1 to 1½ m width and 15 cm height. Regular watering is necessary for good germination. Germination may commence from about the 30th day and last up to 90 days after sowing. About 20 day old sprouts are transplanted to polythene bags containing a mixture of good soil, sand and cow dung (3:3:1).

4.1.1. *Epicotyl grafting*

The selected rootstock at the first leaf stage should have a thick stem (diameter of 0.5 cm or more) with sufficient length to give a cut of 3 cm long. Scions with 2-3 leaves, collected from high-yielding trees can be used for grafting. The stock and scion should have approximately the same diameter. A 'V' shaped cut is made in the stock and a tapered scion is fitted carefully into the cut. Bandaging at the grafted region may be done with polythene strips. The completed grafts are to be planted in polythene bags of 25 cm x 15 cm size containing potting mixture. The scion is covered with a polythene bag and kept in a cool shaded place protected from direct sunlight. After 1 month, the bags can be opened and those grafts showing sprouting of scions may be transplanted into polythene bags, containing a mixture of soil, sand and cow dung (3:3:1) and kept in shade for development. The polythene bandage covering the grafted portion can be removed after 3 months.

During grafting, precautions should be taken to prevent wilting of scions and to complete the grafting as soon as possible. The grafts can be planted in the field after 12 months.

4.1.2. Top working in nutmeg

Nutmeg is a dioeceous plant with separate male and female trees and normally the sexes segregate in 1:1 ratio. A softwood grafting technique with 100% success was standardized in *in situ* trees for converting male tress into female tress and for rejuvenation of unproductive old female trees. The technique involves detopping male trees at 1 m height and grafting the newly emerged shoots with scions from high yielding female trees by wedge grafting. The method is now being widely adopted by farmers.

5.0. PLANTING AND AFTER CARE

5.1. Preparation of land and planting

Planting in the main field is done at the beginning of the rainy season. Pits of 0.75 m x 0.75 m x 0.75 m size are dug at a spacing of 9 m x 9 m and filled with organic manure and soil about 15 days earlier to planting. For planting plagiotropic grafts, a spacing of 5 m x 5 m has to be adopted. A male graft has to be planted for every 20 female grafts in the field.

The plants should be shaded to protect them from sun scorch during early stages. Permanent shade trees are to be planted when the site is on hilly slopes and when nutmeg is grown as a monocrop. Nutmeg can best be grown as an intercrop in coconut gardens more than 15 years old where shade conditions are ideal. Coconut gardens along river beds and adjoining areas are best suited for nutmeg cultivation. Irrigation is essential during summer months.

5.2. MANURING

Manures are applied in shallow trenches or pits dug around the plants. The Kerala Agriculture Department recommends 20 g N (40 g urea), 18 g P_2O_5 (110 g superphosphate) and 50 g K_2O (80 g muriate of potash) during the initial year and progressively increasing the dose to 500 g N (1090 g urea), 250 g P_2O_5 (1560 g superphosphate) and 1000 g K_2O (1670 g muriate of potash) per year in subsequent years for a fully grown tree of 15 years or more. FYM is to be applied @ of 25 kg for 7-8 year old trees and 50 kg for fully grown up tree of 15 years.

6.0. DISEASES AND THEIR MANAGEMENT

6.1. Die back

The disease is characterized by drying up of mature and immature branches from the tip downwards. *Diplodia* sp. and a few other fungi have been isolated from such trees. The infected branches should be cut and removed and the cut branches pasted with Bordeaux mixture 1%.

6.2. Thread blight

Two types of blights are noticed in nutmeg. The first is a white thread blight wherein fine whitish hyphae aggregate to form fungal threads and traverse along the stem underneath the leaves in a fan shaped or irregular manner causing blighting of affected portions. The dried up leaves with mycelium form a major source of inoculum for the spread of the disease. The disease is caused by the fungus *Marasmius* pulcherima.

The second type of blight is called horse hair blight. Fine black silky threads of the fungus form an irregular, loose network on the stems and leaves. These strands cause blighting of the leaves and stems. However, these threads hold up the detached, dried leaves on the tree, giving the appearance of a birds nest, when viewed from a distance. This disease is caused by *Corticium equicrinus*. Both the diseases are severe under heavy shade. These diseases can be managed by adopting phytosanitation and shade regulation. In severely affected garden, Bordeaux mixture (1%) spraying may be undertaken in addition to cultural practices.

6.3. Fruit rot

Immature fruit split, fruit rot and fruit drop are highly prevalent in a majority of nutmeg gardens in Kerala. Immature fruit split and shedding are noticed in some trees without any apparent infection. In the case of fruit rot, the infection starts from the pedicel as dark lesions and gradually spreads to the fruit, causing brownish discolouration of the rind resulting in rotting. In advanced stages, the mace also rots emitting a foul smell. *Phytophthora* sp. and *Diplodia natalensis* have been isolated from affected fruits. However, the reasons for fruit rot could be both pathological and physiological. Bordeaux mixture 1% may be sprayed when the fruits are half mature to reduce the incidence of the disease.

In addition to these, occasional dark sunken lesions, dark scabbing, mostly restricted to the outer layers of the pericarp without affecting the mace, have also been noticed. The causative organisms, have not yet been isolated.

6.4. Shot hole

The disease is caused by the fungus *Colletotrichum gloeosporioides*. Necrotic spots develop on the lamina which is restricted by chlorotic halo. In advanced stages the necrotic spots become brittle and fall off resulting in shot holes. A prophylactic spray with Bordeaux mixture 1% is effective against the disease.

7.0. INSECT PESTS AND THEIR MANAGMENT

7.1. Black scale

The black scale (*Saissetia nigra*) infests tender stems and leaves especially in the nursery and sometimes young plants in the field. The scales are seen clustered together and are black, oval and dome shaped. They feed on plant sap and severe infestations cause the shoots to wilt and dry.

7.2. White scale

The white scale (*Pseudaulacaspis cockerelli*) is greyish white, flat and shaped like a fish scale and occurs clustered together on the lower surface of leaves especially in nursery seedlings. The pest infestation results in yellow streaks and spots on affected leaves and in severe infestations the leaves wilt and dry.

7.3. Shield scale

The shield scale (*Protopulvinaria mangiferae*) is creamy brown and oval and occurs on tender leaves and stems especially in nursery seedlings. The pest infestation results in wilting of leaves and shoots.

The scale insects mentioned above and other species that may also occur sporadically on nutmeg can be controlled by spraying monocrotophos 0.05%.

8.0. POST HARVEST PROCESSING AND VALUE ADDITION

8.1. Harvesting and drying

8.1.1. Fruits

The female nutmeg tree starts fruiting from the sixth year, though the peak harvesting period is reached after 20 years. The fruits are ready for harvest in about 9 months after flowering. Flowering and harvesting continue throughout the year, but June-August is the peak period.

The fruits are ripe and ready for harvesting when the pericarp splits open. After harvest the outer fleshy portion is removed, and the mace is manually separated from the nut. The nut and mace are then dried separately either in the sun or by passing hot air. The scarlet coloured mace gradually becomes yellowish brown and brittle when drying is completed. The fleshy pericarp can be used for making pickles, jams and jellies.

Fruits are harvested when they split open on ripening. The split fruits are either plucked from the tree with a hook bill or are collected soon after they drop onto the ground. Nutmeg is dried in large trays by various procedures. The unshelled nutmegs are dried in the sun until the seeds inside rattle on shaking. Normally, nutmeg dries in about a week. The seed cover is removed by breaking the hard seed coat mechanically.

Nutmeg is usually packed in double layered linen, jute, sisal or polythene bags. If other packing materials are used, care must be taken to avoid materials which might lead to 'sweating' and mould development. Packaging should be such that the maximum weight loss is 10%. Spices must be dried thoroughly prior to shipment. They can then be transported in conventional vessels.

Powdered nutmeg is prepared by grinding at ambient temperature. Since during traditional grinding, most of the volatile oil escapes and quality deteriorates, chill conditioning and cryogenic grinding are alternative methods followed at present. The myristicin fraction of the volatile oil together with elemicin is responsible for the hallucinogenic property of the seed.

8.1.2. Mace

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-as and the colour retention is much better than sun dried mace. Dried mace is graded and packed. The fixed oil content of mace ranges from 20% to 35%.

Central Plantation Crop Research Institute, Kasaragod, Kerala has developed a small dryer for drying mace which has burning cum heat exchanger and drying chamber. Mace is spread in single layer over the wire mesh separating the plenum and drying chamber. The temperature of drying is maintained around 50°C.

As a pretreatment mace is subjected to blanching in 75°C hot water for 2 minutes, after which water is drained and mace is put for drying. Due to blanching the leathery texture does not turn soft and the mace become very vulnerable to moisture loss. Hot air requires 4 hrs to complete the process. The moisture content, volatile oil and oleoresin in dried mace range from 4.85-5.05, 11.57-12.40 and 21.25-22.57 per cent respectively while the lycopene is upto 149.0-182.2 mg/100g.

Blanching of mace: Mace after blanching takes only three and half hrs (reduction by 12.5%) for complete drying. In blanching lycopene increases significantly (increase by 22.3%). This is attributed to cessation of oxidative reaction and other physiological changes during blanching. Blanching softens the mace tissue and ruptures the cell wall making it more susceptible to loss of moisture. In addition, blanching provides glossiness and thus mace acquires more attractive and pleasing appearance. Reduction in mould and fungal population in dried mace due to blanching is also a possibility. Therefore, a simple blanching in hot water at 75°C for 2 minutes is recommended for quality of mace during drying.

If drying is delayed or prolonged even by a day, chances of mould and fungal contamination are very high. Drying to optimum moisture level without losing the inherent qualities especially the colour, is a prerequisite for long storage and better price. Sun drying bleaches the colour and may contaminate mace with mould. But artificial drying at 50°C, which takes 28 hours to reduce moisture content from 36 per cent to 9 per cent showed 'case-hardening' effect after drying

8.2. Value added products

8.2.1. Nutmeg oil and mace oil

The essential oil from nutmeg is steam distilled usually from substandard nutmeg and nutmeg oil ranges from 5% to 15% of the seed weight. The essential oil is highly sensitive to light and temperature and yields a colourless, pale yellow or pale green oil with a characteristic odour of nutmeg. The oil is soluble in alcohol and insoluble in water. The essential oil of East Indian nutmeg and West Indian nutmeg differ in their flavour and odour characteristics. The East Indian nutmeg oil is considered superior to the West Indian nutmeg oil, having a better aroma and a higher amount of phenyl propanoid ethers and terpenes. The physico-chemical properties of the two oils are reported to be different. East Indian nutmeg oil is also reported to have a higher concentration of myristicin (up to 13.5%), than West Indian nutmeg oil (less than 1%).

Mace oil is obtained by steam distillation of dried aril and yields 4% to 17% oil. It is a clear red or amber dark red liquid with characteristics odour and flavour. Mace oil is more expensive than nutmeg oil. Leaves also yield oil (0.34-0.65%), chemically similar to nutmeg oil, but its flavour and odour are inferior to both mace and nutmeg oil.

Extraction of essential oil can be carried out by different methods. However, mace oil extracted using liquid and carbon dioxide was superior in quality and flavour compared with the steam distilled oil. Essential oil has got several compounds, most of which are invaluable to industries. In addition to its use in cosmetic industries, nutmeg is also used in the pharmaceutical industry. The pharmacological properties of nutmeg are attributed to the compounds found in the essential oil. Numerous compounds have been isolated from nutmeg and mace. The yield and quality of the oil depends on the geographical location, grades and the distillation process involved.

8.2.2. Nutmeg oleoresin

Nutmeg oleoresin is obtained by solvent extraction of spices. Oleoresins contain saturated volatile oil, fatty oil and other extractives soluble in the particular solvent employed. Nutmeg oleoresins, obtained by solvent extraction from the dried spice of nutmeg, are used in colouring and flavouring in the food industry. The spice oleoresin can be used in place of the dried spice. The commercial products exhibit a range in their essential oil and fixed oil content depending on the method of extraction and solvents employed. Nutmeg extracted with benzene yields 31 to 37 % of oleoresins and with cold ethanol yields 18 to 26%. Higher fatty oil is obtained by hydrocarbon solvents while polar solvent like alcohol and acetone yield low fatty oils and resins. Commercial mace oleoresins are available with volatile oil content ranging from 10 to 55 %. When extracted with petroleum ether, it yields 27 to 32% and contains 8.5-22% volatile oils, and after chilling the yield reduces to 10-13%. Oleoresins extracted with non-polar solvents are preferred in flavouring processed foods since they are more stable to heat, whereas the perfume industry prefers polar solvents since they are soluble in most perfume materials and do not deposit any fatty materials in the bottles or containers.

8.2.3. Nutmeg butter

The fixed oil of nutmeg is known as nutmeg butter. Nutmeg butter contains 25 to 40% fixed oil, which is obtained by expressing the crushed nuts or by extracting with solvents. Fixed oil is a semi solid or reddish brown fat with both the aroma and taste of nutmeg. It is completely soluble in hot alcohol and sparingly soluble in cold alcohol. The fixed oil is freely soluble in ether or chloroform and is composed of trimyristin, unsaponifiable constituents (9.8%), oleic acid (3.5%), resinous materials (2.3%), linolenic acid (0.6%) and formic, acetate and cerotic acids in traces. Trimyristicin is a triglyceride of myristic acid and is volatile to yellowish grey solid. Reports say that the best nutmeg butter is imported from the East Indies. The fixed oils are also used in perfumes and medicines. In medicines, it is used for external application for sprains and rheumatism.

9.0. MARKETING

9.1. *Grading*

East Indian nutmeg and West Indian Nutmegs are the two grades of nutmeg. Good quality has to be maintained for trade of nutmeg and mace. Whole nutmegs are grouped under three board quality classifications:

- Sound: Nutmegs which are used mainly for grinding and to a lesser extent for oleoresin extraction.
- Substandard: Nutmegs which are used for grinding, oleoresin extraction and essential oil distillation.
- Distilling: Poor quality nutmegs used for essential oil distillation.

In Indonesia, high quality of sound whole nutmeg are traded in grades which refer to their size in numbers of nutmeg per pound: 80s, 110s and 130s or 'ABCD' which is an assortment of various sizes. Substandard nutmegs are traded as 'sound shrivelled', which in general have a higher volatile content than mature sound nutmeg and are used for grinding, oleoresin extraction and oil distillation. 'BWP' (broken, wormy and punky) are used mainly for grinding, as volatile oil generally does not exceed 8%. Distilling grades of nutmeg are of poor quality: 'BIA' or 'ETEZ' with a volatile oil content of 12-13%.

In Grenada, sound nutmegs are sold as sound unassorted which corresponds to the Indonesian grade 'ABCD'. Substandard nutmegs are classified as floats and as defective, the latter is similar to the Indonesian BWP grade but considered of high quality. Distilling grades of nutmegs are primarily exported to the USA and consist of floats.

Mace is classified as whole pale mace, No. 1 broken mace, selected, unassorted or siftings (Indonesia) and as whole, broken blades or siftings (Grenada). The International Standards applicable for trade in spices of nutmeg and mace are ISO 6577:1990.

During storage and transportation, oils should be protected from light and stored in tightly-packed containers at a temperature not exceeding 25°C. Prolonged storage deteriorates the composition of the oil.

9.2. Quality specifications

Though national standards are available for maintaining the quality, the European traders prefer the ASTA cleanliness specifications as they are more stringent than the National standards. The specifications are furnished in table 7. The Quarantine system and Plant Projection Law and the Food Sanitation Act set the quality standard in Japan.The Dutch standards for cleanliness is furnished in table 8. Aflatoxin and salmonella are the common complaints on the imports of nutmeg. The presence of insects is a major complaint for US importers.

Adulteration is common in the nutmeg trade. The essential oil has often been extracted before they are marketed and such nuts can be detected by their light weight and are more subjected to insect attack. *M.fragrans* is adulterated with *M. argentea*, *M. malabarica* and *M. otaba* which can be identified by their poor quality. The mace from *M. argentea* is imported as Papuan nutmeg from Papua New Guinea; *M. malabarica* is traded as Bombay nutmeg from India and from M. *otaba* as *Otaba* nutmeg. Trade of wild nutmeg exists and they are marketed as long, female, Papua, Guinea, or Norse nutmeg. All these have been traced to *M. argentea* of New Guinea from where they enter into the market as Madagascar nutmegs.

Table 7. American Spice Trade Association (ASTA) cleanliness specifications

Product	Insect (by count)	Excreta mammalian (mg/lb)	Excreta other (%wt)	Mould (% wt)	Insect infested (% wt)	Foreign matter (%wt)
Nutmeg (broken)	4	5	1.0	*	*	0.5
Nutmeg (whole)	4	0	0.0	*	*	0.0
Mace	4	3	1.0	2.0	1.0	0.5

* Not more than 5% by weight insect defiled and mould infected.

Table 8. Dutch regulation for cleanliness specifications

Product	Ash content (max.%)	Sand content (max%0	Volatile oil (Min. %)	Others
Nutmeg	3.5	0.5	4.0	NVEE* 5.0
Mace	3.5	0.5	4.0	NVEE* 4.0

NVEE - Non-volatile ether extract

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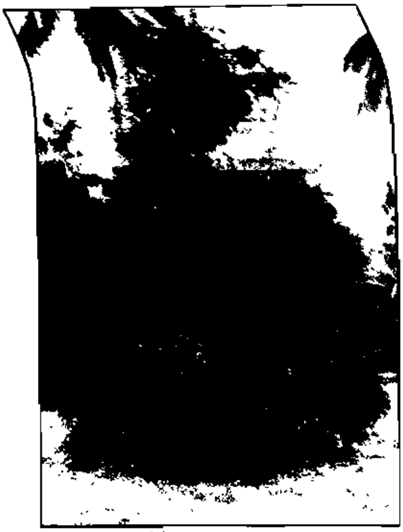
Nutmeg tree


Nutmeg fruit, mace and seed

IISR Viswasree


A. Epicotyl grafting in Nutmeg


B. Epicotyl grafting in Nutmeg

CINNAMON AND INDIAN CASSIA

J. Rema, N. K. Leela, T. K. Jacob, B. Krishnamoorthy

The genus *Cinnamomum* Schaeffer (Lauraceae) consists of 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 of which 12 species each are reported from North East and South India. Many of the species of *Cinnamomum* have medicinal and spice value and are of great demand commercially. *Cinnamomum verum* Presl. (syn. *C. zeylanicum* Nees) (true or Sri Lankan cinnamom), 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. In India, *C. verum* and *C. tamala* are cultivated. *C. verum* is cultivated in Kerala, Tamil Nadu, Karnataka and some parts of Maharashtra and Orissa. In Kerala cinnamon is grown commercially at Anjarakandy Estate near Kannur. Indian cassia is grown in North eastern states of India namely, Arunachal Pradesh, Assam, Manipur, Nagaland and Tripura. This article details with C. verum and *C. tamala*.

1.0. INTRODUCTION

Cinnamon is one of the oldest spices known to man. The true cinnamon, Cinnamomum verum (Lauraceae) is a native of Sri Lanka and was introduced in to India by the Britishers in the 18 century. The crop is cultivated in certain states of India in a very limited scale. The Sri Lankan cinnamon is mainly produced in Sri Lanka, India and Madagascar. The name cinnamon refers to the tropical evergreen tree as well as the bark that is extracted from the plant. Cinnamon is known as *cannelle* in French; *ceylonzeimt/ kaneel* in German; *canella* in Italian; *canela* in Spanish, *yook gway* in Chinese, *dal-chini* in Hindi and *kurunda* in Sinhalese. The other synonyms used for cinnamon in the Indian languages are:Hindi: *Dalchini, Darchini;* Bengali, Gujarati, Marathi, Oriya, Punjabi and Urdu: *Dalchini*; Kannada: *Lavangpattai;* Malayalam: *Karuvapatta;* Sanskrit: *Darushila;* Tamil: *lavanga patta*. Cinnamon spice is obtained by drying the inner bark and is marketed as quills or powder.

1.1. Area and production

Sri Lanka is the major cinnamon producing country in the world. It controls 60 percent of the cinnamon trade in the world. An area of about 24,000 ha is under cinnamon in Sri Lanka producing around 12,000 tonnes quills annually. The country also produces around 120 tonnes of leaf oil and 4-5 tonnes of bark oil every year. Seychelles, Madagascar and India are also producing cinnamon in minor quantities. Seychelles produces around 600 tonnes quills yearly from about 34,000 ha of cinnamon. No published information is available on the present area and production figures of cinnamon in India. However, India has exported 18.12 tonnes of oleoresin and 17.39 tonnes of cassia oil in 2002-03.

1.2. Composition and uses

The dried inner bark of C. *verum* contains volatile oil, fixed oil, tannin, resin, proteins, cellulose, pentosans, mucilage, starch, calcium oxalate and mineral elements (table 1). The relative abundance of these components can vary according to the geographical origin of the spice, its quality and the duration of storage. The major constituent of cinnamon bark oil is cinnamaldehyde while that of the leaf oil is eugenol. The root bark provides an essential oil, which is of no importance commercially, containing camphor as the major constituent. The chemical composition of bark and leaf oils of cinnamon is given in table 2. The chemical composition and quality of individual samples of both bark and leaf oils can vary considerably. The factors affecting variation of individual oils include: the geographical origin of the material used, harvesting practice, distillation method and, in the case of bark oil, the quality of the bark distilled.

Bark oil is a pale yellow to dark yellow liquid with a strong, warm, sweet, spicy odour and a sweet, pungent taste. The bark oil consists of cinnamaldehyde, eugenol, eugenol acetate, cinnamyl acetate, cinnamyl alcohol, methyl eugenol, benzaldehyde, cinnamaldehyde, benzyl benzoate, linalool, monoterpene, hydrocarbon, caryophyllene, safrole, pinene, phyllandrene, cymene and cineol.

The leaf oil is a yellow to brownish yellow liquid with a warm, spicy odour lacking the richness of bark oil. Cinnamon leaf oil has eugenol (80-88%), cinnamaldehyde, cinnamyl acetate, pinene, linalool, eugenol acetate and some minor compounds. It also contains up to 4% volatile oil, tannins, *catechins and pre-anthocyanidins*, resins, mucilage, gum, sugars, calcium oxalate, two insecticidal compounds (cinnezalin and cinnzelanol); coumarins etc.

Table 1. Composition of cinnamon bark:

Compound	Content (%)
Moisture	09.90
Protein	04.65
Fat (Ether Extract)	02.20
Fibre	20.30
Carbohydrates	59.55
Total Ash	03.55
Calcium	01.60
Phosphorus	00.05
Iron	00.004
Sodium	00.01
Potassium	00.40

Table 2. Chemical composition of the leaf and bark oils of *Cinnamomum verum*.

Compound	Leaf oil (%)	Bark oil (%)
α-pinene	0.73	3.34
Camphene	0.29	0.63
β-pinene	0.26	0.61
Myrcene	0.77	2.70
α-Phellandrene	0.65	0.14
Limonene	0.32	1.21
1,8-Cineole	0.51	4.60
Benzaldehyde	0.14	0.61
Terpinolene	0.61	0.21
Linalool	2.77	3.70
α-Humulene	0.57	1.30
β-Caryophyllene	3.47	8.00
Isoborneol	-	0.08
α-Terpineol	0.28	0.70
Safrole	0.08	0.08
Hydrocinnamaldehyde	0.12	0.80
Methyl eugenol	-	0.15
Cinnamaldehyde	2.81	46.70
Eugenol	76.74	4.15
Isoeugenol	0.07	0.08
Cinnamyl acetate	1.00	8.78
2-Phenethyl acetate	-	0.18

1.2.1. Uses

Cinnamon was used in ancient days by the Egyptians as medicine, as flavoring agent and also as an embalming agent and by the Hebrews for religious ceremonies. The Romans used cinnamon in perfumes and fragrances and to flavor wines. Today, cinnamon bark is widely used as a spice. It is employed in cookery as a condiment and flavoring material, being largely used in the preparation of desserts, chocolate and spicy candies and liquors. It is often used in savory dishes and meat preparations in the Middle East. In America, cinnamon and sugar are often used to flavor cereals and fruits, especially apples. The sweet taste of cinnamon is due to the presence of cinnamaldehyde. It is reported that, when combined with sweet food, the sweet sensation of the food is enhanced because of the synergetic effect between the sweet taste of sugar and sweet aroma of cinnamon. The deodouring/ masking property of cinnamon bark is due to the presence of trimethyl amine.

Cinnamon is a major constituent of the traditional medicines of India and China. Cinnamon is mildly carminative and used to treat nausea and flatulence. It is used alone or in combination to treat diarrhea. It is reported to have antioxidant and anti-clotting activity. The essential oil of cinnamon also has antimicrobial properties.

Leaf oil and bark oil are used in the manufacture of perfumes, soaps, tooth pastes, hair oils and face creams and also as an agent for flavouring liquor and in dentifrices. Leaf oil is used as a flavouring agent for seasonings and savory snacks to a small extent.

2.0. BOTANY AND CROP IMPROVEMENT

Cinnamomum verum is an evergreen tree, which reaches a height of about 8-17 m in a wild state. The bark and leaves are strongly aromatic. Leaves are opposite, petiole are 1-2 cm long and grooved on the upper surface. The lamina is about 5-18 cm long and 3-10 cm wide, ovate or elliptic, the base is more or less rounded and the tip tends to be some what acuminate. There are three, sometimes five, conspicuous longitudinal veins found at the base of the lamina and running almost to the tip. The young leaves of the flush are reddish in colour which later turns to green.

The flowers are borne in lax axillary and terminal panicles on the ends of the twigs. The peduncles are creamy white in colour, hairy, 5-7 cm long. The individual flowers are very small, about 3 mm in diameter, pale yellow in colour, with a fetid smell, and each subtended by a small ovate hairy bract. The calyx is campanulate and pubescent with 6 acutely pointed segments. The corolla is absent. There are 9 stamens, with the six outer stamens being opposite the perianth lobes and an inner whorl of 3, inside which are 3 staminodes. Each perfect stamen has a short hairy filament with two small glands present at its base and a four-celled anther opening by 4 small flap shaped valves. The ovary is superior, unilocular with a single ovule, tapering to a short style.

The trees flower in January and the fruits ripen during June-July. The fruit is a fleshy ovoid drupe, black and 1.5 –2.0 cm long when ripe, with the enlarged calyx at the base.

The method of pollination does not appear to be known with certainty, but it is probably pollinated by insects, especially flies.

In India, 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. Association analysis for nine characters in cinnamon revealed significant correlation of fresh weight of bark and leaf oil with dry bark yield. Bark oil was negatively correlated with leaf oil. Correlation and path analysis studies indicated that the economic yield characters namely, fresh leaf yield, leaf oil yield and eugenol yield were highly correlated among themselves. Plant height and canopy spread were highly and positively correlated with the yield component. Significant variability for bark oil content in cinnamon germpalsm is observed. Among the characteristics, the highest variation was for dry weight of bark followed by fresh weight of bark, bark oleoresin and leaf oil. Moderate variability was noted for bark oil and leaf size index. High association exited between fresh weight of bark and leaf oil with dry weight bark.

2.1. Varieties

Ever since the establishment of Research stations and Agricultural Universities systematic research on cinnamon was intensified. Various programmes on conservation of the biodiversity of *Cinnamomum* species and crop improvement programmes were intensified at various research centres and many promising varieties were released in the past two decades. At present there are seven released varieties in cinnamon. The salient features of these varieties are given in tables 3.

3.0 SOIL AND CLIMATE

Cinnamon is a hardy plant and tolerates a wide range of soil and climatic conditions. In the West Coast of India, the tree is grown on laterite and sandy patches with poor nutrient status. It comes up well from sea level up to an elevation of about 1,000 m. Cinnamon is cultivated in the lower elevations of Western Ghats in Kerala. It is also grown in certain parts of Tamil Nadu, Karnataka, Maharastra and Orissa. Cinnamon is mostly raised as a rainfed crop, an annual rainfall of 200-250 cm is ideal for its growth. The ideal temperature for growing cinnamon is 20-30°C. The quality of the bark is influenced by soil and ecological factors. Though tejpat is cultivated in North east India the climatic conditions prevailing there are ideal for growing cinnamon.

4.0 NURSERY MANAGEMENT

4.1. Propagation

Propagation of cinnamon is by cuttings as well as layers. The tree can be propagated from selected mother trees with the following characters:

1. The main stems should be erect with smooth and easily peelable bark.
2. The tree should be growing vigorously.
3. Trees should be with characteristic high leaf and bark oil contents.
4. Trees should be resistant to pests and diseases.

4.1.1. Cuttings

For raising cinnamon from cuttings; semi hardwood cuttings of about 10 cm length with 2 leaves are taken and dipped in IBA 2000 ppm or in a rooting hormone (seradix)

Table 3. Characters of released cinnamon varieties

Parameters							
Variety	IISR Navashree	IISR Nithyashree	YCD-1	PPI (C) 1	Konkan Tej	RRL (B) C-6	Sugandhini (ODC-130)
Research station	Indian Institute of Spices Research, Calicut	Indian Institute of Spices Research, Calicut	Horticultural Research Station, Yercaud, Salem District	Horticultural Research Station, Pechiparai, Kanyakumari District	Dr. B S Konkan Krishi Vidyapeeth, Dapoli, Maharashtra	Regional Research Laboratory, Bhubaneswar, Orissa	Aromatic and Medicinal Plants Research Station, Odakkali, Ernakulam District, Kerala
Year of release	1996	1996	1996	2002	NA	NA	2000
Pedigree	Seedling selection from Sri Lankan collections	Seedling selection from Indian collections	OP progenies	OP progenies obtained from IISR	OP seedlings	OP seedling progenies	Sri Lankan type obtained from a farmer in Wyanad. Single tree selection
Areas of adoption	All cinnamon growing areas in India	All cinnamon growing areas in India	High ranges of Tamil Nadu at an altitude range of 500-1000 m above MSL	Suitable for high rainfall area and lower elevations ranging from 100-500 m in Tamil Nadu	Konkan region in Maharashtra		Central zone of Kerala
Harvest	Three years for first harvest	Three years for first harvest	Three years for first harvest	Four years for first harvest		-	18.34 kg fresh leaves/tree/year
Average yield	200 kg dry quills / ha	200 kg dry quills / ha	360 kg dry bark/ha	973 kg fresh bark/ ha	378.30 g fresh bark/ plant	-	1.2 kg fresh /tree/year
Quality characters							
Bark oil (%)	2.7	2.7	2.8	2.9	3.20		0.94
Leaf oil (%)	2.8	3.0	3.0	3.3	2.2 %	0.8	1.6
Bark oleoresin (%)	8.0	10.0					
Bark recovery (%)	40.6	30.7	35.3	34.22	29.16		51
Cinnamaldehyde in bark oil (%)	73	58	-		70.23	83	45
Cinnamaldehyde in leaf oil (%)	15	14	-				
Eugenol in bark oil (%)	6.0	5.0			6.93		
Eugenol in leaf oil (%)	62	78		-	75.5	94	

Plant characters						
Height of tree at 5 years (m)	5-7	5-7				
Trunk girth at 5 years (cm)	30	45				
Colour of young flushes	Light purple turning to green in 8 – 10 days	Light purple turning to green in 2-4 days		Purple turning pale green in 4-7 days		
Leaf length and breadth (cm)	13.4/4.69	15.40/5.70				
Nature of flowering	Terminal and axillary	Terminal and axillary				
Time taken for flowering	4 years	4 years				
Shoot regeneration capacity	25.45 shoots/4 plants	18.90 shoots/4 plants	19.2 shoots/year	32 shoots/year		
Yield of dry bark per plant (g)	201.1	194.6				
Colour of dry bark	Light brown	Light brown				
Resistance to major pests and diseases	No major pest or disease attack was noticed	No major pest or disease attack was noticed	Resistant to major pests and diseases	Resistant to major pest and diseases		
Special characteristics	A selection with high shoot regeneration capacity. Higher cinnamaldehyde and oleoresin in bark.	A selection with high shoot regeneration capacity Gives quality quills. Bark oil, leaf oil and oleoresin contents high, giving good aroma and taste		Drought tolerant, high yielding		

and planted either in polythene bags filled with sand or a mixture of sand and coirdust in the ratio 1:1 or in sand beds raised in a shaded place. The cuttings in polythene bags must also be kept in a shaded place or in a nursery. The cuttings are to be watered regularly 2-3 times a day for maintaining adequate moisture and prevent wilting. Rooting takes place in 45-60 days. The well rooted cuttings can be transplanted to polythene bags filled with potting mixture and maintained in a shaded place and watered regularly.

4.1.2. Air layering

Air layering of cinnamon is done on semi hardwood shoots. A ring of bark is removed from the semi hardwood portion of the shoot and a rooting hormone (IBA 2000 ppm or IAA 2000 ppm) is applied on the portion where the bark has been removed. Moist coir dust or coir husk is placed around the region where the hormone has been applied and is secured in position by wrapping with a polythene sheet of 20 cm length. This would also avoid moisture loss. Rooting takes place in 40-60 days. The well rooted air layers are separated from the mother plant and bagged in polythene bags filled with potting mixture and kept in a shaded place or nursery by watering the plants twice daily. The rooted cuttings and layers can be planted in the main field with the onset of rains.

4.1.3. Seedlings

Cinnamon can also be propagated through seeds. In such cases variability is observed among the seedlings as it is cross pollinated. Under West Coast conditions, cinnamon flowers in January and the fruits ripen during June-August. The fully ripened fruits are either picked up from the tree or the fallen ones are collected from the ground. The seeds are removed from the fruits, washed free of pulp, and sown without much delay as the seeds have a low viability. The seeds are sown in sand beds or polythene bags containing a mixture of sand, well rotten cattle manure and soil (3:3:1). The seeds start to germinate within 15-20 days. Frequent irrigation is required for maintaining adequate moisture. The seedlings require artificial shading till they are about 6 months old.

5.0. PLANTING AND AFTER CARE

5.1. Preparation of land and planting

The area for planting cinnamon is cleared and 50 cm x 50 cm x 50 cm size pits are dug at a spacing of 3 m x 3 m. They are then filled with compost and top soil before planting. Cinnamon is planted during June-July to take advantage of the monsoon for the establishment of seedlings. For transplanting, 10-12 months old seedlings or well rooted cuttings or air layers are used. In each pit 3-4 seedlings or rooted cuttings or air layers can be planted. In some cases, the seeds are directly dibbled in the pits that are filled with compost and soil. Partial shade in the initial years is advantageous for healthy, rapid growth of plants.

6.0. MANURING

Two weedings in an year during June-July and October-November, and one digging of the soil around the bushes during August-September is recommended. A fertilizer dose of 20 g N, 18 g P_2O_5 and 25 g K_2O per seedling is recommended in the first year. The dose of fertilizers is increased gradually to 200 g N, 180 g P_2O_5 and 200 g K_2O for grown up plants of 10 years and above. The fertilizers are to be applied in two equal split doses, in May-June and September-October. Mulching with green leaves (25 kg) during summer and application of FYM (25 kg) during May-June is also recommended.

7.0 DISEASES AND THEIR MANAGEMENT

7.1. Pink disease

The pink disease is caused by the fungus *Corticium javanicum* and is more common during the monsoon season. The fungus develops as a pale pinkish white layer on the stem and destroys the corky layer resulting in the death of the twig. The disease can be controlled by spraying Bordeaux mixture 1%.

7.2. Seedling blight

Seedling blight is caused by the fungus *Diplodia* sp. and occurs on seedlings in the nursery. The disease results in the formation of light brown patches on the stem and often causes the death of affected seedlings. The disease can be controlled by spraying Bordeaux mixture 1%.

7.3. Leaf spot

The disease initially manifests as irregular grey patches on the leaves and later the infested portion dries and drops down. Fungi such as *Gloeosporium* sp. and *Cephaleuros* sp. have been isolated from infected leaves. Spraying Bordeaux mixture 1% can keep the disease under check.

8.0 INSECT PESTS AND THEIR MANAGEMENT

8.1. The cinnamon butterfly

It is a serious pest of cinnamon. The larvae of the pest are voracious feeders on the tender and maturing leaves and defoliate the trees completely. Nursery plants and trees in flushes suffer heavily from the attack of the pest. The adults are large with a wing span of 90 mm. In the field, the adults exist in 2 forms; the *clytia* and *dissimilis* forms mimicking *Euploea* sp. and *Danais* sp. respectively. In the *clytia* form the insect appears with blackish brown wings having a series of marginal white arrowhead shaped spots. The *dissimilis* forms have black wings with elongated white spots and a series of marginal arrowhead shaped spots.

The adult lays eggs singly on tender shoots and young leaves. The egg period is 3-5 days. The larvae on hatching are pale green in colour with a pale yellow dorsal line and irregular white stripes on the body. There are 5 larval instars and the fully grown larvae are dark brown and yellow in color with four rows of red spots. They measure about 25 mm in length. The larval period is from 11-18 days and prepupal period is 1 day. Pupation takes place on the stem of the tree and pupal period varies from 11-14 days. The life cycle is completed in 24-37 days. *Telenomus remus* Nixon (Hymenoptera: Scelionidae) is an major natural enemy of the pest, parasitizing more than 50% of the eggs in the fields. The pest can be controlled by spraying quinalphos 0.05% on tender and partly mature leaves.

8.2. Leaf miner

It is a major pest of the nursery plants and trees in flushes in the fields. The larvae mine into the leaves between the upper and lower epidermis and feed on the tissues. The attack results in leaf blotches. In severe cases of attack the leaves become crinkled and malformed. When the leaves mature, the damaged portions develop into holes.

The adult is a minute silvery white moth with fringed wings and the wing span is about 5 mm. Newly hatched larvae are pale creamy white in color and fully grown larvae become pinkish red. Pupation takes place outside the larval mines on the leaves.

8.3. Shoot and leaf webber

The larvae of the pest web the tender shoots and leaves and feed from within. The infestation is maximum in the fields during post monsoon periods.

The adult is a small moth with a wing span of 15 mm. The forewings are characterized with black spots. The adult lays eggs on newly emerged leaves and the egg period ranges from 3-4 days. The larva is pale green in color and larval period is completed in 10 days. Pupation takes place in the webs in silken cocoon and lasts for 6-7 days. *Goniozuz* sp.(Hymenoptera: Braconidae) is reported as a major larval parasite of the pest.

8.4. Chafer beetle

The beetles feed on the tender leaves of the tree. Their population becomes very high during monsoon period (July-August). The adult is a small beetle measuring 15X6mm in size and brown in color with metallic green head and thorax. The adult female lays eggs in the root zone of the tree and the egg period lasts for five days. The grubs on hatching are creamy white in color and measure 2.5 mm in length. They feed on the roots and complete larval period within 10 days. Pupation takes place in the soil in earthen cocoons and the pupal period is completed in 15 days. The pest can be controlled by spraying quinalphos 0.05% on tender and partly mature leaves.

8.5. Cinnamon blue bottle

The pest defoliates the crop. The larvae voraciously feed on the tender leaves, leaving behind only the midrib and veins. The adult butterfly is large with a wing span of 80 mm. The wings are blackish brown with pale greenish-blue elongated spots arranged in a row in the middle of fore and hind wings. The eggs are laid on tender leaves and the incubation period lasts for 5-6 days. The newly hatched larvae are spiny in appearance and as they grow become green in color and pale yellow lines appear longitudinally on the lateral and lower sides of the body. There are 5 larval instars which are completed in 29-31 days. Pupation takes place on the lower sides of leaves and is completed in 19-20 days.

8.6. Leaf webber

The larvae of the pest web together the tender leaves of the tree into clusters and feed on the leaf tissue within the clusters. Each cluster harbors several larvae in it. The eggs are laid in groups on tender leaves and the egg period lasts for 4-5 days. The newly hatched larvae are initially gregarious in nature and feed on the tender leaves by scrapping the tissue. Fully grown larvae are pale green in color with dark bands. There are 5-6 larval instars and the larval period is completed in 28-30 days. Pupation takes place in silken cocoons inside the webs. Pupal period is 11-14 days.

Pest management

Spraying of quinalphos(0.05%) can control leafminers, leaf eating caterpillars and beetles and monocrotophos (0.05%) against leaf miners.

9.0. HARVESTING, POST HARVEST PROCESSING AND VALUE ADDITION

9.1. Harvesting and processing

The cinnamon tree may attain a height of 10-15 m, but in cultivation, it is generally coppiced or cut back periodically. When the plants are 2 years old, they are coppiced during June-July to a height of about 12 cm from the ground. The stump is then covered by earthing up. This operation encourages the development of side shoots from the stump. This is repeated for every side shoot, developing from the main stem during the succeeding season, so that the plant will assume the shape of a low bush of about 2 m height and a bunch of canes suitable for peeling would develop in a period of about 4 years. Coppicing can be commenced from the fourth or the fifth year of planting.

The shoots are harvested from September to November, under Kerala conditions. Coppicing is done in alternate years and shoots having 1.5-2.0 cm thickness and uniform brown colour are ideal for bark extraction. A 'test cut' can be made on the stem with a sharp knife to judge the suitability of the time of peeling. If the bark separates readily, coppicing can be commenced immediately. The stems are cut close to the ground when they are about 2 years old, as straight as possible, 1.00 to 1.25 m length. Such shoots are bundled after removing the leaves and terminal shoots.

Cutting is followed by scraping and peeling operations. Peeling is a specialized operation, requiring skill and experience. It is done by using a specially made knife, which has a small round end with a projection on one side to facilitate ripping of the bark. The rough outer bark is first scrapped off. Then the scrapped portion is polished with a brass or an aluminium rod to facilitate easy peeling.

A longitudinal slit is made from one end to the other. Then working the knife between the bark and the wood, the bark is ripped quickly. The shoots cut in the morning are peeled on the same day. The peels are gathered and kept overnight under shade. They are dried first in shade for a day and then in sunlight for four days. During drying, the bark contracts and assumes the shape of a quill. The smaller quills are inserted into larger ones to form compound quills.

The quills are graded from '00000', being the finest quality, to '0' the coarsest quality. The small pieces of the bark, left after preparing the quills are graded as 'quillings'. The very thin inner pieces of bark are dried as 'featherings'. From the coarser canes, the bark is scraped off, instead of peeling, and this grade is known as 'scraped chips'. The bark is also scraped off without removing the outer bark and is known as 'unscraped chips'. The different grades of bark are powdered to get 'cinnamon powder'.

9.2. Value added products

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

9.2.1. Bark oil

Bark oil is one of the expensive oils in the world market. It is extracted from the bark through steam distillation. The quills can yield high quality oil when distilled. Usually, quillings are used for quality bark oil extraction. Commercial grade bark oil is prepared from a mixture of broken pieces of quills, quillings, pieces of inner bark from twigs and twisted shoots. The oil is light yellow in color when distilled and turns to red on storage. The bark oil is graded based on its cinnamic aldehyde content. The oil is widely used for flavoring confectionary, liquors, pharmaceuticals, soaps and dental preparations. Its major constituent is cinnamaldehyde, but other components present in minor or trace quantities impart the characteristic odour and flavour which distinguishes this oil from other oils.

9.2.2. Leaf oil

It is obtained by distilling the leaves through steam or water distillation. The leaves are allowed to dry for 3-4 days before distillation. Cinnamon leaf oil is yellow to brownish-yellow in colour and possesses a warm, spicy but rather harsh odour. The major constituent of leaf oil is eugenol (70-90%) while the cinnamaldehyde content is less that 5 per cent. It is used as a raw material for synthesis of vanillin. The oil is used for flavouring confectionary and sweets and in perfumery. The yield and quality of cinnamon leaf oil, like that of the bark oil, is dependent upon the geographical origin of the leaf material and upon the cropping and distillation practices used.

9.2.3. Cinnamon powder

The quills and remnants of the bark can be powered and used as cinnamon powder. For most baked products, cinnamon is used in the powdered form. The essential oil content of the powder is less compared to the bark due to losses during the process of grinding.

9.2.4. Oleoresin

The oleoresin may be prepared by extracting cinnamon bark with a variety of organic solvents. It contains the steam-volatile oil, fixed oil and other extractives of the spice soluble in the particular solvent employed. The characteristic organoleptic properties of the spice and its oleoresin are determined by the composition of their steam-volatile (essential)oils. The small amount of coumarin present also influences the flavour but other non-steam-volatile constituents appear to be unimportant.

9.2.5. Root bark oil

Cinnamon root bark oil is a colourless to pale yellowish-brown liquid with an odour similar to the stem bark oil but it is weaker, lacking in fragrance and is camphoraceous. The major component of this oil is camphor (about 60 %) which crystallizes out on standing.

9.3. Storage

Cinnamon should be stored in a cool, dry place. Excessive heat will volatilize and dissipate its aromatic essential oils, and high humidity will tend to cake it. Date the containers when they arrive, so that older stock will be used first. Store them off the floor and away from outside walls to minimize the chance of dampness. All spice containers shall be tightly closed after each use, because prolonged exposure to the air will also cause some loss of flavour and aroma. Under good storage conditions, the qualities of aroma and flavour for which cinnamon is prized will be retained long enough to meet any normal requirements of commercial baking. Whole cinnamon does not lose its volatile oil as fast as that of the ground form. When ground cinnamon is stored in bulk in an ambient warehouse, a loss of 0.1% volatile oil per month occurs. Whole quills will keep their flavour longer. Oleoresin flavour is stable at high temperature. On prolonged storage, owing to oxidation, it becomes contaminated with resin and cinnamic acid and changes to cherry red.

10.0. MARKETING

The quality of cinnamon is primarily assessed on the basis of their appearance and on the content of the aroma/ flavour character of their volatile oil. The appearance of the spice is rather more important when it is to be sold in the whole form on the retail market than if it is to be used for grinding or for the preparation of the essential oil or the oleoresin. The spices are prepared and supplied to the market in various forms, the most elaborate type of product being the compound cinnamon quills.

Sri Lanka followed by the Seychelles and Malagasy Republic are the major producers of true cinnamon bark with the best quality. The finest Sri Lankan cinnamon is very thin smooth bark, light-yellowish brown in color, highly fragrant, sweet and with peculiar pleasing aromatic taste. The major use of cinnamon is in the form of ground cassia and comes from Indonesia. The low grade cinnamon comprising feathering and chips is produced in limited quantities in Sri Lanka but constitutes a much larger share of total exports from Madagascar. The major importer of cinnamon is Mexico followed by West Germany, USA and Great Britain. Other importers are Saudi Arabia, Taiwan, Singapore, Hong Kong and France. The export of cinnamon and its products from India are given in Table 4. Spice is traded internationally in whole form and grinding is often carried out in the consuming centres.

Bark oil is produced from the distillation of imported cinnamon in Western Europe and North America. The major cinnamon bark oil supplier is Sri Lanka. France is the biggest importer followed by USA. Leaf oil is distilled in Sri Lanka and the Seychelles. USA and Western Europe are the largest markets for cinnamon leaf oil.

10.1. Grading

According to the Sri Lankan system of grading the cinnamon quills are graded into four groups

Alba (Less than 6 mm in diameter); *Continental*; *Mexican*) and *Hamburg* grades. These groups are further divided into specific grades, as follows

Fine/continental grades (6–19 mm diameter)

C- 00000 special (Thinnest)(6 mm); C-00000 (10 mm); C-0000 (13 mm); C-000 (16 mm) C-00 (17 mm); C- 0 (thickest) (19 mm).

Mexican grade (16 mm diameter)

M00000 special, M00000 and M0000 depending number of quills per kg. Mexican grade is intermediate in quality between Fine and Hamburg grades.

Hamburg grade (23–38 mm diameter)

H-1 grade (23 mm); H-2 (25 mm); H-3 (38 mm).

10.2. Exports

Table. 4. Export of Cinnamon and Cassia extractives from India

Product	1998 –99		2000 -01		2002 –03	
	Quantity (Mt)	Value (Million Rs)	Quantity (Mt)	Value (Million Rs)	Quantity (Mt)	Value (Million Rs)
Cinnamon oleoresin	0.54	136	2.92	536	-	-
Cassia oleoresin	15.55	6041	4.79	1524	18.12	4091
Cinnamon/ Cassia oil	1.16	121	0.69	64	17.39	788

Adulteration

Cinnamon is frequently adulterated with a rougher, thicker and less aromatic bark from cassia and *C. tamala*. Bark oil is usually adulterated with leaf oil.

INDIAN CASSIA (TEJPAT)

1.0. INTRODUCTION

Cinnamomum tamala (Lauraceae) or Indian cassia is known by different names in different languages (table 5). It is a moderate sized evergreen tree which is the source of *tejpat*, *tejpat* oil and Indian cassia bark. *Tejpat* is the dried leaf of *C. tamala and tejpat oil is the oil obtained by distilla*tion of the leaves. The dried bark of the stem is the Indian cassia bark. *C. tamala* is listed as nearly threatened as the crop is facing over exploitation and habitat destruction in India, such that the plant populations are considerably reduced.

Table 5: Vernacular names of *Cinnamomum tamala*

Language	Name
Assamese	Mahpat, Tejpat
Bengali	Tejpata
Hindi	Tejpat
Kannada	Patraka
Marathi	Tamaal patra
Oriya	Tejpatra
Punjabi	Tejpatra
Sanskrit	Tejpatra
Tamil	Talishappattiri
Gujrati	Tamalpatra
Telugu	Talisha, Patta akulu
Burmese	Thitchabo
Chinese	La pi shu
Danish	Indisk Laurbærblad
English	Indian bay leaf, Indian cassia, Indian cassia bark, Tamala cassia, Tejpat
Finnish	Kanelilaakeri
French	Laurier des Indes
German	Indisches Lorbeerblatt
Hungarian	Indiai babérlevél
Nepalese	Shisii, Tejapaat

1.1. Area and production

C. tamala is native to India and is reported to have originated in the Himalayas. Indian cassia is distributed in the Indian sub continent, Indo-China region, Bangladesh and Nepal. In tropical and sub-tropical

Himalayas it is distributed upto an altitude of 900-2500 m. Occurs in the north western, eastern and Sikkim Himalayas. It is also found in Meghalaya (Khasi Hills and Jaintia Hills) Assam (North Cachar Hills); Jammu and Kashmir; Himachal Pradesh (Drang Forest in Dauladhar ranges, Hamirpur, Shimla, Kangra, Chamba, Mandi, Solan, Nahan, Palampur) and Uttar Pradesh (Jaunsar, Tehri Garwal and Kumaon). Commercial cultivation of *C. tamala* is very limited and is reported in certain parts of the country. Plantations occur in Khasi and Jaintia Hills, Garo Hills, Mikir Hills, Manipur and Arunachal Pradesh, and in limited areas in Nainital district (U.P) and Kangra district (Himachal Pradesh). Since it is not grown commercially no statistics is available on the area and production of this crop.

1.2. Chemical composition and uses

1.2.1. Leaf oil or tejpat oil

The leaf oil is obtained by hydro or steam distillation of fresh, wilted or dried leaves. The leaf oil is lemon-yellow in colour. Wide variability is reported in the oil content of the leaf obtained from various localities. The leaf oil ranged from 0.03% to 0.9% in *C. tamala*. An oil yield of 0.03% was reported in the market samples from Pakistan. Leaf oil content of 0.23–0.36%, 0.4–0.45% (Himachal Pradesh), 0.7% and as high as 0.9% was reported. Seasonal variation was reported in the yield of leaf oil and the yield was maximum during November to December (0.4%-0.45%).

The chemical composition of *tejpat* oil is given in table 6.

Table 6. Chemical composition of tejpat oil

Compound	Per centage
α-pinene	0.13%
linalyl acetate	0.82%
Camphene	0.07%
β-terpineol°	0.82%
β-pinene	1.55%
β -terpineol	0.20%
(z) - β-ocimene	0.11%
β -terpinyl acetate	0.45%
β-phellandrene	0.97%
Borneol	0.40%
Limonene	0.45%
phenethyl alcohol	1.12%
β -terpinene	0.05%
Carvone	0.42%
p-cymene	.84%
Perillyl alcohol	0.16%
6-methyl-5-hepten-2-one	0.01%
Cis-carveol	0.04%
benzyl alcohol	0.59%
trans-carveol	0.01%
β-caryophyllene	1.18%
citronellyl acetate	0.74%
β -farnesene°	0.94%
(e)-cinnamaldehyde	52.86%
β -curcumene	0.67%
isoeugenol°	4.90%
β -bisabolene	1.63%
methyl isoeugenol o	1.63%
linalool	19.75
farnesol°	0.69%

1.2.2. Uses

Leaves of *tejpat*, are widely used in northern India as a spice for flavouring meats, sausages and sauces. The bark is also used as a spice for flavouring food. The leaves are used in place of betle leaf for *pan* making.

2.0. BOTANY

A small to medium sized aromatic evergreen tree. The leaves of a number of *Cinnamomum* species are being used by the local people of North East India as tejpat. Species of *Cinnamomum* namely *C. impressinervium*, Meissn, *C. bejolghota* (Buch Ham) *C. sulphuratum* Nees, *C. tamala* and few unknown types are used by the local people in Meghalaya as tejpat. A taxonomic key to the taxa of *Cinnamomum* used as tejpat in North East India is given in table 7.

2.1. Variants

The description of the four variants of *C. tamala* described are given below .

2.1.1. Variant I

Variant I. (RRL J 1607) is a medium-sized evergreen tree, growing to a height of 8 m high with zigzag branching; Bark rough, dark grey, aromatic, reddish brown, darkening on exposure. Leaves-alternate, subopposite or opposite on the same twig, coriaceous, aromatic, glabrous, shining above, dark green, pale below, pink when young, strictly ovate to ovate - lanceolate, apex acute to sharply acuminate, base acute to obtusely acute, variable in size, 2–4.5 x

Table 7. Key to the taxa of *cinnamomum*

1a.	*Panicles shorter than leaves (Fruit ellipsoid).*
2a.	Leaves with a strong clove like odour, elliptic-oblong to elliptic-lanceolate; Flowers February to April, Fruits May to August; Epidermal cells highly sinuous, stomata/mm^2 550 and stomatal index 19:52; Areoles tetragonal to polygonal, average frequency of areole/mm^2 7.88..*C. impressinervium*
2b.	Leaves with a sweet smell but not clove like, elliptic-lanceolate to narrowly ovate-lanceolate; Flowers August to October, Fruits November to April; Epidermal cells moderately sinuous, stomata/mm^2 511 and stomatal index 16:46; Areoles trigonal to polygonal, average, frequency of areole/mm^2 16.46...C. *sulphuratum.*
1b.	Panicles exceeding the leaves or slightly shorter than.
3a.	Leaves with a clove like odour. Staminode head sagittate; Epidermal cells highly sinuous.
4a.	A small to moderate-sized tree; Staminode head not broadly sagittae; Pistil up to 2 mm long. Ovary elliptic-oblong; Fruit ovoid to oblong- elliptic ....*C. tamala* Variants
5a.	Leaves strictly ovate to ovate-lanceolate, apex sharply acute to acuminate, base acute to obtusely acute...*C. tamala* Variant I
5b.	Leaves elliptic-lanceolate to ovate-lanceolate, apex acuminate, base acute .... *C. tamala Variant II*
5c.	Leaves broadly elliptic to elliptic-lanceolate, apex acuminate, base acute to decurrently acute...................................... *C. tamala* Variant III
5d.	Leaves narrowly elliptic to oblong-lanceolate, apex acuminate, base cuneatly acute..*C. tamala* Variant IV
3b.	Leaves unlike to that of clove smell. Staminode head (narrowly) hastate; Epidermal cells moderately sinuous...*C. bejolghota*

6.5–11.5 cm, triplinerved, lateral nerves not reaching the tip, basal to suprabasal perfect to imperfect, midrib moderate to stout, petiole up to 1.3 cm long, concave above; panicle sub-terminal to axillary, equal to the leaves or slightly exceeding them, stout, pale yellow, silky pubescent, glabrate with age. Flowers- 5–7 mm long, pedicel 3 mm long, perianth 3+3, elliptic-ovate-lanceolate, sub-equal, outer 2.5 mm long, inner 2–2.5 mm long, silky pubescent on both surfaces, longitudinally brown ribbed. Stamens - 3+3+3, 1.5–2 m long, anther 4-locular, pollen dehiscence occur through the opening of valve, introrse, extrorse in whorl III, glands of whorl III attached 1/3 of the base of the filament, glands and anther pale yellow, filaments silky tomentose, pale yellow, head sagittate. Pistil-1.5–2 mm long, pale yellowish-green silky minutely puberulous, style filiform, ovary elliptic-oblong; Drupe-black when ripe, 10–14 mm long, 5–6 mm in across, ovoid to oblong-elliptic, supported by the thickened peduncle and the enlarged truncate toothed base of the perianth, peduncle 3–4 mm long.

Found in cultivated condition mostly in Arunachal Pradesh, Assam, Manipur, Nagaland and Tripura. The flowering and fruiting occurs during February to May and June to September respectively.

2.1.2. VARIANT II

Variant II (RRLJ 1608) can be easily distinguished from the other three variants by its leaf morphology having elliptic-lanceolate to ovate-lanceolate shape, apex acuminate, base acute, comparatively larger in size, 2.3–4.5 x 8–18 cm. The floral and other characters including phenology, localities where it is known and used as *tejpat*, and distribution and ecology were similar to that of Variant I.

2.1.3. VARIANT III

Variant III (RRLJ 1866) is a moderate-sized evergreen branchy tree, attaining a height of about 6 m., Trunk - up to 70 cm girth, branches slender. Bark-rather rough, dark grey, blaze aromatic, reddish-brown darkening on exposure. Leaves-opposite; sub-opposite to alternate on the same twig, thinly coriaceous, aromatic, green and shining above, glabrous, pale below with sparsely distributed microscopic unicellular hairs, margins entire but undulate, broadly elliptic-lanceolate, apex acute, base decurrently acute to acute, variable in size, 2.1-7.8 x 5.5-20 cm, triplinerved, lateral nerves not continued to the tip, suprabasal perfect to imperfect, midrib moderate, nervules prominent on both surfaces. Petiole-concave above, up to 2 cm long. Inflorescence paniculate cyme, sub-terminal to axillary, not stout, pale yellowish-green, sub-quadrangular, silky pubescent, glabrate with age, shorter or equal to the leaves, upto 11 cm long (2^{0}) peduncle up to 4 cm long). Flower- 4–5 cm long, perianth 3+3, outer broadly elliptic-lanceolate, 2.5–3 mm long, inner elliptic-lanceolate, 2 mm long, without longitudinal brown ribbed, silky puberulous on both surfaces. Stamens - 3+3+3, 1.5 mm long, minutely puberulous to tomentose at base, pale yellowish-green, anther 4-locular, introrse, whorl III extrorse, glands marble white, attached 1/3 of the base of the filament. Staminode - 3, 1 mm long, marble white, minutely puberulous, head sagittate. Pistil -1.5 mm long, minutely puberulous, stigma capitate, ovary elliptic to globose.

Found in wild condition with rare occurrence in lower Assam. Rarely sold and found in markets. The flowering and fruiting occurs during March to May and June to August respectively.

2.1.4.VARIANT IV (RRLJ 1839)

In Variant IV (RRLJ 1839) except the leaf morphology of this variant, the floral characters including phenology are similar to that of Variant I and Variant II. The leaves are comparatively smaller in size (1.5-3 x 6-15 cm) and its shape vary from elliptic to oblong-lanceolate, apex acuminate, base cuneately acute.

3.0. CLIMATE

It comes up well up to an altitude of of 900-2500 m. Found abundantly both in wild and cultivated conditions in Meghalaya up to an altitude of 1250 m and North Cachar Hills of Assam up to an altitude of 1050 m.

4.0. NURSERY MANAGEMENT

Tejpat is grown as homestead crop in North eastern states. It also forms part of agro forestry in certain parts of the country. For cultivation, plants are raised from seeds sown in nursery beds during July-September. Seedlings are transplanted into polythene bags filled with forest soil, FYM and sand (3:3:1) and kept in the nursery till they attain sufficient growth. Seedlings are planted in the field at a spacing of 2 m x 3.5 m just before the onset of monsoon.

5.0. PLANTING AND AFTER CARE

Since it is a crop which is grown mostly as a wild and homestead crop no special care is needed to cultivate the crop. However, applying green leaf manure and farm yard manure can be practiced for increasing the yield. Mulching the tree with green leaf manure can be practiced. Weeding is done 2 to 3 times, till the trees are three to five years old, but for the older plants, weeding is done only once a year.

6.0. INSECT PESTS AND THEIR MANAGEMENT

The crop is relatively free from pest and no insect pests have been reported in C. tamala.

7.0. DISEASE AND THEIR MANAGEMENT

Very few diseases have been reported on *C. tamala*. Rust caused by *Aecidium cinnamomi* occurs during the onset of the south west monsoon attacking leaves and young. Leaf blight caused by *Glomerella cingulata*, thread blight caused by *Marasmius pulcherima* and leaf spot caused by *Colletotrichum gloeosporioides* has also been reported in *tejpat*. These diseases do not cause serious damage to the crop.

8.0. HARVEST AND POST HARVEST

Harvesting can be done when the trees have put on sufficient vegetative growth. Large trees are generally pruned. Cutting of old branches is usually done when the plants have attained a height of about 4 to 6 meters. The leaves are collected every year from healthy branches. Leaves are collected in dry weather mostly during November to February, every year from vigorous plants, dried in the sun for 3-4 days and tied up into bundles for marketing. The yield depends upon the age of the plant and also the size of the tree. The production from small and big trees ranged from 30 - 40 and 55 - 65 kg/tree/harvest respectively.

9.0. MARKETING

Meghalaya is the main market for *tejpat* and from there it is transported to different places. The bark of the tree is coarser and less aromatic than true cinnamon (*C. verum*) and is used to adulterate the true cinnamon bark. The leaves of a number of *Cinnamomum* species are being used by the local people of North East India as tejpat. Species of *Cinnamomum* namely *C. impressinervium*, Meissn, *C. bejolghota* (Buch Ham) *C. sulphuratum* Nees, *C. tamala* and few unknown types are used by the local people in Meghalaya as tejpat.

CHINESE CASSIA

Chinese cassia is not cultivated in India, except in a private estate at Valparai (Tamil Nadu). Indian Institute of Spices Research, Calicut has collected a germplasm of the available cassia lines from this location and evaluated for quality and four lines have been short listed. Unlike cinnamon, Chinese cassia has cinnamaldehyde as the major constituent in both leaf and bark oils. The climatic conditions prevailing in South India and North Eastern states of India are conducive for the cultivation of Chinese cassia. The management practices adopted for cinnamon can be followed for cultivation of Chinese cassia. However, harvesting of cassia for bark extraction is to be carried out once in 4 to 5 years depending upon the growth of the tree.

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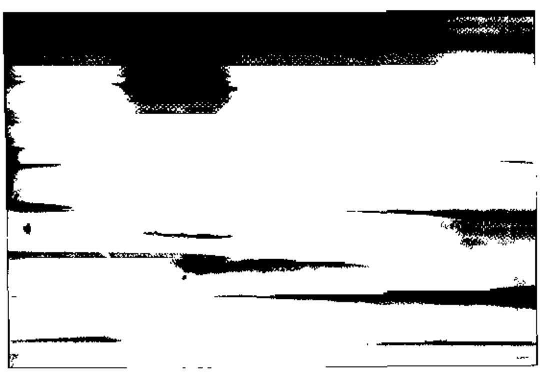
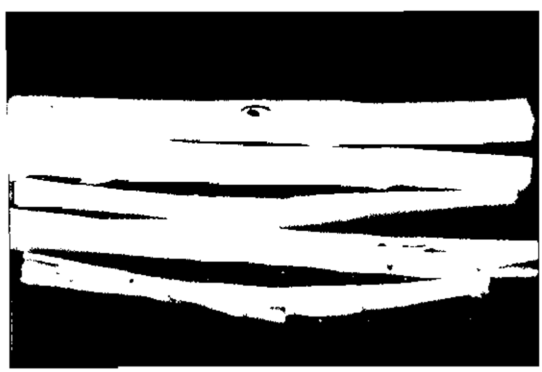
Cinnamomum veerum tree

Cinnamomum thamala tree

IISR Nithyashree variety



IISR Navashree variety



Cassia Quills

GARCINIA

P.A. Mathew, K.V. Saji

1.0. INTRODUCTION

Several *Garcinia* Spp. belonging to the family Clusiaceae traditionally provided spice, condiment, gamboge, source of colour, polishing material for metallic surface and medicines. As natives of the Old World Tropics and associated with local cultures, these group of plants came to prominence by the discovery of the (-) hydroxy citric acid present in them that influenced the lipogenesis in human beings and there by reducing obesity. Ever since this has been published the garcinias are attracting increasing attention world wide as a source of medicine, colour, bio preservative etc. The two species commercially important are i) Kokum (*Garcinia indica* Choisy) and ii) Malabar tamarind [*G. gummigutta* (L.) Robson]. The former is cultivated in a semi wild state and extensively used by the natives from South Kanara towards the Konkan in the West Coast and has assumed the status of a commercial crop owing to the varied products obtained from it such as dry rind, syrup, colour and butter. The malabar tamarind on the other hand is used mostly in the Travancore area of Kerala especially as flavouring for fish curries or in ayurvedic medicine. It is also quite popular in Coorg District of Karnataka where fruit rind is used to prepare vinegar and in meat dishes and butter from seed is utilized as edible fat, which is prepared on a cottage scale by women. But the useful products are limited and hence it has not assumed the status of kokum commercially. Nevertheless, it enjoys its own niche market in South India. Since the cultivation practices are more or less similar for both the species these are dealt with together here

1.1. Area and production

Being mostly collected from the scattered trees among other trees like cashew, mango or forest species or from trees existing in homesteads or riverbanks the exact area and production of kokum and Malabar tamarind are not available. As per available reports from Maharashtra it is estimated to exist 45 lakh trees with a production of 8,900 tonnes in the case of kokum. No such report is available on Malabar tamarind.

1. 2. Composition and uses

1. 2. 1. Kokum

The kokum of commerce is the dried rind of the fruit used as a garnish giving acid flavour to curries. The acid in kokum rind and leaves is identified as (-) hydroxy citric acid. The composition of fresh kokum rind is given below (table-1) as reported by Sampathu and Krishnamoorthy (1982).

Table 1. Composition of fresh kokum rind

Sl.No.	Components	Percentage*
1.	Moisture	80.0
2.	Protien (Nx6.5)	1.92
3.	Crude fibre	14. 28
4.	Total ash	2.57
5.	Cannin	2.85
6.	Pectin	5.70
7.	Starch	1.00
8.	Crude fat	10.00
9.	Acid (hydroxy citric acid)	22.8
10.	Pigment	2.4
11.	Ascorbic acid	0.06
12.	Carbohydrates	35.00

*Moisture free basis

The rind is also rich source of colour. The major pigments are cyanidine 3 sambubioside and cyanin 3 glucoside. It also contains a fat soluble yellow pigment garcinol.

The seeds contain 23-26% fat known as kokum butter which remains solid during summer and hence available as egg shaped lumps or cakes of light grey or yellowish colour with a greasy feel and bland oily taste. The fat is mainly used for edible purpose or used for adulterating ghee. It is rich in combined stearic and oleic acids.

Apart from being used as an acid flavourant in curries, the fresh fruit is used for preparing cooling syrup called 'Amrut kokum' which is popular in summer. It has sweetish acid taste with acid flavour. The dried rind soaked in water and after boiling and straining gives the soup 'solkadi' consumed with meals as a digestive. The fruit is also pickled. The pulpy aril covering the seed is either eaten or made into curries. 'Kokum agal' is a product with juice by adding salt, which is also used for preparing 'solkadi'.

Apart from being used as edible fat, kokum butter is suitable for use in confectionary and preparation of candles and soap.

Kokum has several medicinal uses. The fruits are antiscorbutic. It is anthelmenthic, cardio tonic, used in treating piles, dysentery, tumours, pains and heart complaints. Fruit juice is given in bilious affections. Kokum butter is deonulcent, nutritive, astringent and emollient. It is suitable for local applications in ulcerations excoriations, chaps and fissures in hands, legs etc. The cake after fat extraction is a good manure. The butter is used as a specific remedy for diarrhoea and dysentery. The rind is taken to control acidity, diabetes, in liver or respiratory problems, removal of urinary stones and expulsion of worms. It is also an excellent antioxidant and bio preservative.

1. 2. 2. Malabar tamarind

The dried fruit rind of Malabar tamarind is hard and dark brown in colour. It is also rich in (-) hydroxy citric acid which is known to inhibit lypogenesis in human beings and hence regular in controlling obesity. The composition of this fruit is given in table 2. (Sara *et al* 2000).

Table 2: Nutritive value of Malabar tamarind (rind)

Sl. No.	Component	Value
1.	Moisture (%)	76-78
2.	T.S.S (°Brix)	8
3.	Acidity (%)	18.91
4.	Ascorbic acid (Mg/100g)	72
5.	Non oxidizing sugar (%)	1.04
6.	Protein (%)	4.79
7.	Fat (%)	4.8
8.	Fibre (%)	5.12
9.	(-) HCA	16.06
10.	Total phenol (mg/100g)	313.1

The fruit rind after drying is used as a flavouring in Travancore, Kochi and Malabar areas of Kerala especially in fish curries for imparting a special flavour. The under ripe fruits are sliced, dried and used in curing of fish. A decoction of fruit rind is given for rheumatism and bowel complaints. It is also employed as a rinse in oral disease of cattle. The extracts are said to activate digestion and used in treatment of worms, parasites, tumors and dysentery. Since HCA has been found to be a potential dietary supplement for weight loss, and appetite control several preparations are available to control weight gain. The rind powder is also given in bleeding of piles. A decoction is given during post delivery period.

Some non food uses are also common. For polishing gold and silver the rind is specifically used. Recent studies show that it can remove arsenic from water and can be a source of the anesthetic 'Masculin isocitramide lactone' the source material of which has got dwindled in recent years.

2.0. BOTANY AND IMPROVEMENT

2.1. Kokum (*Garcinia indica* Choisy)

It is a small slender evergreen tree reaching to a height of 10-15 meters with drooping or spreading branches-with small ovate or oblong leaves with reddish colouration having a conical or cylindrical canopy; orthotropy and plagiotropy are seen in branching. The tree flowers in November to February and fruits ripen in April – June. The flowers are born axillary or terminal either singly or in clusters. Trees are either male or female or bisexual. The male tree produces only male flowers with numerous stamens. The female flowers are either single or bundled into 2 or 3 flowers and are seen in female trees and only female trees bear fruits. The fruit is a berry 2.5-3.8 cm in diameter; red, purple, yellow or white coloured types exist; globose or spherical in shape and not furrowed containing 4-8 seeds embedded in a fleshy aril which is acidic or sweet. Only the red fruited types are preferred for cultivation. The average fruit weight is about 35 g.

Being dioecious and highly cross pollinated, a lot of variability is seen in the kokum population. Variation in vegetative characters, earliness in flowering, fruit shape, colour, acid content, rind thickness, yield fruit fly damage etc. have been observed. Attempts have been made by the Dr B.S Konkan Krishi Vidyapeeth, Dapoli, Maharashtra to select superior types. A seven year study of 12 selections helped to isolate the types with high yield and superior quality which is released as 'Konkan Amruta' (see table 3). This is the first variety of Kokum released so far. Tree morphology is also important in selection. Trees having horizontal branching with orthotropic growth in grafts are needed. Studies on seedling progenies revealed that almost 58% were males and 42% were females. Since only female trees give fruits, 10% males are to be retained in a plantation.

Early maturing types that can escape the monsoon are ideal and have been identified. Though red colour of fruit is preferred, yellow, white or purple colour are also reported. Types with thick rind are reported. Generally the fruit size is about 35 g but types with 85 g fruit are also available. Since fruit fly is a major problem, resistant types are needed. The grafts tend to grow spreading and hence efforts are being made to develop varieties with erect growing habit. There is a need to develop varieties that are early, having short harvesting phase, high yield, big fruit with thick rind, good colour sweet taste, more acid, more butter, good keeping quality and resistance to fruit fly.

2.2. Malabar tamarind [*G. gummi-gutta* (L) Rob.]

It is a small or medium sized tree with a round or hemispherical or conical crown with horizontal or drooping branches.

Orthotropy and plagiotropy are observed in branches. Leaves are simple, dark green opposite elliptic ovate or lanceolate and the bark is dark.

The tree is dioecious exhibiting male and bisexual types. Flowers are axillary or terminal, either solitary or in groups. Male trees produce only male flowers 10-20 per cluster with numerous stamens that fall of quickly. In the female or bisexual trees the flowers appear single or in clusters of 3 or 4 flowers and are bigger than male flowers. The stamens are 6-20, unequal, mostly sterile; arise around the ovary which is superior with 6-10 carpels with single ovule in each. The fruit is a berry, ovoid or spherical in shape 5.7 to 7.5 cm in diameter, yellow or red when ripe, has 7-13 grooves, and contains 7-10 seeds surrounded by an aril which is sweet or acrid. The weight of the fruit varies from 50-200 g or more.

Very little crop improvement has been done in this species to facilitate release of a variety. Most of the work is confined to Kerala Agricultural University, Kerala. Accordingly, high variability has been observed for vegetative, floral fruiting and biochemical characters of the fruits. Trees exhibited round, dome, conical or pyramidal canopies. Dome shaped trees were generally high yielding; so also horizontal branching types. Seedling population consisted of male and bisexual types generally. The male trees flowered in December-March or up to July. The bisexual trees were found to flower from February-March, though in some cases January or April flowering was also observed.

Though peak period of fruit ripening is in June-July early ripening (May) and later ripening (October) were also observed. The yield range from 50 kg -600 kg/tree is reported. The fruit colour is generally light yellow to dark yellow but red types are also reported. Not only variations in fruit shape (round, oblong, oval, cordate, pear, napi form) but physical parameters of the fruit such as segments, segment width, length, girth, weight, volume, rind thickness, seed weight and rind weight are also reported. Biochemical parameters such as moisture, rind recovery, T.S.S, mucilage, acidity, HCA, phenol content etc. also indicated variation among types.

There is a need to develop varieties with orthotropic growth habit, high yield, high rind recovery, less tannin, more HCA, ripening in non rainy period etc.

2.3. Varieties

Only one variety has been released in kokum by name 'Konkan Amrutha' by the DB Konkan Krishi Vidyapeeth, Dapoli in Maharashtra, and the features of which are given below. For malabar tamarind no variety has been released but it is recommended to use any tree with regular annual yields, mean fruit weight of 200 to 275 g, having high levels of acid and low tannin content.

Table 3. *Characters of Konkan Amrutha'*

1	Yield (Fresh)	138.28 kg/tree
2	Pre bearing period (grafts)	4-5 years
3	Period of flowering	November
4	Period of harvest	March- April
5	Harvesting period (days)	78 (3 pluckings)
6	Fruit shape	Apple
7	Fruit weight (Fresh)	34.95 g
8	Rind thickness (mm)	4.45
9	Shelf life (Days)	15
10	(-) HCA (%)	22.8
11	Rind recovery (%)	57.0
12	Fat/Butter in seed (%)	33.34
13	Colour in the rind (%)	2.40

3.0. SOIL AND CLIMATE

The most favorable region for kokum cultivation are warm moderate humid with a temperature range of 20°C to 35°C, 60-80% humidity, having a well distributed annual rain full of 2500 mm to 4000 mm. Extreme aridity is harmful. As regards soils it grows on wide rage of soils from marginal to deep alluvial soils, well drained. Laterite soils are quite suitable but moisture retention capacity is most important favorable soil character.

The malabar tamarind prefers a warm highly humid tropical climate. It is seen in the coastal areas, evergreen forests up to 1800 meters above MSL. Dry areas are not suitable. Alluvial soils are preferred by the species as seen by occurrence in river bank. It is also seen growing in salty or marshy soils. It can grow very well in laterite soil where soil moisture retention is adequate.

4.0. NURSERY MANAGEMENT

4.1. Propagation

Both kokum and malabar tamarind are propagated through seeds. However, being heterozygous a lot of variation is seen in the seedling progenies and the occurrence of male trees also compounds the problem. Therefore, it is necessary to plant grafted plants of good varieties or types to develop high yielding plantations producing fruits of high quality. Nevertheless, seedlings are to be raised for preparing grafts in these species. Since the nursery techniques for both the garcinias are the same, the methods described are applicable for both.

4.1.1. Seed propagation

The seeds of both kokum and malabar tamarind are recalcitrant i.e. these should not get dried up; then they will not germinate. So precaution is needed to extract fresh seeds for sowing. In kokum, the fruits ripen from April to June when seeds will be available. In malabar tamarind, the fruits ripen from May to July and seeds have to be collected at that time. In the latter, since the fruit ripening coincides with the rainy season the chances of seed drying up is almost nil. The seed viability is very short for both types under dry conditions.

Extraction of seeds is done in both the species by cutting the fruits into halves along with the pulp which is removed by hand and washing etc. In the case of kokum seed is mixed with ash and dried in shade. Two days prior to sowing, the seeds are soaked in water and such seeds are sown@ 2 seeds/ bag in polybags of 25 cm X 15 cm and watered daily which gives good germination (90%) in 30 to 60 days. The potting mixture can be of soil: sand: FYM in 2:1:1 proportion. Depending on growth six to eight month old seedlings can be used for grafting that will have 15-20 cm height and 0.25 cm thickness. When seedlings are used for agro-forestry purposes one year old seedlings are planted.

In malabar tamarind, after extraction, the seeds are washed and dried in shade in a thin layer for 20 days. Afterwards, it is sown in polybags as above around Aug- Sep. and these seeds start germination by Dec-Feb. To reduce the germination period the following pretreatments are recommended.

1. Remove the seed coat without injuring cotyledons. Sow at 3 cm deep. Germination is seen in 20-25 days.

2. Remove seed coat. Soak in GA @ 250 ppm for 6 hrs. Soak in mancozeb (4 g/l) for 2 hrs. Sow them in bags. Germination is seen in 16-20 days.

3. Follow the second method. Transfer seeds to a 20 X 25 cm polybag with 30-50 ml water. Tie the bag tightly with rubber band holding the air inside. Keep for germination for 10-12 days. Sow the germinated seeds in polybags and irrigate.

One year old seedlings having a thickness of 3-4 mm can be used for grafting in this tree

4.1.2. Grafting

The method of grafting is the soft-wood grafting method that has been standardized for both kokum and malabar tamarind. Since grafts from plagiotropic or side branches grow into dwarf spreading trees, the shoots for grafting are to be collected from orthotropic (erect) shoots. These shoots may be of 3 or 4 months old. In kokum, scions of 10 cm length are sufficient whereas in malabar tamarind 15 cm long green shoots are used. Removal of leaves on scion may be helpful while grafting or may be cut to half the size. A simple cleft of about 4 cm length is made on the top of the seedling after the growing tip is cut off and the base of the scion is shaped into a wedge to the same length and inserted into the cleft and the union is tied with a polystrip of 250 gauge and 1.5 cm width. The operation is done under the shade of a shed and daily irrigation is needed. Success will be indicated by the sprouts emerging on the scion 15-20 days after grafting. After the first leaf has expanded the grafts can be kept in 50% shade for further growth. The plastic tying can be removed after three months. The best period of grafting in kokum is Oct-Nov and May-June, where as in malabar tamarind June-Oct is the best period. More than 80% success is obtained in grafting. Grafts that are four months old are ready for planting in the field.

5.0. PLANTING AND AFTER CARE

5.1. Land preparation and planting

Being trees, the garcinia do not need much land preparation except removal of weeds, bushes, etc. before the on set of monsoon. A spacing of 4 to 5 meters are given for grafts whereas 7 m X 7 m is required if seedlings are planted in agro forestry. A pit size of 60 cm^3 for kokum and 75 cm^3 for malabar tamarind is sufficient. The pits may be filled with 5 kg FYM and 10 g carbaryl (10% dust) to prevent termite and mixed with top soil before planting. Planting is taken up at the onset of monsoon and staking is done to prevent lodging. Male grafts may have to be planted in grafted plantation of kokum for pollination. This is not needed in malabar tamarind.

5.2. After care

The orchard should be kept free of weeds and protected from stray cattle. Shading is to be provided during summer and winter months. Irrigation once in a fortnight is needed during summer and winter months to get good establishment. The height of grafts may be restricted to 4 m in malabar tamarind after 7 years. The same may be followed for kokum if necessary. Where kokum grafts are planted 10% male plants also needs to be established. In seedling plantations only 10% males are to be retained and the rest may be top worked with female scions.

6.0. MANURING

The following manuring schedule for kokum is adequate for good production. For one year old plant 5 kg FYM or green manure and 50 g N, 25 g P_2O_5, 25 g K_2O should be applied. The dosage is increased progressively every year so that a 10 year old tree will get 50 kg FYM or green manure, 500 g N, 250 g P_2O_5 and 250 g K_2O per year. A circular trench of 30 cm depth and 45 cm width is made below the canopy and the manures and fertilizers are applied in August in the trench and covered.

The manorial dose for malabar tamarind is as follows. A one year old tree should be given 10 kg FYM, 20 g N, 18g P_2O_5 and 50 g K_2O per year which is progressively increased every year so that a 15 year old tree will get 50 kg FYM, 500 g N, 250 g P_2O_5 and 1000 g K_2O per year. The method of application is the same as for kokum.

7.0. DISEASES AND DISEASE MANAGEMENT

No serious diseases are reported in the above species. Thread blight, sooty mould and blight may be caused by fungi that can be controlled by Bordeaux mixture spraying.

8.0. INSECTS AND NEMATODE PEST MANAGEMENT

In kokum, leaf minor may be a problem for which dimethoate or phosphamidol 0.03% spray is sufficient. Fruit fly is a real problem and planting early varieties and field sanitation are the best control measures to be adopted. Hard scales, on tender shoots, defoliating grubs, leaf folders, hoppers etc., may cause concern for malabar tamarind for which dimethoate 0.03% or monocrotophos 0.02% or quinalphos 0.02% can be sprayed. For hoppers carbaryl 0.5 w. p 2g + dichlorvos 1ml/l of water if sprayed can control them.

9.0. POST HARVEST PROCESSING AND VALUE ADDITION

9.1. Harvest

Kokum seedling start bearing at 7 to 8 years while grafts from 5 to 6 years. Fruit maturity is indicated by red colour. Harvesting is done by pole harvesters at intervals. The yield may range from 31 to 173 kg per tree in a seedling orchard whereas that of *Konkan Amruta* is 138 kg/tree.

The yield obtained from malabar tamarind ranges from 50 to 600 kg per tree. Full bearing is obtained at 12-15 years.

9.2. Processing

The most important product in both species is the dried rind. Since kokum ripens in the summer season, drying is easy. After harvest the fruits are cut into halves and the pulp with seeds are removed, and kept in a bamboo basket for draining and the juice is collected in a wooden trough but the rind is dried in the sun. After drying, the rind is again dipped in the juice and again dried. This may be repeated 3 to 4 times and the dried rind is black in colour which forms the 'Binda' or 'kokum' of commerce. If this rind is sprinkled with salt at the time of drying the product is called 'kokum agal'. The dry recovery is about 57%. Since the syrup has a cooling effect and possesses several medicinal properties, it has good demand during summer. The syrup is prepared by adding sugar 1 to 2 kg to fresh rind on weight basis and the sugar acts as a preservative. No artificial preservatives are used. The red colour also makes it attractive. This syrup is called 'Amrut kokum' or kokum syrup which is very popular in the Konkan region.

A simple local method to prepare kokum syrup is as follows. The fruits are washed, cut into halves and the pulps with seeds are removed. The inside of the halves are filled with sugar and placed in a container in layers and after it is full it is covered with a cloth and kept in sun for two days. For one kilo fruit 750 g sugar is enough. After two days the whole pulp with sugar is wringed and strained to get the juice. Add 100 g sugar every week for two weeks and mix thoroughly and keep for 3 weeks. One kilo fruit will give 1.5 litre of juice. Keep it in bottles and no preservatives are added. This syrup can be kept for one year. The proportion is to use 20 g sugar and 25 ml juice to prepare one glass of squash.

The seeds are thoroughly dried in the sun and stored during the rainy season for extraction of butter which is generally done in the cool season after the rains are over. The seeds are cracked and the seed coat is removed and the kernels are separated. These are pounded in a stone mortar and the pulped mass is put in an earthen pot with water and boiled. The butter comes to the surface. It is poured into another vessel and allowed to cool. The oil on the surface is moulded into egg shaped masses, since it become solid gradually. The pounded mass can also be kept with some water overnight to settle. During night the oil comes to the surface which is removed in the morning and churned. The oil rises to the surface in a solid form and is removed by hand. This gives the best product and best performed in winter. Machines also may be used to extract the oil and solvent extraction is also possible. The seeds yield about 25% of oil called as kokum butter which remains solid under ordinary temperatures and melted when warm (40°C). Kokum butter as is found in the market are egg shaped masses or cakes with a dirty white or yellowish colour, friable with a greasy feel, have a faint smell with bland oily taste. It finds commercial use in cosmetics, chocolate manufacture, pharmaceuticals etc.

The rind also is rich in red natural pigments to the extend of 2.4% one of the richest known sources in plant kingdom and processes of extraction have been developed by CSIR.

The fruits of malabar tamarind ripens in the rainy season and artificial drying is needed. The fruits are cut into halves and the seeds along with pulp are removed. The rind may or may not be washed. If the sun is available the rind is kept for sun drying but to get a good product drying under wood fire is necessary. In sun drying the cut halves with concave side up is spread over bamboo mats or specially made floors. It takes about 6 to 7 days and a brownish black product is obtained. In another method natural fibres from fronds of coconut are tied across wooden poles or trees in the sun. The fruit halves are hanged on these fibres for drying. This results in uniform drying giving the best quality rind. During rains the prepared halves are spread over an attic over a wood fuelled fireplace in a kitchen or special smoke houses. It takes a week for complete drying. The smoke dried rind will have a shiny black colour due to the smoke. Oven drying at 70°-80° C is also done nowadays. Properly dried rind keeps for long period without any preservatives. The dry recovery ranges from 20 to

28.38%. A local method of rind preservation uses 50 ml of coconut oil and 150 g common salt for each kilos of dry rind which is rubbed on the product. Smoke dried rind give the best product in term of appearance, retention of shape, moisture content and flexibility.

10.0. ECONOMICS AND MARKETING

The economics of kokum cultivation and marketing has been studied by the Dr. B.S Konkan Krishi Vidyapeeth, Dapoli in Maharashtra and kokum has been identified as an important cash crop especially under marginal conditions of the West Coast. One study involving planting of improved variety with grafts revealed that an amount of Rs. 62,884/ was needed to establish one hectare of kokum plantation in the Konkan region for five years including cost of land. The maximum establishment cost was incurred during the first year because of the involvement of more labour (29%). At the age of 7th year the cost of production per hectare was Rs 17,959/ha with a return of Rs 21180/ indicating that the profits can be realized after 7 years. The pay back period was estimated to be 9 years.

In another study on existing seedling plantations of kokum revealed the following. Kokum is not cultivated as a sole crop but consisting of a few trees. Therefore, based on an estimated number of 277 tree/ha; an input cost of Rs 16, 917/, rental value of land at Rs. 21,038/ with cent at Rs 2968/ were arrived at as a net profit of Rs 43,226/ was realized in this study made in 2001. The estimated yield was 8.4 t of fruit with a price of Rs 10,000/t. The net profit for there was Rs 156/ and the tree were 34 years old.

The economics of home scale processing of kokum also has been studied. Kokum rind, Amrut kokum (syrup) and butter are the three main products prepared. On an average each house hold in South Konkan produce 15 kg of dry rind, 8.5 liters of syrup and 3.5kg of butter. The savings from these products over the cost of production is 15%. Most of the rind and syrup (5C consumed at home whereas 79% of the butter is sold locally. The ratio of fresh fruit to the final product is 0.196 for rind, 0.187 for syrup and 0.10 for butter. The cost of production of dry rind and syrup was about Rs 50 to 52 per kg and of butter around Rs 200perkg. The costs ware very less under large processing units especially in butter which was about Rs 15 per kg.

No economic study has been made in the cultivation or processing of Malabar tamarind.

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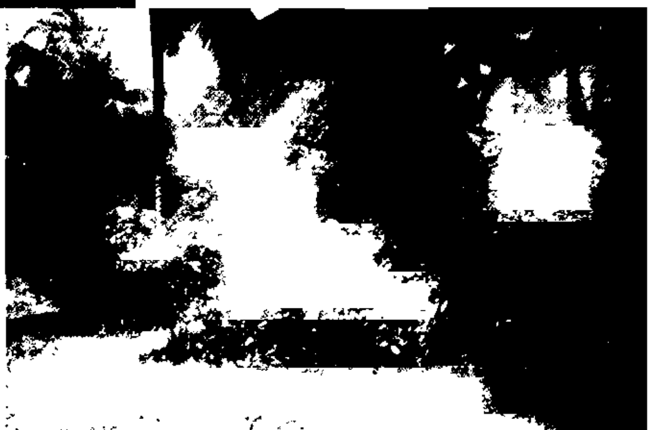
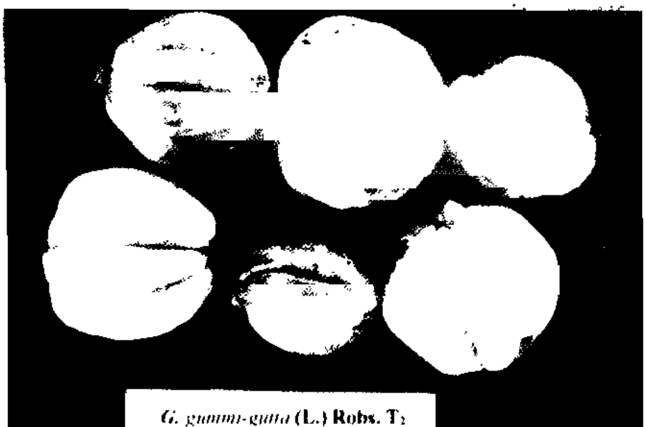
Garcinia indica (Kokam tree)

Garcinia gummi - gutta tree





Garcinia gummi - gutta fruits

Garcinia inidica (Kokam) fruits