VARIABILITY ANALYSIS IN

Garcinia cambogia Desr. (Malabar Tamarind)

By

P. MUTHULAKSHMI

THESIS

Submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF POMOLOGY AND FLORICULTURE
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 654
KERALA, INDIA

1998

DECLARATION

I hereby declare that the thesis entitled **'Variability analysis in *Garcinia cambogia* Desr. (Malabar Tamarind)'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

College of Horticulture
Vellanikkara
19-9-1998

P. Muthulakshmi

P. MUTHULAKSHMI

Dr.Sarah T. George
Assistant Professor (Sr.Scale)
Department of Pomology and Floriculture
College of Horticulture
Vellanikkara - 680 654

CERTIFICATE

Certified that the thesis entitled **'Variability analysis in *Garcinia cambogia* Desr. (Malabar Tamarind)'** is a record of research work done independently by **Miss.P. Muthulakshmi**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Sarah T George

Dr.Sarah T. George
Chairperson, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss.P.Muthulakshmi,** a candidate for the degree of **Master of Science in Horticulture** with major in **Pomology**, agree that the thesis entitled **'Variability analysis in *Garcinia* cambogia Desr. (Malabar Tamarind)'** may be submitted by Miss.P.Muthulakshmi in partial fulfilment of the requirement for the degree.

Dr.Sarah T. George
Assistant Professor (Sr.Scale)
Department of Pomology and Floriculture
College of Horticulture, Vellanikkara

Dr.P.K.Rajeevan
Associate Professor & Head
Department of Pomology and Floriculture
College of Horticulture
Vellanikkara

Dr.K.Lila Mathew
Associate Professor
Department of Pomology and Floriculture
College of Horticulture
Vellanikkara

Dr.A. Augustin
Associate Professor
AICRP on M & AP
College of Horticulture
Vellanikkara

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

It is with great pleasure that I express my deep sense of gratitude and indebtedness to ***Dr.Sarah T. George****, Assistant Professor, Department of Pomology and Floriculture, College of Horticulture, Vellanikkara and Chairperson of my Advisory Committee for her expert guidance, constant encouragement, keen interest, esteemed advice, constructive criticism and thought provoking discussions all through the research work, all of which had contributed to the most in making this venture a success. It is her cordial support, good will and lively inspirations that made me to complete the Master's Degree programme successfully. I really consider it my greatest fortune in my life in having her guidance for my research work.*

I sincerely thank ***Dr.P.K.Rajeevan****, Associate Professor and Head, Department of Pomology and Floriculture, College of Horticulture, Vellanikkara and a member of my advisory committee, for his timely advice, valuable instructions and suggestions extended at all stages of this study.*

I am extremely grateful to ***Dr.K.Lila Mathew****, Associate Professor, Department of Pomology and Floriculture, College of Horticulture, Vellanikkara and a member of my advisory committee for her critical suggestions and support rendered all throughout the investigation.*

I express my profound gratitude to ***Dr.A.Augustin****, Associate Professor, All Indian Co-ordinated Research Project on Medicinal and Aromatic Plants, College of Horticulture, Vellanikkara and a member of my advisory committee for his scholarly suggestions, sustained interest and timely help at different periods of my study.*

I sincerely thank Sri.S.Krishnan, Assistant Professor, Department of Agricultural Statistics for valuable suggestions during the analysis of data and preparation of thesis.

My profuse thanks to Dr.Sadhan Kumar, Assistant Professor (Hort.), for permitting me to take observations on kodampuli trees available in the research field of Department of Olericulture.

With immense delight that I acknowledge my appreciation to teaching and non teaching staff, research associates and post-graduate students of the Department of Pomology and Floriculture, for their good will and co-operation.

I am extremely thankful to Ms.Preetha, Ms.Shoby, Ms.Mridula, Ms.Leenamol, Mr.Sabhu, Ms.Samitha and Ms.Ambili who were co-operative and supportive during the course of my study.

I extend my profound thanks to my friends, Ms.Smitha, Ms.Faseela, Ms.Jissy George, Ms.Latha, Ms.Mini P. Jose and Mr.Ajithkumar, B. for their whole hearted support during the investigation.

I further express my thanks to Mr.Joy for his commendable care and labour put in to do this typing work elegantly.

The assistance and co-operation rendered to me by the labourers especially Sri.Raman of the Department of Pomology and Floriculture are very much appreciated.

I remember with great pleasure and thankfulness, the immense love, help and encouragement given to me by my parents, brother, grand mother and all other relatives, who always have been the prime source of strength and inspiration for me.

The award of ICAR Junior Research Fellowship is gratefully acknowledged.

Last but not the least I bow my head before the ALMIGHTY for His grace in providing me with health and strength even during some difficult periods.

P. MUTHULAKSHMI

In the memory of
my everloving
Grand father

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

INTRODUCTION

Kodampuli, commonly known as Malabar Tamarind, is one of the potential under-exploited fruit crops, currently gaining much commercial, agricultural, industrial and medicinal importance. It is a crop in which sufficient attention has not been paid for commercial cultivation as well as for genetic improvement.

> ***"One new variety or crop raised by man will be more important and interesting subject for study than one more species added to the infinitude of the already recorded species"***
>
> (Darwin, 1859)

If Darwin is correct, it is our duty to explore this widely grown under-exploited crop where practically not much work has been done.

A moderate to large sized tree, *Garcinia cambogia* Desr. grows in the evergreen forests of the Western Ghats in Southern India. It's habitat extends from Konkan southward to Travancore, and into the Shola forest of Nilgiris where it can reach an altitude of up to 6,000 ft (Majeed, 1994).

In Kerala, it occurs widely all over the State, even in the low lands of Kuttanadu and is very popular in the Central Travancore areas. Though common in Kerala, it's potential remains under-exploited as the tree is not generally cultivated at an orchard level and often seen neglected as a miscellaneous tree crop in the backyards of homesteads.

The fruits are valued for their dried rind which fetches a high price of about Rs.200 per Kilogram. The fruits have an unique use in Kerala, being exclusively preferred in culinary preparations involving fish.

Kodampuli rind is the richest source of (-)-hydroxycitric acid (HCA) and its derivatives are unique, potent metabolic regulators of obesity (Verghese, 1996).

Being rich in acids, the rind possesses marked antiseptic properties. In indigenous medicine, Kodampuli is listed as a remedy against rheumatism, rickets and enlargement of spleen and also in veterinary medicine as a rinse for mouth disease in cattle.

The seeds yield 36 per cent of an edible fat resembling Kokam butter. The tree yields a transluscent yellow resin which is soluble in turpentine giving an yellowish varnish.

Kerala seems to be one of the centres of origin of Kodampuli. It is a cross-pollinated and heterozygous crop. Kodampuli available in Kerala are all seedling progenies and a lot of variability is seen with respect to size of the tree, bearing age, flowering and ripening season, fruit size, shape and colour, rind recovery, yield and (-)- HCA content.

As a priliminary step in crop improvement as well as for commercial exploitation, it is desirable to investigate the nature of divergence in terms of vegetative, flowering and fruiting characters. Survey to collect indigenous diversity is very important since there are possibilities for genetic erosion due to urbanisation, industrialisation and the resultant felling of trees.

In Kodampuli, apart from longer prebearing period, segregation of seedling is recognised as one of the major problems of cultivation. The seedlings segregate into productive bisexual and unproductive male trees. Sex is revealed only after flowering, for which the seedling takes 7-8 years. Presently the only option to overcome this problem is the use of vegetatively propagated material or top working of male plants. Eventhough vegetative propagation is standardised (Nazeema, 1992), the large scale adoption of this method is constrained due to non-availability of orthotropes in sufficient numbers which are required for the production of plants with normal growth habit. So seedlings continue to be the major propagating material. Hence the identification of sex of the plants in the seedling stage remains a viable alternative for which no attempt has been made so far.

This programme of variability analysis in *Garcinia cambogia* Desr. has been carried out with the following objectives.

1. To select early flowering and early ripening types in order to avoid the coincidence of peak harvest season with monsoon.
2. To study variation in flower and sex types
3. To select high yielding types in terms of more number of fruits per tree, bigger fruit size and higher thickness of fruit rind.
4. To select quality types, i.e., fruits free from astringency and bitterness.
5. To select types with higher total acidity and (-)-HCA content
6. To compare the quality of the rind under different drying conditions.
7. To study the pattern of fruit development in terms of morphological and biochemical components.
8. To make a comprehensive study to differentiate the sex of Kodampuli through morphological observations and biochemical analyses.

Review of Literature

2. REVIEW OF LITERATURE

Information available on Kodampuli, especially on variability analysis and sex differentiation, is limited. In order to project the magnitude of the problem, its overall dimension and to have a general guidance, information on other crops which would substantiate the present study, has been reviewed and presented here.

Garcinia cambogia Desr., known as Kodampuli in Kerala, belongs to the family Clausiaceae (Majeed, 1994), earlier known as Guttiferae (Trimen, 1893). *Garcinia* is a large genus of evergreen trees or shrubs distributed in tropical Asia, Africa and Polynesia. About 30 species occur in India (CSIR, 1956).

From its original home in the Western Ghats of Kerala at altitudes of 1,300 m to 2,000 m above M.S.L., Kodampuli has been distributed by natural agencies and by man, throughout Kerala upto the low lying reclaimed lands bordering the backwaters (George, 1988).

According to Beddome (1978) the synonyms for *Garcinia cambogia* are *Cambogia gutta* Linn. and *Mangostana cambogia* Gartn. According to Vajravelu (1990) the synonyms are *Garcinia gummi-gutta* (L.) Robs. and *Cambogia gummi-gutta* Linn. Of which, *Garcinia gummi-gutta* (L.) Robs. is the correct name of South Indian species.

Kodampuli is an evergreen tree with round crown and horizontal or drooping branches (CSIR, 1956). The tree is reported to be dioecious with male and female flowers found on separate plants (Chandrarathna, 1948).

Male flowers are fascicled, terminal or axillary, sepals four in number and the outer ones are larger. Petals yellowish and fleshy. Female flowers are

usually solitary with 6-12 locules in the ovary and staminodes form a ring around the ovary (Saldanha and Nicolson, 1978).

Fruits are of the size of a small apple, yellow or red with 6 to 8 grooves. The top of the fruit is flat and the mamilla is thick. Aril is succulent with 6 to 8 seeds (Anderson, 1875).

The fruits are too acidic to be eaten raw. They are valued for the dried rind which is used in Kerala as an important ingredient for flavouring fish curries (Verghese, 1991a).

The rind contains about 30 per cent HCA which is present in the form of (-)-HCA, on dry weight basis (Lewis *et al.*, 1964).

The fruits contain tartaric acid, 10.6 per cent; reducing sugars (as glucose), 15.0 per cent and phosphoric acid (as calcium triphosphate), 1.52 per cent. Of the total acid present in the material, nearly 90 per cent is non-volatile (CSIR, 1956). Lewis *et al.* (1964) identified that the acid present in the dried fruit rind is (-)-HCA, which accounts to about 30 per cent.

Sherly (1994) reported that the rind of *Garcinia cambogia* had an average of 6.68 per cent acidity; 7.2 mg/100 g of ascorbic acid; 8° brix TSS and 1.04 per cent reducing sugar. Mucilage around the seed contains 2.64 per cent reducing sugar and 3.3 per cent acidity and on an average, a loss of 75 per cent weight was recorded on drying the rind.

The pharmaceutically active ingredient in citrin is extracted from *Garcinia cambogia* and *Garcinia indica* as they contain an active sterio-isomer of (-)-HCA which has been shown to accelerate fat burning and inhibits fatty acid

synthesis. It lowers the blood lipids such as cholesterol and triglycerides by triggering fatty acid oxidation in the liver via. thermogenesis. It burns the fat softly and gently without the stimulation of central nervous system. It blocks the enzymes responsible for storing fat in our body. It mobilises the bodies fat stores and dissolves fat in the liver and also throughout the body. Thus it paves way for slower weight loss and supports body's natural appetite suppression mechanism without altering one's food habits (Majeed, 1994).

Fruits are used as an appetizer in the East Indies (Sturtevant, 1919). Because of its intense acidity, the dried rind possesses marked antiseptic properties (Chandrarathna, 1948).

The seeds of Kodampuli yields about 36 per cent of edible fat rich in stearic and oleic acid (Verghese, 1991b).

2.1 Variability study

2.1.1 Variability in Kodampuli

George (1988) reported that a tremendous diversity in populations of Kodampuli is available in Kerala particularly along the backwaters and riverbelts and suggested that this diversity can be exploited for developing an ideal plant type with short stature, year-round fruiting and desirable fruit characters like edible pulp and seedlessness.

2.1.1.1 Varieties / Types

Anderson (1875) reported two varieties namely, *conicarpa* and *papilla*. Variety *conicarpa* includes trees with leaves broader beyond the middle or linear-oblong and fruits are ovoid-conical with four grooved to the top and angular

furrows. Variety *papilla* includes trees with leaves large, elliptic and fruits are ovoid, four to eight grooved to the top with a terminal mamilla. Jacob (1992) reported the existence of different types of Kodampuli such as sweet acidic types, sour tasted wild types, those producing fruits with immature seeds and those with different size and shape of fruits in Kerala.

2.1.1.2 Tree size and branching

CSIR (1956) reported size variation in Kodampuli trees ranging from small to medium. Different habit of branching like horizontal and drooping were reported (CSIR, 1956; Thomas, 1965 and Majeed, 1994).

2.1.1.3 Leaf characters

Leaf shape can be of oblong or sub-obovate (Thomas, 1965). Saldanha and Nicolson (1978) reported that the shape of the leaves may be elliptic-oblong or obovate, shortly acute to obtuse at apex. Vajravelu (1990) as well as Sasidharan and Sivarajan (1996) reported that leaves may be elliptic or oblong in shape with acute-obtuse apex and cuneate base. Majeed (1994) reported that the leaves can be elliptic-obovate (widening towards the tip), lanceolate (broad with tapered points at each end), or lanceolate-oblong in shape.

2.1.1.4 Flowering season

George (1988) observed flowering in Kodampuli from February to April. George *et al.* (1992) and Sherly (1994) reported that the flowering season ranges from January to April.

2.1.1.5 Flower types

Beddome (1978); Saldanha and Nicolson (1978); Vajravelu (1990) and Sasidharan and Sivarajan (1996) revealed the existence of pistillate and staminate flowers in Kodampuli. Anderson (1875), George (1992) and Sherly (1994) reported the presence of male and hermaphrodite flowers in Kodampuli.

2.1.1.6 Fruit characters

George (1988) reported that the fruits vary in weight from 50 g to 180 g.

Fruits can be of shapes like ellipsoid, ovoid and spherical (George, 1988). Vajravelu (1990) reported that the fruit shape may vary from elliptic to oblong.

CSIR (1956) reported that fruit colour can be red or yellow. Majeed (1994) reported about the presence of red and orange coloured fruits in Kodampuli.

The fruits have 7 to 13 deep longitudinal furrows which are not extending to the apex (Trimen, 1893). Saldanha and Nicolson (1978), Anderson (1875), Majeed (1994) and Sasidharan and Sivarajan (1996) reported that the fruits are having 6 to 8 grooves. According to Beddome (1978) and George (1988) the fruits are having 7 to 10 grooves.

Sherly (1994) observed the existence of variability in fruit volume, length, girth and percentage rind weight due to the heterozygous nature of seedling progeny.

According to Thomas (1965) yield of a fully grown tree ranged from 127.00 to 254.02 kg. Sherly (1994) reported that yield per tree varied from 8.13 to 130.80 kg.

Anderson (1875) and Majeed (1994) reported that the fruits were having 6 to 8 seeds per fruit. Beddome (1978) recorded that the number of seeds per fruit varied from 6 to 10.

2.1.2 Variability in other crops

Singh (1963) and Nand (1970) reported two main Carambola types namely, sour and sweet.

In ber, a lot of variability has been identified in several districts of Uttar Pradesh, Rajasthan, Haryana, Gujarat, Madhya Pradesh, Maharastra, Andra Pradesh, Karnataka and Tamil Nadu and commercial cultivars have persumably developed through selections made by local people in these areas (Pareek and Vashishtha, 1983 and Vashishtha and Pareek, 1989).

Beddard (1969) recorded higher extent of variation for the characters such as vigour, height and spread of plant, susceptibility to diseases, number of fruits and yield in strawberry.

Srinivasan (1970) reported that jack, being a cross pollinated and mostly seed propagated, there are inumerable types of jack fruit which differ widely in respect of density of spines on rind, bearing capacity, size, shape and quality of the fruit and period of maturity. A lot of variability occurs in the evergreen forests of Western Ghats, Gorakhpur, Dewarice (40 kg size fruits) and Allahabad (small with white, juicy and soft pulp) districts of Uttar Pradesh.

Jackfruit types like Varikka, Kooza, Navarikka, Rudraksha chakka or Thamarachakka and other wild forms have been collected from Wynad plateau in Western Ghats of Kerala (NBPGR, 1986 and NBPGR, 1987). Three types of jackfruit namely, Rasdar, Khajwa and Sugandhi were identified through survey in the plains of Eastern Uttar Pradesh (NBPGR, 1988).

Jauhari and Singh (1971) surveyed important bael growing areas of Bihar and Uttar Pradesh, and found that Kaghji Etawah, Sewer Large, Mirzapuri and Deoria Large were excellent in taste and other quality traits. Of the five types of bael fruit analysed in West Bengal, the spherical flattened ones were considered as the best on the basis of fruit weight and chemical composition (Mazumdar, 1975).

Thimmaraju *et al.* (1977) reported that tamarind, being a highly cross pollinated crop and owing to its wide geographical distribution and adaptability to different agroclimatic regions, a large genetic diversity is present in seedling population.

Singh (1978) noticed a lot of variability in annona in Andhra Pradesh, Madhya Pradesh, Gujarat, Maharastra and Rajasthan.

Pareek and Panwar (1981) reported that in phalsa, a lot of variability exists in Central India, Rajasthan, Bihar and drier parts of South India and suggested that surveys have to be made to collect promising types.

Due to seed propagation, considerable heterozygosity and large variation is observed in the fruit characters of karonda such as shape, size, pulp quality and yield in North-Western India, particularly in Mount Abu in Rajasthan and Khandala in Maharastra and this offers a great deal of scope for improvement in karonda by seedling selections (Bhagwat, 1984 and Joshi *et al.*, 1986).

Pareek and Sodagar (1986) identified 26 elite date palms from the variability in coastal belt of Kachch in Gujarat which produce large fruits with high pulp content and sweetness in doka stage.

2.2 Fruit development

In grapes, the berries showed a double sigmoid growth curve with three distinct periods of growth (Farmahan and Pandey, 1978).

Reports from Indonesia showed that in mangosteen the maximum physical growth of fruit reached at 103 days from full bloom, when pulp acidity attained its highest value and soluble solids in the pulp increased with increasing days from full bloom until the skin became purple and fruit ripened on the tree at 114 days (Sosrodhiharjo, 1980).

Alex (1996) reported that the mangosteen fruits ripened on the tree by 98-105 days after fruit set and the fruits showed a sigmoid growth pattern during development. Physical parameters, like, pulp weight, rind weight and pulp to fruit ratio increased upto harvest. Chemical composition of pulp showed that TSS, total sugars, reducing sugars, non-reducing sugars and sugar-acid ratio increased upto ripening, while ascorbic acid and acidity decreased till ripening.

Pal *et al.* (1987) suggested that harvest maturity in mango was obtained 120 days after fruit set. Mango fruit growth is characterised by sigmoid curve and the development of fruit in Langra and Dashehari starts in the last week of March and is completed by the end of second week of July (Singh, 1990).

Sherly (1994) observed that the Kodampuli fruits attained maturity in 130-140 days after fruit set. The developing fruits followed a sigmoid growth

pattern. The chemical composition of the rind showed an increase in TSS content till maturity. Total acidity increased upto 80 days after fruit set and showed a gradual decline towards ripening. Ascorbic acid content was also high in the initial stages and decreased towards maturity.

Joseph and Kumaran (1996) reported that the growth of the jack fruit showed sigmoid pattern, the rate being rapid upto the first 80 days and thereafter declined gradually. The time required for the full development of fruit ranged from 100 to 138 days after fruit set.

2.3 Fruit drop

Formation of abscission mechanism as reason for abscission was supported by various workers like Addicot and Lynch (1955), Chadha and Singh (1963) and Randhawa (1971). Chacko (1984) reported that at pea and marble stages of fruit development, the low level of auxin and gibberellins and high level of abscissic acid and ethylene could be responsible for the heavy drop.

The abscission of fruits subsequent to bloom or those developed partially occurs in definite waves. Chandler (1925) recognised three waves of abscission in decidious trees as (1) at blooming time or shortly after pistil abortion, (2) two weeks after flowering following failure of fertilisation, (3) June drop following competition for nutrients and failure of embryo development.

Musahib-Ud-Din and Dinsa (1946) reported as many as four drops in mango at one week interval. Gokhale and Kanitkar (1951) observed most of the mango fruit drop in very early stages of development and they termed it as post-setting drop. Occurrence of fruit drop in mango was also reported by Chadha and Singh (1964) and Singh (1965).

In citrus, the occurrence of fruit drop was reported by Nauriyal (1955) and Pollard and Biggs (1969). Randhawa and Singh (1962) recorded two definite waves of fruit drop in Nagpur mandarins during April-May and September-October.

Sherly (1994) recorded a fruit drop of 35.50 per cent in Kodampuli. The major part of the drop occurred during the first thirty days.

Joseph and Kumaran (1996) reported that the post-set drop ranged from 30 to 40 per cent in Varikka and Koozha jack types and the peak period of drop was observed between the 60th and 80th day after emergence of the catkin.

2.4 Sex differentiation

2.4.1 Dioecy in *Garcinia* species

Garcinia cambogia was reported to be dioecious in nature with male and hermaphrodite flowers seen in separate trees (Chandrarathna, 1948; CSIR, 1956; George, 1988; KAU, 1991 and Nazeema, 1992). George *et al.* (1992) and Sherly (1994) described *Garcinia cambogia* as androdioecious since the male and bisexual flowers occur in separate trees.

In *Garcinia indica*, Gunjate *et al.* (1982) identified 11 flower types based on structural differentiation and classified the trees according to their bearing tendancy, flower types and morphological differentiation into three types, viz., male or staminate, hermaphrodite or bisexual and pistillate or female.

In *Garcinia mangostana* the existence of male and hermaphrodite flowers were reported by Cobley (1956), CSIR (1956) and Veeraragavathatham and Balashanmugham (1989). Krishnamurthy *et al.* (1964) had reported female

trees with staminodes. Mangosteen was reported to be unisexual and dioecious, but only female trees with infertile staminodes had been found in Malaya and Jawa (Purseglove, 1969). Richards (1990) observed mangosteen to be invariable and almost all being female. Alex (1996) reported that mangosteen produced female flowers terminally on branchlets as solitary but rarely in pairs or in groups of 3 to 4.

2.4.2 Sex determination in Kodampuli

Sherly (1994) reported that in Kodampuli, the colour of emerging leaves showed marked differences among male and hermaphrodite trees. In male trees, the emerging leaves were light green in colour while they showed pinkish red colour in hermaphrodite trees.

Mathew *et al.* (1996) reported that there was significant variation in length and breadth of the leaves of male and female Kodampuli trees. Difference in leaf breadth was more conspicuous than leaf length and hence leaf breadth can be taken as one of the identifying characters for distinguishing the female trees from male ones.

2.4.3 Sex determination in other crops

2.4.3.1 Influence of sex on morphological characters

Differences in the morphological traits have been observed in the male and female plants of different dioecious species. The possibility of using morphological characters as sex markers has been investigated by many scientists.

Janse (1898) stated that male nutmeg trees had smaller leaves and less horizontal branches. But this difference was not clear and prominent enough in young seedlings and hence it was not possible to determine the sex of the plant in

the seedling stage. Prestoe (1948) reported that sex of nutmeg seedlings less than 30 cm high could be identified by observing the leaf form and venation. Leaves of female trees would be nearly elliptical with more or less straight veins, whereas male trees would possess nearly obovate leaves with their veins running to the more pronounced point of the leaf.

Flach (1966) observed a slight difference in the size between female and male nutmeg trees. Krishnamoorthy *et al.* (1992) conducted a detailed study of characters in nutmeg like leaf shape, size of leaves, venation, colour of new sprouts and days for germination of seeds and concluded that none of these characters can be considered as a marker for sex in nutmeg seedlings. Thomas (1997) reported that nutmeg male plants had higher length/width ratio of leaves than that of female ones.

Lacombe (1980) observed significant differences in the internodal length and growth rate of male and female plants of dioecious hemp (*Cannabis sativa*). He also reported that the sex of the plants could be determined from the age of 15 days, based on early vegetative characters.

Kotaeva *et al.* (1982) studied male and female individuals of *Morus alba*, *Ficus carica* and two other members of the family; female of all the species had larger leaves with denser and more spreading crown. Leaf fall began earlier in males than in females. In *Morus alba* and *Ficus carica*, the leaves and the spongy parenchyma were thicker in females and concluded that the transpirational activity was greater in females and the water content of leaves was lower in males.

Chen *et al.* (1985) registered 100 per cent correlation between sex and length/width (L/W) ratio of leaves of jojoba (*Simmondsia chinensis*), a dioecious dessert shrub. He observed (L/W) ratio of all females was greater than average and

that of all males was smaller. Kohorn (1994) reported that the females of jojoba were found to have larger leaves and more open canopies than males.

In the dioecious palm, *Chamaedorea tepijelote*, the male plants showed spatial variation in growth rate but not the females. Both sexes had different rates of production of leaves among years and males produced significantly more inflorescence than females (Oyama, 1990).

In odum (*Milicia excelsa*), a forest tree species, the females were found to possess more spreading crown and thicker stems than the males (Nyong *et al.*, 1994).

Machon *et al.* (1995) reported that in the dioecious perennial *Asparagus officinalis*, the male plants produced more but thinner stems than the females.

2.4.3.2 Influence of sex on biochemical characters

2.4.3.2.1 Phenolics and sex expression

The number of phenolic compounds present and the content were found to be differing in males and females of some dioecious species. Singh and Jindal (1974) subjected the leaf extracts of *Carica papaya* to ten colorimetric tests specific to phenolics and determined the sex of the plant with an accuracy of 86 per cent using Folin-Ciocalteau's reagent.

Billau *et al.* (1987) conducted high performance liquid chromatography analysis of phenolic compounds in storage roots of asparagus during vegetative period and found that male plants contained less caffeic acid and chelidonic acid and more coniferin than the female plants.

In the dioecious plant sorrell (*Rumex accetosella*) the content of hydroxy cinnamic acid (P - caumaric acid and ferulic acid) and hydroxy benzoic acids (Vanillic acids) were found to be more in the leaves and reproductive organs of male plants than female plants (Dyurdevich *et al.*, 1992).

Thomas (1997) reported that leaves of the male nutmeg plants had higher phenol content than female ones.

2.4.3.2.2 Protein and sex expression

Dutt and Mazumdar (1989) studied about the protein content of male and female papaya plants and reported that the protein content was higher in the female trees regardless of plant part examined.

Prasad and Iyengar (1982) reported that the leaves of female jojoba plants had higher total protein than males. DNA, RNA and carbohydrate contents were also higher in females.

2.4.3.2.3 Isozyme and sex expression

In recent years, the analysis of isozyme by polyacrylamide gel electrophoresis (PAGE) has been considered as a unique and powerful technique for ascertaining genetic relationships in plants. Further PAGE provides a tool for species and cultivar identification where morphological and cytological data are inadequate (Wilkinson and Beard, 1972).

Isozyme or multiple molecular forms of enzymes are enzymes that catalyse the same reaction but differ in physicochemical properties (Market and Moller, 1959). Among organic molecules isozymes are very useful aids in

deciphering the evolutionary relationship within different groups of plants and animals (Oliver and Zapater, 1985).

Munoz *et al.* (1982) observed the sex of the adult and juvenile plants of papaya could be identified using peroxidase zymogram where the male plants had more bands than females. Jaiswal *et al.* (1984) reported that reproductive tissues of male papaya plants showed greater activities of acid and alkaline phosphatase than those of female plants whereas the activity of each enzyme in vegetative apical meristem was more or less similar in both sexes. Peroxidase isozyme pattern was successfully used by Sriprasertek *et al.* (1988) to distinguish the sex and cultivar of tissue culture derived plants of papaya.

Suganuma and Iwasaki (1983) analysed peroxidase isozyme in the leaves of date palm electrophoretically and reported that there was difference in the zymogram of male and female plants. The female zymogram showed two additional bands and sex of the seedlings could be identified at two leaf stage using peroxidase isozyme.

In nutmeg, Thomas (1997) reported that the peroxidase banding pattern was similar for both male and female plants.

In *Asparagus officinalis*, association of malate dehydrogenase locus with sex determining genes was reported by Maestri *et al.* (1991). Shuang-xi and Xue-Feng (1995) analysed peroxidase isozymes from different organs and tissues of male and female plants of asparagus using PAGE and reported that male plants had one band less than females in the zymograms of callus. Stem apices from tissue culture also showed same pattern.

Deng *et al.* (1982) reported that peroxidase activity in the leaves of *Actinidia chinensis* was considerably higher in male plants than in female plants. Xia-Renxue and Xia-Rx (1997) reported that the male plants of *Actinidia chinensis* were characterised by one strong and one weak superoxidase dismutase band, while in the females there were three moderatively active and two weak bands. They also observed a similar situation in *Ginko biloba*.

Isozyme analysis has been reported to be useful in varietal characterisation and classification in a variety of crops. Different male cultivars of date palm was identified by using esterase and peroxidase banding pattern (Al-Jibouri, 1988). Durham *et al.* (1989) used nine different isozymes systems for the clonal identification of peach. Bhat *et al.* (1992) demonstrated the usefulness of analysis of esterase, acid phosphatase and catalase isozymes to distinguish the different cultivars of banana.

Materials and Methods

3. MATERIALS AND METHODS

The investigations were undertaken to study the variability in kodampuli in terms of vegetative, floral, fruiting and biochemical characters, to compare the quality of the rind under different drying conditions, to find out the pattern of fruit development and to differentiate the sex in terms of morphological and biochmeical characters. The study was conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 1996-98.

3.1 Variability study

Surveys were conducted in the homesteads of Thrissur and Pathanamthitta districts during the period 1996-98. Observations on general tree characters, leaves, flowers and fruits were recorded on 50 collections. Scion shoots were also collected during the survey and grafted on seedling root stocks for the maintenance of soft wood grafts in the Department.

3.1.1 General tree characters

The following observations on general tree characters were made on 50 collections.

3.1.1.1 Shape of the tree

Canopy shape of the trees of different accessions was recorded.

3.1.1.2 Branching habit

Branching habit of the trees of different accessions was visually observed.

3.1.1.3 Season of flowering

Flowering season in different trees was recorded.

3.1.1.4 Season on fruit ripening

Fruit ripening season in different collections was recorded.

3.1.1.5 Bearing capacity

Bearing capacity of different accessions was assessed based on their yield per annum.

3.1.1.6 Incidence of disease, pest and physiological disorder

Occurrence of disease, pest and physiological disorder in different trees were recorded.

3.1.2 Leaf characters

From each accession, 10 leaves were collected and the following observations were made.

3.1.2.1 Leaf length (cm)

The length of the leaf was measured from the base to apex and recorded in cm..

3.1.2.2 Leaf width (cm)

The width of leaf at maximum point was measured and recorded in cm.

3.1.2.3 Length/width ratio

The length/width ratio was worked out for each leaf.

3.1.2.4 Leaf area (cm^2)

The leaf area was worked out by using the following regression equations proposed by Mathew *et al.* (1996) for calculating leaf area in kodampuli leaves.

For male,

Leaf area = 1.011 + 0.987 (Length x Breadth)

For female,

Leaf area = 0.58 + 0.943 (Length x Breadth)

3.1.2.5 Leaf shape

The shape of the leaves was noted visually.

3.1.3 Flower characters

3.1.3.1 Flower and sex types

In order to study the variability in flower and sex types, observations were recorded on 20 young trees of 7 to 8 years age, which have started flowering and 15 mature trees of about 17 years age, all of which are seedling origin, maintained in the research fields of College of Horticulture, Vellanikkara. Random samples of flowers from each tree were collected during the flowering

season and the observations were made. Flowers were also collected from different accessions during the survey to note the variation in flower characters.

3.1.3.2 Variability in morphology and fertility of flowers of male and bisexual trees

The following observations were made separately on 20 male and bisexual trees, each.

3.1.3.2.1 Number of flowers per cluster

The number of flowers in 25 clusters of each tree was counted and the mean number was calculated.

3.1.3.2.2 Length of the pedicel (cm)

The pedicel length of ten flowers from each tree was measured and the mean was worked out.

3.1.3.2.3 Colour of the petals

Intensity of the colour of the petals was noted from flowers of each tree.

3.1.3.2.4 Length of the petals

The length of the petals of ten flowers from each tree was measured and the mean was worked out.

3.1.3.2.5 Weight of the flower

Weight of ten flowers from each tree was taken and mean was worked out.

3.1.3.2.6 Number of stamens per flower

The number of stamens of ten flowers from each tree was counted and the mean was worked out.

3.1.3.2.7 Pollen fertility

Ten well matured unopened buds were selected from male and hermophrodite trees for the study. Pollen from each bud were collected in acetocarmine (one per cent) - glycerin mixture kept on a slide and covered with a clean cover slip. The slides were kept undisturbed for 30 minutes to allow the pollen grains to take stain properly before examining it under the microscope. Fertility was calculated as the percentage of normal, well stained pollen grains to the total number of pollen grains in each microscopic field. Ten such fields were observed in each slide. The average was worked out and expressed as percentage.

3.1.3.2.8 Pollen germination

In vitro pollen germination had been carried out to ascertain the germinability of the viable pollen by using 4 per cent sugar + 0.5 per cent agar as the medium suggested by Sherly (1994) for maximum germinability. Pollen germination was ascertained by examining pollen tube growth to a length atleast double that of a diameter of the pollen 24 hours after inoculation. On an average, 500 pollen grains from 10 microscopic fields were counted. Germination was expressed in percentage with the average worked out from 500 observations.

3.1.4 Fruit characters

3.1.4.1 Morphological characters

The fruits collected during survey were evaluated for the following morphological characters.

3.1.4.1.1 Colour of the fruit

Colour of the fruits of different collections was observed visually.

3.1.4.1.2 Shape of the fruit

Shape of the fruits from different tree was recorded.

3.1.4.1.3 Number of segments per fruit

The number of segments of ten fruits from each accession was counted and the mean was worked out.

3.1.4.1.4 Width of the segment (cm)

Width of the segment of ten fruits at the maximum point was measured from each accession and the mean was calculated.

3.1.4.1.5 Length of the fruit (cm)

Length of ten fruits from each collection was measured from base to apex using a flexible twine and the mean was calculated.

3.1.4.1.6 Girth of the fruit (cm)

Girth of ten fruits at maximum point was measured from each tree and the mean was worked out.

3.1.4.1.7 Weight of the fruit (g)

Weight of ten fruits from each accession was taken and the mean was calculated.

3.1.4.1.8 Volume of the fruit (cm^3)

Volume of ten fruits from each accession was measured using water displacement method and the mean was worked out.

3.1.4.1.9 Thickness of the rind (cm)

Rind thickness of ten fruits at the maximum point from each accession was measured and the mean was calculated.

3.1.4.1.10 Weight of the seed (g)

Weight of the seed along with muscilage of ten fruits from each accession was taken and the mean was calculated.

3.1.4.1.11 Number of seeds

After cutting the fruits into halves, the number of well developed seeds as well as under-developed seeds from ten fruits were counted from each accession and the mean was calculated.

3.1.4.1.12 Weight of the rind (g)

After removing the seed along with muscilage the weight of the rind of ten fruits from each collection was taken and the mean was calculated.

3.1.4.1.13 Fruit rind ratio

The ratio of fruit to rind was calculated by dividing the mean fresh fruit weight by mean fresh rind weight.

3.1.4.1.14 Rind seed ratio

The ratio of rind to seed was calculated by dividing the mean fresh rind weight by mean weight of seed along with muscilage.

3.1.4.2 Biochemical characters

After making morphological observation, the rind was dried in hot air-oven at 70°C. The dried rind was powdered using mixer grinder. Biochemical characters of each accession were determined using the powdered samples.

3.1.4.2.1 Moisture content

Moisture was determined by drying in hot air oven at 60 to 70°C till constant weight was obtained (Ranganna, 1977).

3.1.4.2.2 Total soluble solids

Total soluble solids (TSS) of fresh rind as well as muscilage was found out by using Erma hand refractometer (0 to 32° Brix) and expressed in degree Brix (A.O.A.C., 1980).

3.1.4.2.3 Total acidity

Acidity was determined by titration with standard sodium hydroxide solution and expressed as percentage of citric acid (A.O.A.C., 1980).

3.1.4.2.4 Crude protein

Nitrogen content was estimated by microkjeldhal digestion and distillation method as described by Jackson (1958) which was then multiplied with a factor of 6.25 to get the protein content.

3.1.4.2.5 Crude fat

Crude fat was estimated by using Soxhlet apparatus with petroleum ether as solvent. The extraction was carried out for 16 hours (A.O.A.C., 1980).

3.1.4.2.6 Crude fibre

Crude fibre content of the dried samples was estimated by acid alkali method as suggested by Chopra and Kanwar (1978).

3.1.4.2.7 Hydroxy citric acid

Hydroxy citric acid was extracted using acetone and after concentrating the extract, the acid was taken in water which yielded crystalline lactone on adding lactone crystals and keeping for evoporation (Lewis *et al.*, 1964).

3.1.4.2.8 Total phenol

Total phenol content was estimated by Folin-Ciocalteau method (Sadasivam and Manikam, 1992).

3.1.4.3 Statistical analysis

The data on the above mentioned morphological and biochemical characters of the fruits from different accessions were subjected to analysis of variance as adopted for completely randomised design by Panse and Sukhatme

(1975) in order to test the significance of variation. Duncan's multiple range test was also carried out for the comparison of means of different morphological and biochemical characters of the fruit from different accessions. A simple correlation between rind weight and other morphological characters was worked out. The data were consequently subjected to multivariate analysis utilising non-hierarchial euclidean cluster analysis in order to find out the genetic divergence.

3.2 Rind quality under different drying conditions

Four accessions were selected from which, one kilogram fresh fruit, each, was subjected to different drying conditions, namely, sundrying, smoke drying and oven drying. The dried fruit samples from each of the drying conditions were subjected to different biochemical analysis to compare the quality of the dried rind. The data on the rind quality parameters under different drying conditions were subjected to analysis of variance as adopted for completely randomised design by Panse and Sukhatme (1978) in order to test the significance of variation.

3.3 Fruit development

Young fruits soon after set were tagged for studying the development stages of the fruit. About 100 fruits were tagged on five trees. In order to study the changes with respect to physical parameters such as total weight, volume, rind thickness, etc. and chemical parameters like total acidity, TSS, phenol content, crude fat, crude fibre, crude protein and (-)-HCA, sampling was done at weekly intervals. Analyses were made for the above parameters.

3.4 Fruit drop

Observations on fruit drop was recorded on five bearing trees. To know the extent of fruit drop, about 200 fruits immediately after set were tagged in all the four sides of the tree and observed for drop at weekly interval.

3.5 Sex differentiation

Fifteen each of well differentiated male and bisexual trees of same age group were selected from different locations in Thrissur district. Following morphological observations of the tree and biochemical analyses of leaves were carried out.

3.5.1 Morphological characterisation

3.5.1.1 Plant characters

The following biometric observations of mature trees of age about 17 years were recorded.

3.5.1.1.1 Plant height (m)

The height of the plant from ground level to the tip of the tree was measured an expressed in m.

3.5.1.1.2 Spread of the plant (m^2)

The maximum horizontal extensions of branches in the North-South and East-West directions were measured and their product was expressed as the spread of the plant.

3.5.1.1.3 Collar girth (cm)

The collar girth of the plants at 5 cm above ground level was measured using a tape and recorded in cm.

3.5.1.1.4 Height at the first branching (m)

The height of the plant from the ground level to the first branching point was measured in m.

3.5.1.1.5 Canopy shape and branching habit

The canopy shape and branching habit were observed visually.

3.5.1.1.6 Colour of the young flush

The colour of the emerging flush was visually observed.

3.5.1.1.7 Colour of the latex

The colour of the latex, which is exuding out on removing the growing tip was visually observed.

3.5.1.1.8 Colour of the bark

External as well as internal colour of the bark of the growing shoot was visually noticed.

3.5.1.1.9 Colour of the feeder roots

Feeder roots collected, after removing the top soil to about 30 cm depth under the tree, were visually examined for the colour.

3.5.1.2 Leaf characters

From the male and bisexual plants, 40 leaves each were collected and the following leaf characters were recorded.

3.5.1.2.1 Leaf length

3.5.1.2.2 Leaf width

3.5.1.2.3 Length/width ratio

3.5.1.2.4 Leaf area

3.5.1.2.5 Petiole length

3.5.1.2.6 Internodal length

3.5.1.2.7 Leaf shape

3.5.2 Biochemical characterisation

The following biochemical analyses were carried out in the leaves of male and bisexual trees.

3.5.2.1 Essential oil

Essential oil content was estimated by using Clevenger apparatus.

3.5.2.2 Total acidity

Acidity was determined by titration with standard sodium hydroxide solution and expressed as percentage of citric acid (A.O.A.C., 1980).

3.5.2.3 Total phenol

Total phenol content of both young and mature leaves was estimated by Folin-Ciocalteau method (Sadasivam and Manikam, 1992).

3.5.2.4 Thin layer chromatography (TLC)

TLC was carried out for the separation of phenolic compounds using Precoated ilica gel plantes with the running solvent system of chloroform and glacial acetic acid in the rates of 9:1. Folin-Ciocalteau reagent was used as spraying reagent.

3.5.2.5 Isozyme analysis

Polyacrylamide gel electrophoresis (PAGE) using vertical slab gel was carried out for isozyme analysis for perxodase.

For the preparation of gel, the following stock solutions were made.

Solution A

Tris	- 38.3 g
TEMED	- 0.46 ml
1N HCl	- 48 ml
Distilled water	- 200
pH	- 9.0

Soultion B

	7.5% polymerisation	10% polymerisation
Acrylamide	30.0 g	40.0 g
Bisacrylamide	0.9 g	1.2 g
Made upto	100 ml	100 ml

Solution C

Ammonium persulfate	- 0.14 g
Distilled water	- 100 ml

Preparation of gel column

Gel column of 7.5 per cent and 10 per cent polymerisation were tried. The size of the gel slab was 16 cm x 14 cm x 0.01 cm. Solution A and B were prepared and stored in amber coloured bottles at 0-4°C. Solution C was prepared fresh each time. Stock solution of A, B and C were taken in 1:1:2 proportion and mixed thoroughly. The solution was applied by a springe in between glass plates and kept in the polymerisation stand. Combs were placed at the top to make the wells.

Electrophoretic running

Electrode buffer solution

Tris	- 6 g
Glycine	- 28.8 g
Made upto	- 1000 ml
pH	- 8.3

After polymerisation the gels were transferred to electrophoresis unit. Upper and lower tanks were filled with precooled electrode buffer. Ten and twenty micro litre samples were applied to each well with transfer pipette. Upper tank was connected to the cathode and lower one to the anode. Bromophenol blue (0.002%) was added to the upper tank as the tracer dye.

A constant current of 20 m A was applied for the first half an hour and gradually increased to 40 m A and maintained till the end of running. A cooling system was attached to the electrophoresis unit for heat dissipation and electrophoresis was carried out a 4°C for 6 hrs.

Different extraction buffers were tried

1.	Tris buffer	- 21.199 g
	Citric acid	- 2.626 g
	Vitamin C	- 0.52839 g
	Cystin HCl	- 052689 g
	Made upto	- 500 ml
	pH	- 7
2.	Tris buffer	- 21.1995 g
	Citric acid	- 2.626 g
	L-Cystein HCl	- 0.52689 g
	Mercaptoethanol	- 0.039065 g
	pH	- 7
	Made upto	- 500 ml
3.	Tris HCl	- 28.8 g
	Citric acid	- 2.626 g
	Vitamin C	- 0.52839 g

L-Cystein HCl	- 0.52689 g
Inosluble PVP	- 0.5 g
Mercapto ethanol	- 0.39065 g
Made upto	- 500 ml
pH	- 7

One millilitre of this buffer was taken and made upto 100 ml after adding 17.115 g of sucrose at the time of extraction.

Preparation of sample

Leaf samples of both tender and mature leaves were collected in liquid nitrogen. One gram sample was grinded in 2 ml extraction buffer in a prechilled mortar and pestle. The homogenized material was centrifuged at 1500 rpm for 15 minutes in a refrigerated centrifuge at 5°C. After centrifugation the clear supernatant was collected and stored in a refrigerator and loaded in the wells at the time of electrophoresis.

After running, the gels were immersed in freshly prepared stain containing benzidine - 0.028 g, acetic acid - 18 ml, H_2O_2 3% - 100 ml, water - 80 ml. It was kept for overnight and then destained with 7 per cent acetic acid.

Results

4. RESULTS

The present investigations were undertaken with the objective of studying the variability in vegetative, floral, fruiting and biochemical characters of *Garcinia cambogia* Desr., to compare the quality of the rind under different drying conditions, to find out the pattern of fruit development and to differentiate the sex in terms of morphological and biochemical characters. The study was undertaken in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, during 1996-98.

4.1 Variability study

4.1.1 General tree characters

The information with regard to general tree characters on 50 accessions are presented in the Table 1.

4.1.1 Shape of the tree

The trees showed variation in canopy shape, i.e., round, dome, conical and pyramidal. But majority of the trees surveyed were conical in shape (Table 1).

4.1.1.2 Branching habit

With respect to mode of branching, the trees showed variations. Horizontal, drooping and erect branching habits were observed. Majority of the trees had drooping branches (Table 1).

Table 1. General tree characters of different accessions of *Garcinia cambogia*

AC.No.	Tree shape	Branching habit	Flowering season	Ripening season	Fruit quality	Incidence of disease, pest and physiological disorders	Bearing tendency
1	2	3	4	5	6	7	8
1	Conical	Drooping	February-March	June-July	Medium	Algal rust, sooty mould	Irregular
2	Conical	Drooping	February-March	June-July	Medium	Algal rust, sooty mould	Irregular
3	Conical	Spreading	January-February	May-June	Good	Nil	Irregular
4a	Conical	Drooping	February-March	June-July	Bitter	Malformation	Irregular
4b	Round	Spreading	February-March	June-July	Good	Malformation, leaf spot	Irregular
5	Pyramidal	Spreading	February-March	June-July	Poor	Leaf blight, Gamboge	Irregular
6	Conical	Spreading	February-March	June-July	Medium	Malformation	Irregular
7	Round	Spreading	February-March	June-July	Poor	Malformation	Irregular
8a	Dome shaped	Spreading	February-March (Sporadic flowering in off season)	June-July (Sporadic ripening in off season)	Very good	Malformation, leaf cutting beetle	Irregular
8b	Conical	Spreading	February-March	June-July	Very poor	Malformation, fruit rot	Irregular
9	Conical	Spreading	February-March (Sporadic flowering in off season)	June-July (Sporadic ripening in off season)	Good	Malformation, leaf spot	Irregular
10	Conical	Erect	February-March	June-July	Good	Malformation, Gamboge	Irregular
11	Pyramidal	Drooping	March-April	July-August	Good	Nil	Irregular
12	Conical	Erect	February-March	June-July	Good	Malformation	Irregular
13	Round	Spreading	February-March (Sporadic flowering in off season)	June-July (Sporadic ripening in off season)	Good	Malformation	Irregular
14	Dome	Spreading	February-March	June-July	Excellent	Malformation	Irregular

Contd. ...

Table 1. Continued

1	2	3	4	5	6	7	8
15	Conical	Drooping	February-March	June-July	Poor	Malformation, Gamboge	Irregular
16	Conical	Drooping	February-March	June-July	Very good	Nil	Irregular
17a	Round	Spreading	February-March	June-July	Medium	Fruit rot	Irregular
17b	Round	Spreading	February-march	June-July	Good	Nil	Irregular
18	Conical	Drooping	February-March	June-July	Good	Malformation	Irregular
20	Conical	Drooping	February-March	June-July	Very good	Malformation	Irregular
21	Conical	Spreading	March-April	July-August	Good	Malformation	Irregular
22	Conical	Drooping	February-March	June-July	Medium	Gamboge	Irregular
23	Pyramidal	Spreading	March-April	July-August	Good	Fruit rot	Irregular
24	Conical	Spreading	February-March	June-July	Medium	Malformation	Irregular
25	Conical	Drooping	February-March	June-July	Good	Gamboge	Irregular
26	Conical	Drooping	February-March	June-July	Medium	Fruit rot	Irregular
27	Round	Drooping	February-March	June-July	Medium	Leaf cutting beetles	Irregular
28	Conical	Drooping	February-March	June-July	Good	Malformation	Irregular
29	Round	Erect	February-March	June-July	Medium	Leaf spot	Irregular
30	Pyramidal	Spreading	February-March	June-July	Medium	Malformation	Irregular
31	Round	Drooping	February-March	June-July	Medium	Gamboge	Irregular
32	Round	Drooping	February-March	June-July	Medium	Malformation, leaf spot	Irregular
33	Pyramidal	Spreading	February-March	June-July	Medium	Gamboge	Irregular
34	Conical	Drooping	February-March	June-July	Medium	Fruit rot	Irregular
35	Conical	Drooping	February-March	June-July	Excellent	Malformation	Irregular
36	Conical	Spreading	January-February	May-June	Good	Fruit rot	Regular
37	Conical	Drooping	March-April	July-August	Poor	Malformation	Irregular
38	Conical	Spreading	March-April	July-August	Good	Leaf spot, leaf blight, Algal rust, sooty mould	Irregular
39	Conical	Drooping	February-March	June-July	Medium	Nil	Irregular
40	Conical	Drooping	February-March	June-July	Good	Malformation	Irregular
41	Conical	Drooping	February-March	June-July	Very good	Malformation	Regular

Contd.

Table 1. Continued

1	2	3	4	5	6	7	8
42	Conical	Spreading	February-March	June-July	Good	Nil	Regular
43a	Conical	Drooping	February-March	June-July	Good	Leaf cutting beetle	Irregular
43b	Conical	Drooping	February-March	June-July	Medium	Nil	Irregular
44	Conical	Spreading	February-March	June-July	Very good	Malformation, algal rust, sooty mould	Regular
45a	Conical	Drooping	February-March	June-July	Good	Gamboge	Regular
45b	Conical	Drooping	February-March	June-July	Good	Sooty mould, algal rust	Irregular
46	Conical	Spreading	March-April	July-August	Good	Sooty mould, algal rust	Irregular

4.1.1.3 Season of flowering

In male trees, the peak flowering season was from December to March. But there were trees which showed early flowering, i.e., in November. In certain cases the flowering continued till July. In general the duration of flowering was longer in male trees i.e., about four to five months compared to bisexual.

In bisexual trees, the peak flowering season was from February to March (Table 1). But there were trees which started flowering by January (AC. 3 and 36) and in certain cases flowering was noticed till April (AC. 21, 23, 37, 38 and 46). The duration of flowering was shorter in bisexual trees i.e., about 2 to 3 months. In rare cases, bisexual trees flowered sporadically throughout the year (AC. 8a, 9 and 13). Occasionally both flowering and fruit ripening were noticed simultaneously.

4.1.1.4 Season of ripening

The peak season of ripening was during June-July (Table 1). There were trees in which fruit ripening started very early by May (AC. 3 and 36). In very late types, ripening during July-August (AC. 21, 11, 23, 37, 38 and 46) was also noticed. A few trees could be located in which ripening was noticed throughout the year (AC. 8a, 9 and 13).

4.1.1.6 Bearing capacity

Bearing capacity of the tree vary with genotype, age, climate and management of the tree. There were very prolific bearing accessions (AC. 3, 8a, 9, 14, 36, 40, 42, 43b, 45a and 46) giving yield upto 500-600 kg of fresh fruit per annum (Plate 1) and medium bearing trees (4a, 4b, 5, 6, 7, 11, 13, 16, 18, 20, 23, 24, 27, 28, 29, 30, 31, 32, 33, 34, 35, 38, 39, 41, 43a and 45b) upto 200 kg of fresh

Table 2. Yield of different accessions of *Garcinia cambogia* during 1997 and 1998

AC.No.	Age (years)	Yield per tree (kg)		AC.No.	Age (years)	Yield per tree (kg)	
		1997	1998			1997	1998
1	17	25.0	10.0	25	70	45.0	70.5
2	17	35.0	10.0	26	40	35.0	60.0
3	40	375.0	150.0	27	40	77.0	20.0
4a	20	75.0	10.0	28	20	63.0	26.5
4b	20	125.0	25.0	29	20	81.0	30.5
5	30	60.0	10.0	30	40	79.0	28.5
6	50	65.0	25.0	31	18	67.0	18.0
7	60	58.5	20.5	32	35	75.0	20.5
8a	60	565.0	300.5	33	40	55.0	27.5
8b	30	25.0	40.5	34	17	60.0	175.5
9	70	500.5	200.0	35	40	63.0	30.5
10	60	35.0	100.5	36	50	230.0	240.0
11	60	100.0	45.0	37	40	30.0	10.0
12	75	47.5	10.5	38	60	100.0	45.0
13	80	112.0	20.5	39	40	150.0	68.5
14	70	500.5	10.5	40	45	375.0	200.5
15	50	20.0	100.0	41	15	180.0	195.5
16	30	75.5	10.0	42	30	475.0	483.0
17a	40	45.0	15.0	43a	40	85.0	10.0
17b	60	35.5	18.5	43b	37	360.0	150.0
18	100	83.0	20.0	44	40	210.0	230.5
20	25	70.0	10.0	45a	47	420.0	415.0
21	20	20.0	4.5	45b	47	95.0	130.0
22	25	25.0	10.0	46	60	500.0	200.0
23	40	65.0	35.0				
24	60	60.0	20.5				

fruits per annum. There were also poor yielding trees (1, 2, 8b, 10, 12, 15, 17a, 17b, 21, 22, 25, 26 and 37) which yielded only below 50 kg per annum (Table 2).

Most of the collections showed irregularity in bearing, i.e., one or more years of heavy crop followed by an year of poor crop (Table 2). Only a few accessions like AC. 41, 42, 44 and 45a were having regular bearing tendency.

4.1.1.7 Incidence of disease, pest and physiological disorders

Data pertaining to the incidence of disease, pest and physiological disorders in different accessions are furnished in the Table 1. The most widely prevalent dreadful malady is malformation. Bunching of vegetative shoots resembling the malformation in mango was observed (Plate 2). This condition was found to affect both the vegetative and reproductive parts of the tree and was found to be more prevalent during the flowering season. It was found on both the male as well as the hermophrodite trees. The condition appeared as a swelling of several buds at a place and several small shootlets packed with tiny leaf rudiments. In severe conditions, the transformed shoots appeared as a compact mass which hanged down from the primary and secondary branches. In the early stages, the mass was green or greenish yellow in colour. The mass remained on the tree for more than six months after which it started drying up. A brownish discolouration was seen on the vascular tissues of the branches where the symptoms were observed.

The incidence of malformation severely affected the growth of the branch and flowering did not occurred on such branches. In the case of mild symptoms, the affected branches survived into the next season and showed similar types of symptoms in the next season at the same location. In very severe cases, the whole branch dried up.

Plate 1. A bearing kodampuli tree

Plate 2. Malformed shoots of kodampuli

Plate 3. Fruit rotting in kodampuli fruits

Plate 4. A rare occurrence of male and bisexual flowers in two branches of a single tree

Rare incidence of leaf blight, characterised by the initial symptoms of circular brown spots with concentric rings surrounded by an yellow halo and later these spots coalisced to cover larger area of the leaves causing blighting of the leaves.

Leaf spot disease was also occasionally noticed. The infection initiated with the appearance of small reddish brown spots on older leaves and became circular to irregular in shape, with central grey coloured necrotic portion which on drying produced a shot hole behind.

Fruit rotting was noticed in the fruit which ripened during rainy season. The rotting was caused by *Colletotricum* sp. (Plate 3). Rare incidence of leaf cutting beetles causing semicircular notches on the leaves was also noticed.

Gamboge, a physiological disorder, was widely prevalent. The fruits with gamboge were characterised by an exudation of yellow gum from the rind which gradually penetrated into the fruit. The fruit pulp became yellow and gummy and the rind turned black and bitter. It affected the quality of the dried produce.

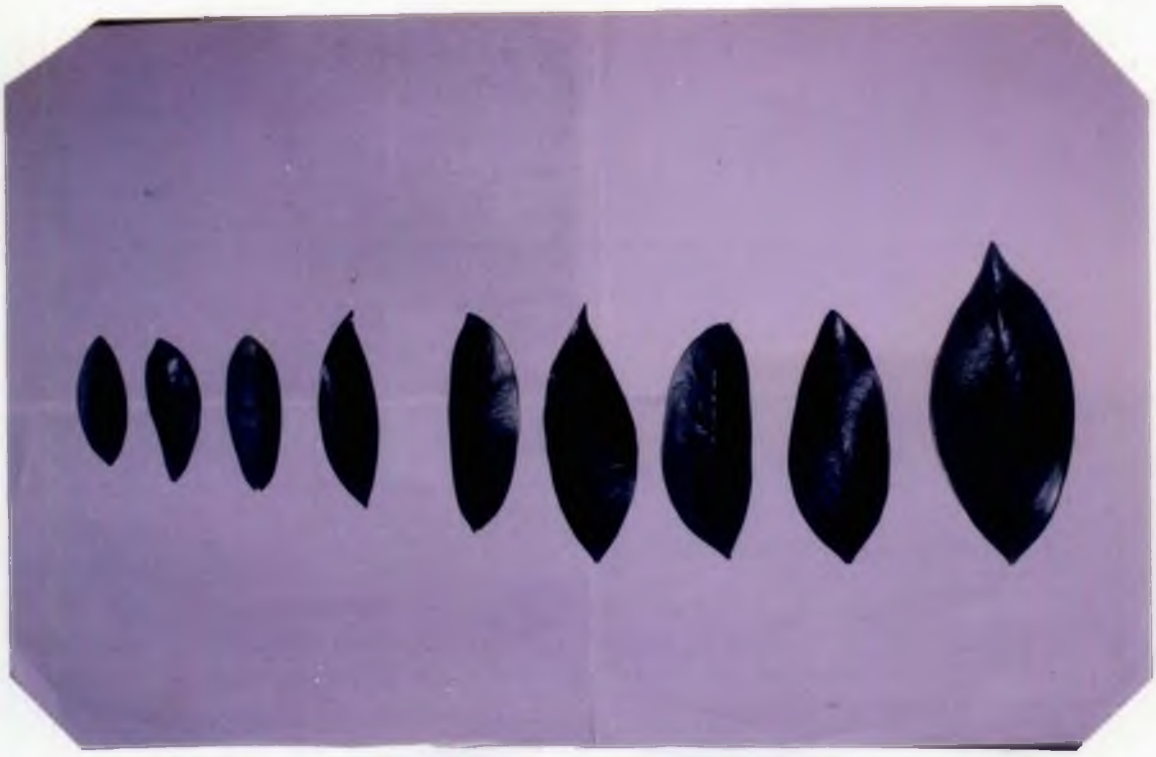
4.1.1.8 Other observations

Certain unexpected but interesting observations were also noticed during the survey.

Wherever the branches were cut and removed with iron knife, the yield was affected considerably and the nearby branches showed symptoms of drying.

Plate 5. Variability in leaf shape and size

Plate 6. Flower types: Type 1 to Type 6



6 5 4

3 2 1

A peculiar character of appearance of male flowers on one branch and bisexual flowers on other branch of a single tree was noticed (Plate 4). Of the 46 accessions observed, only two trees showed such a phenomenon.

4.1.2 Leaf characters

Information regarding the variation in the leaf characters of the different collections are furnished in the Table 3. Wide variation was noticed in leaf length and it ranged from 5.3 cm (AC. 17a) to 14.0 cm (AC.43b). But the majority was in the range of 9.0 cm to 12.0 cm. Regarding the width of leaves, the range was from 2.3 cm (AC. 38 and 39) to 5.6 cm (AC. 3 and 4b) but the majority had the range of 3.0 to 5.0 cm. The length/width ratio ranged from 1.36 cm (AC. 17a) to 4.0 cm (AC. 43b) and the majority of the leaves showed the range 2.0 to 3.5 cm. With respect to leaf area, the range was from 19.88 cm^2 (AC. 38 and 39) to 64.47 cm^2 (AC. 4b) and the majority were in the range of 35.00 cm^2 to 55.00 cm^2.

A variety of leaf shapes were noticed, namely, oblong, elliptic, obovate, oblanceolate and lanceolate. Variation was also noticed in the apex of the leaf, namely, acute, obtuse and acuminate (Plate 5).

4.1.3 Flower characters

4.1.3.1 Flower and sex types

4.1.3.1.1 Flower types

Different flower types were noticed in male and bisexual trees of *Garcinia cambogia* (Plate 6,7 and 8). The flowers could be arranged in an ascending order of increasing function of pistil and decreasing function of the stamen (Table 4). Depending on the function of stamen and pistil, the flowers could be grouped into six types. Their characters are described below:

Table 3. Leaf characters of different accessions of *Garcinia cambogia*

AC.No.	Length (cm)	Width (cm)	Length/ width	Area (cm^2)	Shape	Tip
1	2	3	4	5	6	7
1	9.2	3.9	2.36	34.41	Oblong	Acuminate
2	10.7	5.0	2.14	51.03	Oblong	Obtuse
3	11.9	5.6	2.12	63.42	Oblong	Obtuse
4a	11.5	4.5	2.56	49.38	Elliptic	Acute
4b	12.1	5.6	2.16	64.47	Obovate	Acute
5	13.2	4.6	2.87	57.83	Oblanceolate	Acute
6	9.5	5.5	1.72	49.85	Elliptic	Acuminate
7	8.0	4.0	2.00	30.75	Elliptic	Acute
8a	8.5	5.0	1.70	40.65	Elliptic	Obtuse
8b	13.0	4.2	3.09	52.06	Oblong	Acuminate
9	10.0	5.0	2.00	47.73	Lanceolate	Acute
10	8.0	4.0	2.00	30.75	Elliptic	Acuminate
11	6.9	3.1	2.22	20.75	Obovate	Acute
12	10.3	3.6	2.86	35.55	Lanceolate	Acuminate
13	9.3	3.3	2.81	29.52	Oblong	Acuminate
14	11.5	5.0	2.30	54.80	Elliptic	Acute
15	12.5	3.6	3.47	43.06	Obovate	Obtuse
16	12.5	3.7	3.38	44.19	Lanceolate	Acute
17a	5.3	3.9	1.36	20.07	Obovate	Acute
17b	11.0	3.3	3.30	34.81	Oblong	Acute
18	8.1	4.1	1.97	31.89	Elliptic	Acuminate
19	13.0	4.3	3.02	53.29	Elliptic	Obtuse
20	10.3	5.1	2.01	50.16	Oblong	Acuminate
21	11.2	4.9	2.29	54.88	Lanceolate	Acute
22	7.8	3.1	2.51	24.18	Obovate	Obtuse
23	8.9	5.0	1.78	42.54	Elliptic	Obtuse
24	10.8	4.2	2.57	43.34	Obovate	Acute
25	12.4	3.6	3.44	42.68	Oblong	Acuminate
26	11.6	4.2	2.76	46.52	Oblanceolate	Acute
27	13.0	5.1	2.55	63.10	Lanceolate	Acuminate
28	11.4	3.9	2.92	42.51	Oblong	Acute
29	11.4	3.1	3.68	33.90	Elliptic	Obtuse
30	9.3	2.9	3.21	26.01	Lanceolate	Acute
31	10.8	3.1	3.48	32.15	Obovate	Obtuse

Contd.

Table 3. Continued

1	2	3	4	5	6	7
32	11.2	3.9	2.87	41.77	Elliptic	Obtuse
33	8.7	3.1	2.97	26.01	Oblong	Acuminate
34	9.3	4.1	2.27	36.54	Elliptic	Obtuse
35	9.7	3.6	2.53	31.47	Elliptic	Acute
36	11.2	3.6	3.10	38.60	Oblanceolate	Acuminate
37	7.6	3.1	2.45	22.79	Lanceolate	Acute
38	8.9	2.3	3.06	19.88	Elliptic	Acuminate
39	8.9	2.3	3.06	19.88	Lanceolate	Acute
40	11.3	3.7	3.05	40.01	Oblong	Obtuse
41	8.3	4.0	2.07	31.89	Lanceolate	Obtuse
42	11.3	4.7	2.40	50.66	Elliptic	Acute
43a	10.8	4.4	2.45	45.39	Oblong	Obtuse
43b	14.0	3.5	4.00	46.78	Obovate	Acute
44	8.6	5.0	1.72	41.13	Elliptic	Acute
45a	11.3	5.2	2.17	55.99	Oblanceoate	Obtuse
45b	12.0	5.1	2.35	58.29	Elliptic	Acute
46	13.6	4.9	2.78	63.42	Oblong	Acute

Type I

This was a typical flower of pure male trees (Plate 6,7 and 8). It had long as well as short pedicel, the flower size varied from 0.9 cm to 2.3 cm in length and 1.5 to 2.5 cm in girth. Petal colour variation ranging from light yellow to dark yellow, cream and pink were noticed in the flower of both long and short pedicelled types. Stamens were numerous ranging from 60 to 80, crowded over central hemispherical receptacle (Plate 9). This was the type, having highest pollen viability of 94.00 per cent. Rudimentary pistil was absent.

Type 2

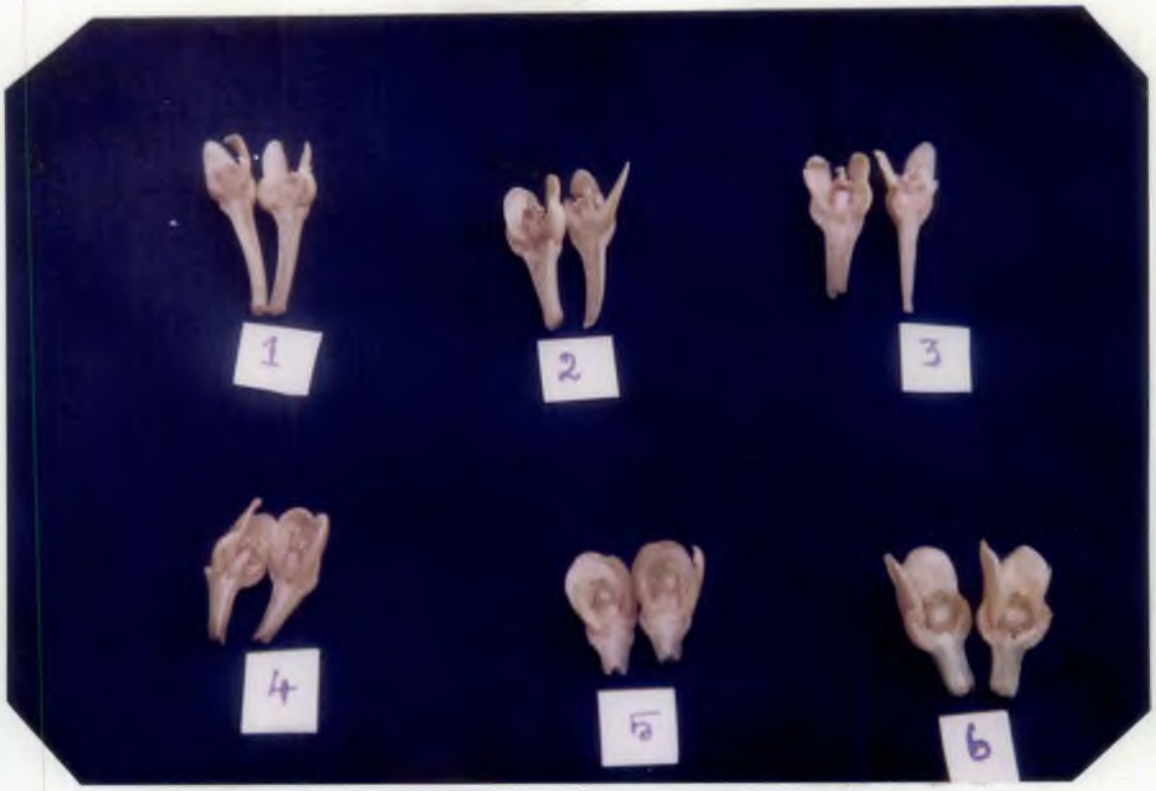
This flower type was also seen on male trees (Plate 6,7 and 8). It had both long as well as short pedicel. Regarding the size variation, it ranged from 0.9 to 2.3 cm in length and 1.8 to 2.5 cm in girth. In both long and short pedicelled flowers, the petals varied in colour ranging from light yellow to dark yellow, pink and cream. Stamens were numerous, 50 to 60 in number (Plate 9). Pollen viability was 83.20 per cent. A rudimentary structure, conical in shape was present in the place of pistil, measuring about 0.5 mm in length and stigma was absent. Cross-section of this structure showed no presence of ovary cells.

Type 3

This type was commonly found on male trees and also rarely on bisexual trees (Plate 6,7 and 8). It had long as well as short pedicel. The flowers varied in size ranging from 0.9 to 2.1 cm in length and 1.5 cm to 2.8 cm in girth. Petal colour variation ranged from light yellow to dark yellow, cream and pink were seen in both long and short pedicelled types. Stamens were numerous, 40 to 50 in number. The percentage of pollen viability was 77.34. The stamens near the rudimentary pistil

Plate 7. L.S. of flower types

Plate 8. Flower types showing ovary and stamen


1
2
3
4
5
6

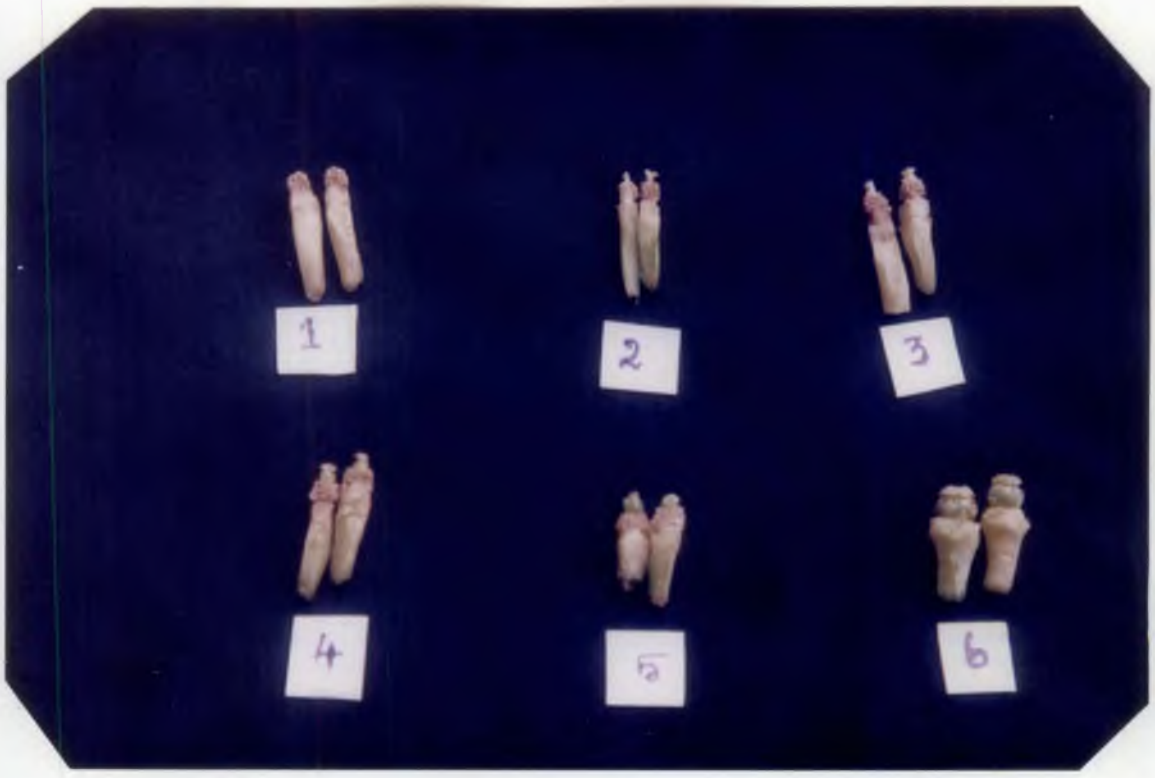
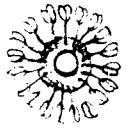
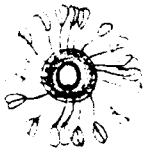
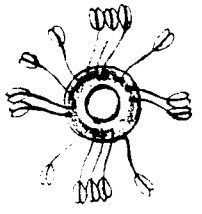
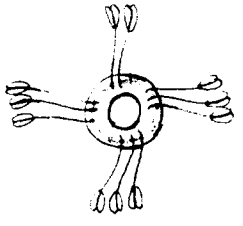
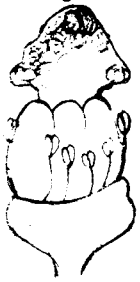
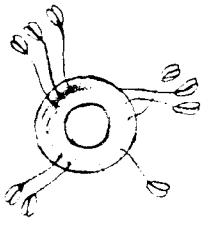

1
2
3
4
5
6

Table 4. Pollen fertility in different types of flowers

Sl. No.	Flower type	Acetocarmine stain test			Fertility from *in vitro* germination tests (%)
		Total number of pollen observed	Number of fertile pollen	Percentage fertility	
1	Type 1	1480	1391	94.00	89.89
2	Type 2	1676	1394	83.20	77.34
3	Type 3	2110	1477	70.00	65.24
4	Type 4	1250	819	65.50	60.10
5	Type 5	1966	1008	51.25	45.28
6	Type 6	2120	535	25.25	20.19

Plate 9 Flower Types in Kodampuli

Side view	arrangement of stamens	view of the ovary
		
Type 1.	1	1
		
Type 2.	2	2
		
Type 3	3	3
		
Type 4	4	4
		
Type 5	5	5
		
Type 6.	6	6

were normally distributed out, at the periphery, appeared to cluster at four corners. This indicates the tendency of the stamen to separate into four tufts as noticed in bisexual flowers (Plate 9). The rudimentary pistil showed further increase in size, measuring about 1 mm. The cross-section of the pistil showed no presence of ovary cells.

Type 4

This type was seen predominantly on male trees and rarely on bisexual trees (Plate 6,7 and 8). It had long as well as short pedicel. The flowers varied in size ranging from 0.9 to 2.1 cm in length and 1.8 to 3.1 cm in girth. Petal colour variation ranging from light yellow to dark yellow, cream and pink were noticed in both long and short pedicelled types. Stamen number varied from 35 to 40 (Plate 9). The percentage of pollen viability was 65.5. Stigmatic surface makes its first appearance. Cross-section of pistil showed ovary cells. It set fruits but the percentage of fruit set is very low.

Type 5

This type was seen predominantly on male trees and to some extent in bisexual trees (Plate 6,7 and 8). It had long as well as short pedicel. The flower size varied from 0.8 to 1.5 cm in length and 2.1 cm to 4.6 cm in girth. Petal colour variation ranging from light yellow to dark yellow, cream and pink was seen in the flowers of both long and short pedicelled types. Stamens ranged from 30 to 35 (Plate 9). The percentage of pollen viability was 51.25. Stigmatic surface with prominent tubercles was noticed and this stigmatal development indicates the stronger tendency of this flower towards attainment of bisexuality. Cross section of pistil showed presence of ovary cells which were slightly bigger than type 4. It sets fruits but the percentage was low.

Plate 10. Flowering shoot in male tree

Plate 11. Flowering shoot in bisexual tree

Type 6

This flower was found only on bisexual trees(Plate 6,7 and 8). The flowers have either long or short pedicel. The flowers varied in size ranging from 0.8 cm to 1.5 cm in length and 2.0 cm to 4.0 cm in girth. Petal colour variation ranging from light yellow to dark yellow, cream and pink were seen in both long and short pedicelled types. Stamens were 8 to 30 arranged in 4 to 5 tufts (Plate 9). Percentage of pollen viability was about 25.25. Stigma was very prominent with symmetrical surface. This was the normal bisexual flower. The cross section of pistil showed higher number of well developed ovary cells. This type had the maximum capacity for fruit set.

3.1.3.1.2 Sex types

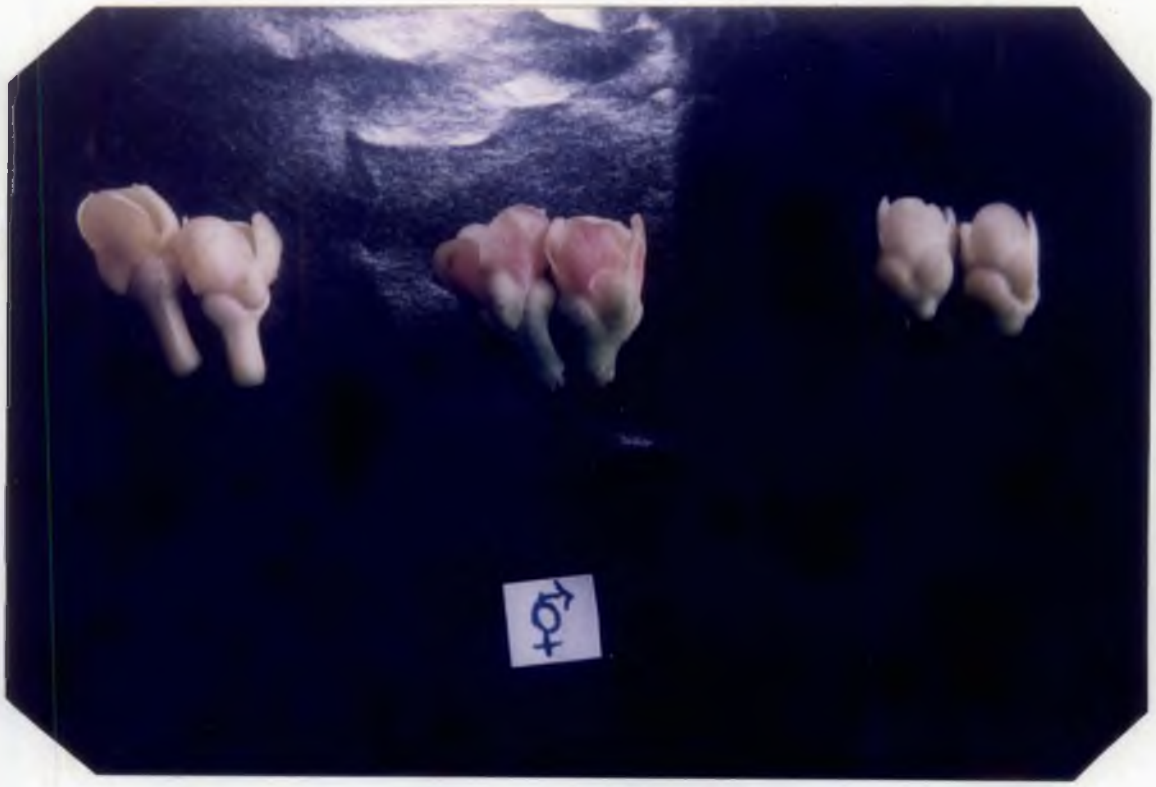
The trees chosen for the study could be designated into two types on the basis of preponderance of particular type of flowers and bearing tendency of individual tree.

Tree type 1. Staminate or male tree

The tree bears flower which were characteristically of type 1, 2, 3 and to some extent of type 4 and 5 (Plate 10). The tree bears either individual flower types or in combinations, with varying proportions. The flowers had both long and short pedicels, mass of stamens crowded on receptacle. They were mostly incapable of producing fruits and serve as pollinators only. But flower types 4 and 5 occasionally set fruits.

Plate 12. Pedicel length variation in bisexual flowers

Plate 13. Pedicel length variation in male flowers



Tree type 2. Hermaphrodite or bisexual tree

The tree bears predominantly type 6 flowers (Plate 11). These trees were profuse bearers. Rarely there were also bisexual trees with majority type 4 and 5 flowers along with type 1, 2, 3 but the fruit setting was very low.

4.1.3.2 Variability in morphology and fertility of flowers of bisexual and male trees

Information regarding the morphology and fertility of the flowers seen on bisexual and male trees are furnished in Tables 5 and 6, respectively.

4.1.3.2.1 Number of flowers per cluster

In bisexual trees, the number of flowers per cluster ranged from 1 to 4. Mostly single flower was noticed. In rare cases, 3 or 4 flowers per cluster were noticed. Regarding male trees, the number of flowers per cluster ranged from 5 to 15. Majority had more than 10 flowers per cluster.

4.1.3.2.2 Length of the pedicel

In the flowers seen on bisexual trees, the mean pedicel length varied from 0.20 cm to 0.90 cm (Plate 12). Most of the flowers recorded pedicel length of below 0.50 cm. In rare cases, pedicel length of above 0.80 cm was noticed. In the flowers seen on male trees, the pedicel length ranged from 0.20 cm to 1.80 cm. Majority had the length of more than 1.0 cm (Plate 13).

Table 5. Variation in flower characters of bisexual trees

Sl. No.	No. of flowers/ cluster	Flower colour	Flower weight (g)	Pedicel length (cm)	Petel length (cm)	No. of stamens/ flower	Percentage of pollen viability	Percentage of pollen germination
1	1	Pink	0.63	0.3	0.7	20	25.03	20.90
2	1	Cream	0.56	0.3	0.8	17	20.23	17.12
3	2	Cream	0.49	0.5	0.6	23	24.5	21.19
4	1	Cream	0.38	0.6	0.4	10	14.8	11.38
5	2	Pinkish cream	0.51	0.4	0.5	15	21.01	18.34
6	1	Cream	0.42	0.3	0.5	18	22.81	19.13
7	2	Cream	0.63	0.9	0.6	25	30.22	27.12
8	3	Cream	0.69	0.8	0.7	17	20.82	17.13
9	1	Cream	0.65	0.7	0.6	30	33.10	30.20
10	1	Cream	0.43	0.3	0.7	12	14.22	11.68
11	1	Cream	0.63	0.8	0.4	20	24.92	21.20
12	2	Creamish pink	0.62	0.9	0.4	21	25.10	21.80
13	1	Pink	0.47	0.3	0.5	18	20.93	17.10
14	1	Cream	0.50	0.4	0.4	12	14.22	11.29
15	1	Cream	0.65	0.5	0.5	9	13.10	10.12
16	1	Cream	0.49	0.6	0.4	16	18.23	15.13
17	4	Yellow	0.39	0.8	0.7	35	38.10	35.12
18	1	Cream	0.63	0.4	0.3	17	20.61	17.19
19	1	Cream	0.59	0.2	0.4	9	14.81	11.83
20	1	Pink	0.48	0.3	0.3	30	34.60	31.26

Table 6. Variation in flower characters of male trees

Sl. No.	No. of flowers/ cluster	Flower colour	Flower weight (g)	Pedicel length (cm)	Petel length (cm)	No. of stamens/ flower	Percentage of pollen viability	Percentage of pollen germination
1	7	Pink	0.22	1.6	0.3	37	55.01	50.18
2	10	Cream	0.11	1.8	0.4	73	93.18	87.69
3	8	Yellow	0.16	1.5	0.3	57	79.29	74.18
4	9	Cream	0.11	1.7	0.2	71	91.08	86.12
5	8	Creamish pink	0.11	0.7	0.5	73	94.00	90.18
6	12	Pink	0.21	0.8	0.3	48	73.34	68.56
7	15	Yellow	0.13	1.2	0.4	65	91.08	85.63
8	11	Cream	0.14	0.3	0.4	55	81.62	75.49
9	9	Cream	0.13	0.9	0.4	62	90.68	84.18
10	11	Yellow	0.31	0.7	0.3	43	60.10	53.23
11	10	Pinkish cream	0.38	1.1	0.5	83	50.18	45.94
12	7	Cream	0.14	1.3	0.6	31	48.93	41.68
13	12	Pink	0.19	0.8	0.6	40	59.08	54.23
14	7	Cream	0.21	0.9	0.4	38	58.19	53.76
15	10	Pinkish cream	0.25	1.4	0.3	31	47.63	41.28
16	15	Yellow	0.12	1.3	0.4	37	56.82	51.23
17	14	Cream	0.19	0.4	0.4	80	94.50	89.19
18	8	Pinkish cream	0.13	0.2	0.3	75	91.51	87.26
19	9	Cream	0.12	0.7	0.3	60	82.38	76.83
20	5	Cream	0.13	0.4	0.4	56	78.38	72.26

Plate 14. Colour variation in male flowers

Plate 15. Colour variation in bisexual flowers

4.1.3.2.3 Colour of the petals

Colours like pink, cream, pinkish cream, creamish pink and yellow were noticed in the petals of the flowers seen on both male and bisexual trees (Plate 14 and 15).

4.1.3.2.4 Length of the petals

Mean length of the petals in the flowers seen on bisexual trees ranged from 0.3 to 0.8 cm, while on the male trees the range was from 0.3 to 0.5 cm (Plate 16).

4.1.3.2.5 Weight of the flower

Mean weight of the flowers seen on male trees ranged from 0.11 to 0.38 g, while on the bisexual trees it ranged from 0.38 to 0.69 g.

4.1.3.2.6 Number of stamens per flower

Number of stamens varied with the type of the flower. In general, the mean number of stamens of the flowers seen on bisexual tree ranged from 9 to 35, while those on male trees recorded a higher range of 41 to 83.

4.1.3.2.7 Pollen fertility

The percentage pollen fertility varied with flower type. Compared to bisexual trees which had mean pollen fertility ranging from 13.10 to 38.10 per cent, the male trees showed a higher fertility of 47.63 to 94.50 per cent.

Plate 16. Petal length variation in kodampuli flowers

Plate 17. Variation in fruit shape and papilla

4.1.3.2.8 Pollen germination

The percentage pollen germination also varied with flower type. The mean pollen germination of the flower on bisexual tree ranged from 10.12 to 35.12 per cent, while in male trees the range was from 41.28 to 90.18 per cent.

4.1.4 Fruit characters

4.1.4.1 Morphological characters

Information regarding the variation in the morphological characters of the fruits from different accessions are furnished in Table 7.

4.1.4.1.1 Colour of the fruit

Fruits of different accessions showed variation in colour, ranging from light yellow to dark orange. Majority of the fruits were dark yellow in colour.

4.1.4.1.2 Shape of the fruit

With respect to the shape, the fruits showed wide variations. Round, oblong, oval, cordate, pear and napiform shapes were observed (Plate 17). Majority of the fruits had round shape. Regarding the fruit tip, there were fruits without papilla and with papilla (Plate 17). The papillated fruits can be grouped into two, namely, fruits with sunken papilla and fruits with prominent papilla. The size of the papilla ranged from 0.1 cm to 1.5 cm in length. Regarding the base, some fruits had outcurved base and some others had incurved base. On an average, about 25 per cent of the fruits had assymetrical shape. In such cases, one half of the fruits had prominent segments and well developed seeds. The other half had less prominent

Plate 18. Assymmetrical fruits

Plate 19. Variation in segment width

segments and poorly developed seeds. Such fruits were smaller in size when compared to the well developed, normal fruits (Plate 18).

4.1.4.1.3 Number of segments per fruit

The number of segments per fruit varied from 6 to 11. Majority of the fruits fell under the range from 8 to 10 segments. Maximum number of segments of 11 was observed in 8b collected from Thalikulam. The accessions like AC. 7, 24, 4b, 6, 43a, 46 and 40 were on par and superior to other entries except 8b, by recording 10 segments per fruit. AC. 27 had the lowest segment number of 6 collected from Vatanappalli. All the other entries were falling under intermediate range of 9 to 7. The mean number of segments per fruit was found to be 8.

4.1.4.1.4 Width of the segment

Maximum segment width of 1.80cm was recorded in AC. 33 collected from Vatanappalli and minimum of 0.40 cm was observed in AC. 20, collected from Kodungalloor (Plate 19). Statistical analysis showed a wide variability among the accessions. Collections like AC. 13, 25, 9, 39 and 3 recorded segment width of more than 1.40 cm. On the other hand accessions like 36, 43b, 14, 32, 4b and 20 recorded segment width of less than 0.90 cm. The average value was found to be 1.12 cm.

4.1.4.1.5 Length of the fruit

Data on the mean fruit length showed the presence of wider variability among the collections. AC. 34 collected from Vellanikkara had the maximum length of fruit with 9.00 cm which was closely followed by AC. 46 (8.9 cm). The other accessions which recorded a length of 8.00 cm and above were AC. 1, 21, 20,

Table 7. Variation in physical parameters of fruits from different accessions

AC. No.	Colour	Shape	Weight (g)	Length (cm)	Girth (cm)	Volume (cc)	No. of segments	Segment width (cm)	Rind thickness (cm)	Seed weight (g)	Rind weight (g)	Rind seed ratio	Fruit rind ratio	No. of seeds
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Dark yellow	Oblong	115.0	8.3	17.5	110.0	7	1.0	0.8	27.2	87.8	3.22	1.37	6(0)
2	Light yellow	Round	98.0	6.8	18.0	68.0	7	0.9	0.7	23.0	75.0	3.26	1.30	5(0)
3	Yellow	Round	180.0	6.0	20.0	150.0	8	1.5	1.4	37.0	143.0	3.86	1.26	6(0)
4a	Yellow	Cordate	160.0	7.0	23.0	145.0	8	1.0	1.0	30.5	129.5	4.24	1.24	7(2)
4b	Dark yellow	Oval	220.0	7.2	24.3	151.0	10	0.5	1.1	63.0	157.0	2.40	1.40	6(1)
5	Dark orange	Round	90.0	4.5	19.9	75.0	8	1.0	1.1	37.5	52.5	1.45	1.71	5(2)
6	Yellow	Round	120.0	5.5	20.1	85.0	10	1.1	1.0	24.0	96.0	4.00	1.25	6(1)
7	Light yellow	Round	140.0	6.1	20.0	117.5	10	1.3	1.1	30.9	79.0	3.52	1.77	5(2)
8a	Yellow	Round	190.0	7.0	23.0	159.2	8	1.4	1.3	30.8	159.2	5.24	1.19	6(1)
8b	Orange	Round	125.0	6.3	21.5	120.0	11	1.2	0.9	27.0	98.0	3.60	1.27	7(0)
9	Yellow	Round	220.0	5.5	27.0	165.0	9	1.6	1.4	40.8	179.2	4.34	1.23	7(0)
10	Lemon yellow	Round	120.0	5.7	21.0	135.0	7	1.2	0.7	33.0	87.0	2.63	1.37	4(2)
11	Yellow	Round	150.0	6.1	21.3	125.0	9	1.2	0.6	50.0	99.9	1.99	1.50	6(1)
12	Light yellow	Round	125.0	6.0	21.7	135.0	9	0.9	1.1	28.0	97.0	3.46	1.29	7(1)
13	Yellow	Oval	100.0	5.9	15.0	100.0	9	1.6	1.0	23.1	76.9	3.33	1.28	6(2)
14	Light yellow	Round	235.0	7.2	23.1	150.5	8	1.2	1.2	50.0	185.0	3.70	1.27	8(0)
15	Dark orange	Oblong	140.0	6.5	20.0	110.0	8	1.1	0.8	36.0	104.0	2.83	1.54	7(0)
16	Yellow	Round	160.0	6.2	23.0	150.5	8	1.3	1.1	28.0	132.0	4.71	1.21	7(1)
17a	Lemon yellow	Round	110.0	4.8	20.0	85.0	8	1.0	0.7	22.0	88.0	4.00	1.13	6(2)
17b	Yellow	Round	125.0	6.9	20.5	120.0	9	1.0	0.9	42.0	83.0	1.98	1.51	6(2)
18	Lemon yellow	Oval	160.0	6.5	23.0	160.0	8	1.4	1.0	35.0	125.0	3.57	1.28	5(3)
20	Dark yellow	Round	120.0	8.3	22.1	110.0	9	0.4	0.9	30.0	90.0	3.00	1.33	8(1)
21	Yellow	Oval	100.0	8.3	18.7	105.0	8	1.0	0.7	28.3	71.7	2.53	1.39	6(1)
22	Lemon yellow	Round	130.0	5.0	26.0	110.0	9	1.0	0.6	38.0	92.0	2.42	1.14	6(3)
23	Yellow	Oval	150.0	6.0	22.2	140.0	8	1.2	1.2	25.3	124.7	4.90	1.20	6(0)
24	Light yellow	Round	175.0	6.6	22.0	145.0	10	1.1	1.1	45.0	130.0	2.80	1.34	6(3)

Contd.

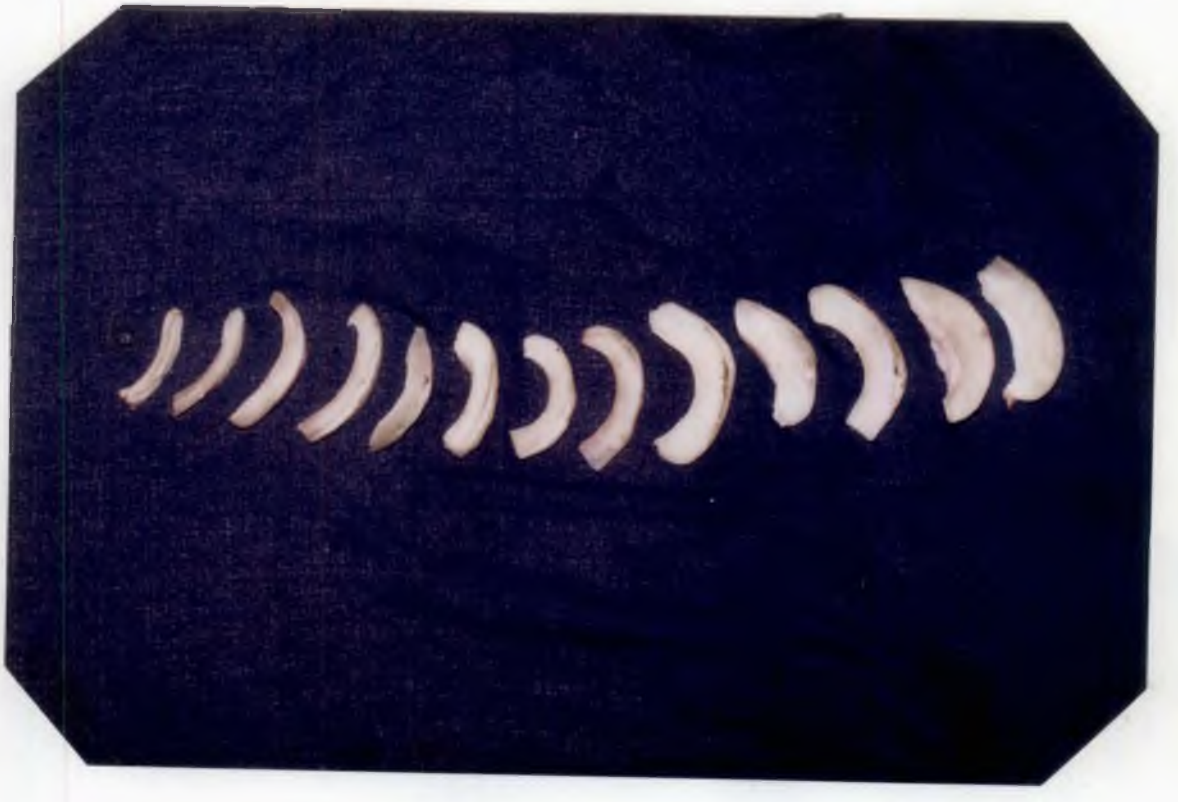
Table 7. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	Yellow	Round	130.0	5.4	20.5	110.0	8	1.6	1.3	24.0	106.0	4.40	1.20	6(2)
26	Light yellow	Round	95.0	4.9	19.0	85.0	9	1.0	0.9	26.0	69.0	2.60	1.37	5(3)
27	Light yellow	Oval	115.0	7.0	19.8	120.0	6	1.2	1.1	24.0	91.0	3.70	1.26	6(2)
28	Orange	Oval	140.0	7.9	20.2	140.0	9	1.0	1.1	38.1	109.0	2.60	1.28	4(3)
29	Yellow	Round	175.0	7.0	25.0	155.0	8	1.0	1.3	42.0	133.0	3.64	1.27	8(1)
30	Yellow	Round	120.0	6.0	19.8	100.0	9	1.0	0.9	31.0	89.0	1.28	1.34	4(3)
31	Yellow	Round	110.0	6.0	20.0	120.0	8	0.9	0.9	29.0	81.0	2.89	1.24	4(3)
32	Yellow	Round	120.0	6.8	20.9	140.0	8	0.7	0.8	35.0	85.0	2.42	1.41	9(1)
33	Yellow	Round	210.0	6.2	25.0	180.0	8	1.8	1.1	65.0	145.0	2.23	1.45	7(1)
34	Dark yellow	Oblong	150.0	9.0	20.0	145.0	7	1.3	0.7	35.0	115.0	3.28	1.30	6(1)
35	Lemon yellow	Pear	60.0	6.0	17.0	110.0	8	0.9	0.7	20.0	40.0	2.00	1.50	5(2)
36	Yellow	Round	120.0	8.0	20.1	120.0	8	0.7	0.4	33.0	87.0	2.63	1.37	7(2)
37	Yellow	Round	110.0	6.5	20.0	100.0	8	1.1	1.2	25.0	85.0	3.40	1.32	1(7)
38	Light orange	Round	210.0	7.9	24.5	220.0	9	1.4	1.4	60.0	150.5	2.52	1.49	5(2)
39	Dark yellow	Oval	150.0	6.8	21.0	135.0	7	1.5	1.3	29.0	121.0	4.17	1.16	3(4)
40	Golden yellow	Napiform	200.0	8.1	24.0	130.0	10	1.3	1.4	41.6	158.4	3.80	1.26	4(2)
41	Yellow	Round	200.0	7.9	25.3	200.0	9	1.4	1.4	42.0	158.0	3.76	1.26	8(2)
42	Yellow	Round	110.0	6.4	18.9	85.0	7	0.9	0.9	27.0	83.0	3.07	1.32	5(3)
43a	Lemon yellow	Round	200.0	7.8	20.0	161.0	10	0.9	1.5	39.0	161.0	4.13	1.24	6(4)
43b	Yellow	Pear	155.0	8.1	21.6	111.0	7	0.8	1.0	44.0	111.0	2.52	1.39	5(2)
44	Yellow	Round	140.0	7.0	21.2	110.0	7	1.3	1.1	30.0	110.0	3.67	1.27	6(2)
45a	Dark yellow	Round	250.0	7.3	28.0	207.0	9	1.1	1.5	43.0	207.0	4.80	1.21	7(2)
45b	Yellow	Round	160.0	7.8	21.3	130.0	9	0.9	1.0	30.0	130.0	4.33	1.23	6(2)
46	Dark yellow	Round	260.0	8.9	26.1	218.7	10	1.3	1.8	41.3	218.7	5.29	1.90	8(1)
	Grand total		7554.4	337.5	1073.1	6567.3	420	55.9	52.9	1738.6	5700.8	168.40	66.20	315(140)
	Average		155.1	6.8	21.5	131.4	8.4	1.1	1.0	34.8	114.1	3.37	1.32	6.3(2.8)
	SEm±		0.672	0.014	0.163	0.824	0.03	0.003	0.001	6.50	6.27	0.016	0.002	0.13(0.09)
	CD		1.91	0.039	0.463	2.35	0.085	0.0085	0.0028	1.43	1.77	0.045	0.0056	0.38(0.26)

The data inside the parenthesis denotes the number of undeveloped seeds

Plate 20. Variation in fruit size

Plate 21. Variation in rind thickness



43b, 40 and 36, all of them were on par with each other. A lower value of 5.00 cm and below was observed in collections like AC. 26, 17a and 5, with a minimum of 4.50 in AC. 5. The average fruit length of 50 entries was found to be 6.76 cm.

4.1.4.1.6 Girth of the fruit

The mean values for the fruit girth ranged from 15.00 cm to 28.00 cm Table 7). Statistical analysis showed the presence of wide variability in fruit size (Plate 20) among the accessions in terms of fruit girth. AC. 45a from Haripad had a maximum girth of 28.00 cm followed by AC. 9 (27.65 cm). Some of the other accessions having a girth of more than 25.00 cm were AC. 46, 41 and 22. AC 13 recorded a lowest girth of 15.00 cm. A few other entries having girth less than 19.00 cm were AC. 1, 21, 42, 2, 13 and 35. Other collections fell under the intermediate range of 19.00 cm to 25.00 cm. Average girth of 50 collections was 21.46 cm.

4.1.4.1.7 Weight of the fruit

Data on the mean fruit weight showed a wide variation among the collections and the variation was highly significant (Table 7). The maximum fruit weight of 260.00 g was observed in AC. 46, collected from Veeyapuram and the minimum weight of 60.00 g was recorded in AC. 35 collected from Eymanom. AC. 45a of Veeyapuram recorded a fruit weight of 250.00 g which was significantly superior to all other entries, except AC. 46. The average fruit weight was 151.11 g. This was followed by AC. 14, 4b, 9, 33, 38, 43a and 41. On the other hand, some of the other accessions, namely, AC. 2, 26 and 5 recorded fruit weight of less than 100.00 g. All other entries had medium fruit weight ranging from 100.00 g to 200.00 g.

4.1.4.1.8 Volume of the fruit

The highest mean volume of 220.0 cc was noticed in AC. 38 collected from Eymanom. AC. 46 which recorded highest fruit weight ranked only second with respect to volume (218.7 cc) and was significantly superior to all other accessions, except AC. 38. The other entries which had the volume 150.0 cc and above were AC. 45a, 41, 33, 9, 43a, 18, 8a, 29, 4b, 3, 16 and 14. There were accessions like AC. 17a, 6, 26, 42, 5 and 2 which recorded volume below 100.0 cc. All the other entries had the volume in the intermediate range of 100.0 cc to 150.00 cc. The average volume was found to be 131.5 cc.

4.1.4.1.9 Thickness of the rind

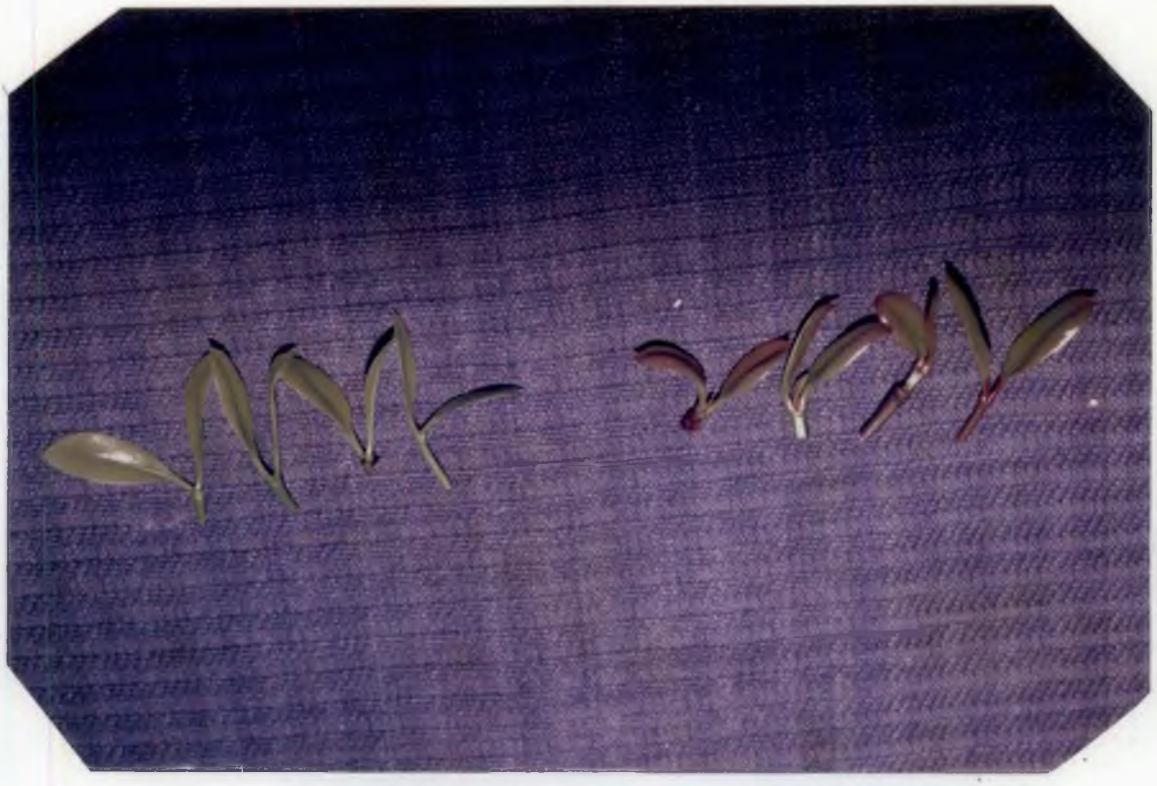
Very wide variation was noticed with respect to the thickness of the rind too (Plate 21). The highest value of 1.80 cm, which was significantly superior to all other entries, was recorded in AC. 46, which also recorded the highest fruit weight. This was followed by AC. 43a and 45a (1.50 cm). Other entries which had higher rind thickness of above 1.20 cm were AC. 3, 41, 9, 38, 45a, 40, 39, 29, 8a and 25. Some of the entries had rind thickness less than 0.70cm such as in AC. 22, 17a, 11 and 36. Of which, AC. 36 recorded the lowest rind thickness of 0.40 cm. Rest of the entries had their rind thickness in the intermediate range of 0.7 to 1.2 cm. The average rind thickness of the 50 entries was 1.07 cm.

4.1.4.1.10 Weight of the seed

The data showed a wide variation in the seed weight among 50 entries ranging from 20.00 g to 65.00 g. Highest value of 65.00 g was recorded in AC. 33, a collection made at Vatanappally, which was on par with 4b (63.00 g) of

Plate 22. Fruits with developed and undeveloped seeds

Plate 23. Colour variation in young flush of male (Green) and bisexual (Pinkish) trees



Arimboor. The accessions which recorded higher seed weight of more than 40.00 g were AC. 11, 14, 24, 43b, 17b, 29, 45a, 9, 38, 40, 46 and 41. There were also accessions which recorded lesser seed weight of below 25.00 g (AC. 24, 27, 46, 2, 13 and 17a). AC. 35 collected from Kaipuzha recorded the lowest seed weight of 20.00 g. All the other entries fell under the intermediate range of 25.0 to 40.0 g.

4.1.4.1.11 Number of seeds

There were two groups of seeds namely developed seed and undeveloped seed (Plate 22). The developed seeds ranged from one to nine. The maximum number of developed seeds of nine was recorded in AC. 32, a type from Vatanappalli and this was on par with the entries AC. 14, 20, 29, 41 and 46 all of which recorded eight seeds per fruit. The lowest number of one per fruit was noticed in AC. 39, collected from Thiruvalla. Average number of developed seeds was six.

Regarding the undeveloped seeds, the highest number of seven was recorded in AC. 37 and the lowest number of one was recorded in AC. 4b, 6, 8a, 11, 12, 16, 20, 29, 32, 33, 34 and 46. Out of 50 entries observed, 42 were having atleast one undeveloped seed.

4.1.4.1.12 Weight of the rind

The data on the mean rind weight of 50 entries revealed a great diversity among them. The highest rind weight of 218.7 g was observed in AC. 46 which also recorded the maximum fruit weight (260.00 g) and higher volume (217.90 cc). Another accession AC. 45a had the rind weight of 207.0 g which was on par with 46. A few other collections having higher rind weight of more than 150.0 g were AC. 14, 9, 43a, 40, 41, 4b, 8a and 38. There were also collections which recorded

lower rind weight of below 80.0 g (AC. 13, 2, 21, 26, 7 and 5). The lowest rind weight of 40.00 g was noticed in AC. 35. All the other entries had the rind weight falling under the medium range of 75.0 g to 150.0 g (Table 7).

4.1.4.1.13 Fruit rind ratio

The fruit rind ratio of different accessions had the range from 1.13 to 1.77 (Table 7). The highest ratio of 1.77 was observed in the AC. 7 collected from Thalikulam which was closely followed by AC. 5 (1.71). There were a few other collections which had the value of above 1.40, namely, AC. 17b, 11, 35, 33, 15, 32 and 38. On the other hand, accessions like AC. 8a, 39, 46 and 22 recorded the lower fruit rind ratio of below 1.20. The lowest ratio of 1.13 was recorded by 17a collected from Kaipamangalam. Rest of the entries fell under the intermediate range of 1.20 to 1.40.

4.1.4.1.14 Rind seed ratio

The data revealed that there was a wide variation in the rind seed ratio ranging from 1.45 to 5.29 (Table 7). The highest ratio of 5.29 was recorded in the AC. 46 which also had the highest fruit weight, volume, rind thickness and minimum fruit rind ratio. This was closely followed by 8a (5.24), collected from Thalikulam. Accessions like AC. 23, 16, 25, 39, 43a, 45a, 45b, 17a, 9, 4a and 6 had higher rind seed ratio of above 4.00. Collections like AC. 5, 11 and 17b recorded rind seed ratio less than 2.00, of which the lowest value of 1.45 was noticed in the accession AC. 5, collected from Thalikulam. Others fell under the intermediate range of 2.00 to 4.00. The average rind seed ratio was 3.25.

4.1.4.2 Biochemical characters

The data regarding the biochemical characters of the fruits from different accessions are presented in Table 8.

4.1.4.2.1 Moisture content

The mean values of the moisture content of 50 entries revealed wide variation among the collections (Table 8). The highest moisture content of 81.46 per cent was observed in AC. 2 collected from Vellanikkara and the lowest of 71.62 per cent in AC. 46 which was also superior in terms of fruit weight, rind weight, seed weight, volume and rind thickness. AC. 26 recorded a moisture content of 80.05 per cent which was significantly superior to all the other entries and was on par with AC. 2. A few other entries which recorded moisture content of more than 79.00 per cent were AC. 4a (79.64%), 27 (79.38%) 25 (79.31%), 31 (79.23%), 42 (79.16%), 10 (79.12%) and 8b (79.01%). There were also entries which had lower moisture content of less than 74.00 per cent like AC. 8a, 9, 43b, 41, 45a, 16, 43a and 14. All the other collections had the medium moisture content ranging from 76.00 per cent to 78.00 per cent.

4.1.4.2.2 Total soluble solids (TSS)

Statistical analysis of the data on the mean values of TSS of the rind and the mucilage revealed the existence of wide variation. Regarding the TSS of the rind, the values ranged from 6.3° to 8.9° brix (Table 8). Maximum value for rind TSS was recorded in the accession AC. 3 collected from Karayamparambu and it was significantly different from all other entries. The minimum value of 6.3° brix was observed in AC. 3 collected from Nattika. Some other collections which had the higher TSS of 8.0° brix and above were AC. 7, 8a, 16, 3, 10, 18 and 35, whereas

the accession having lower values below 7.0° brix were AC. 11, 17a, 34, 4a, 22, 13, 43b, 12 and 46. The average rind TSS was found to be 7.42° brix.

With respect to TSS of mucilage, the range varied from 9.8° to 14.3° brix. AC. 8b collected from Thalikulam had the highest mucilage TSS of 14.3° brix. AC. 22 and 29 collected from Vatanappalli recorded the lowest value of 9.8° brix. A few other accessions which also recorded higher mucilage TSS of more than 14.0° brix were AC. 8b, 7, 43a, 5 and 3, all of which were on par with AC. 8b. The mucilage TSS of rest of the entries was in the medium range of 10.0° to 14.0° brix.

4.1.4.2.3 Total acidity

Wider variation was noticed in the mean values of total acidity of the 50 accessions and the range was found to vary from 14.76 to 24.89 per cent. The highest value of 24.89 per cent was observed in the accession. AC. 40 collected from Thiruvalla which was closely followed by AC. 23 (24.3%) collected from Kodungalloor. A few of the other collections like AC. 4a, 35, 33, 6, 46, 42 and 24 recorded a total acidity of more than 22.00 per cent. On the other hand there were accessions which recorded a total acidity of less than 16.00 per cent were AC. 12, 18, 44, 25, 9, 21 and 8b. The lowest value for total acidity (14.57 per cent) was noticed in AC. 20, a type collected from Kodungalloor. The average value of the 50 entries was 18.91 per cent.

4.1.4.2.4 Crude protein

The data on the mean value of crude protein of 50 entries showed the presence of limited variability among the entries. AC. 14 recorded the highest protein content of 5.91 per cent which was on par with AC. 14, 9, 25, 2, 8a, 8b, 23 and 38. The minimum crude protein of 3.32 per cent was observed in AC. 11,

Table 8. Variation in biochemical parameters of fruits from different accessions

AC. No.	Moisture %	Dried rind recovery %	TSS °brix		Total acidity %	Crude fat %	Crude protein %	Crude fibre %	Total phenol (mg/100 gm)	(-)-HCA %
			Rind	Mucilage						
1	2	3	4	5	6	7	8	9	10	11
1	79.03	21.00	7.3	12.5	18.96	5.50	4.28	5.63	320.01	15.68
2	81.46	18.54	7.1	12.0	18.31	4.60	5.36	4.87	301.63	15.96
3	75.04	24.96	8.9	14.1	21.83	5.20	3.84	6.96	296.01	18.96
4a	79.64	20.36	6.9	12.0	23.82	5.34	4.63	4.59	380.80	19.50
4b	77.04	22.96	7.2	13.8	19.46	4.18	4.82	4.86	297.54	17.86
5	77.93	22.07	7.5	14.1	19.89	5.70	4.96	5.27	356.27	18.01
6	76.48	23.52	7.8	13.7	22.80	5.21	5.08	5.89	311.87	19.16
7	76.41	23.59	8.0	14.2	19.97	4.32	4.01	3.86	367.94	15.18
8a	73.01	26.99	8.0	12.0	17.82	3.52	4.73	4.71	280.56	16.15
8b	79.01	20.99	7.6	14.3	14.81	4.98	5.51	5.23	363.17	10.85
9	73.36	22.64	7.3	12.8	15.65	5.21	5.32	5.93	297.83	13.08
10	79.12	20.88	8.1	13.2	16.81	5.00	4.97	5.87	317.56	13.17
11	78.34	21.66	6.9	11.1	18.91	4.28	3.50	4.93	320.23	16.09
12	76.04	23.96	6.7	12.3	15.98	3.72	4.98	4.32	314.76	13.28
13	74.00	26.00	6.3	12.6	19.86	4.68	5.11	5.68	325.26	16.23
14	72.08	27.92	7.3	11.4	19.30	4.82	5.91	5.00	265.00	17.01
15	78.32	21.68	7.4	13.1	21.30	5.23	4.82	4.96	352.84	19.16
16	72.41	27.59	8.1	9.9	17.36	3.98	4.97	5.28	287.52	15.83
17a	74.34	25.96	6.9	11.3	18.16	4.72	5.16	5.63	317.29	16.03
17b	76.31	23.69	7.1	10.9	17.14	5.31	4.76	5.71	290.16	15.95
18	76.31	23.69	8.0	12.2	15.72	5.12	4.89	6.52	295.23	13.08
20	74.38	25.62	7.9	11.9	14.76	4.13	5.26	5.38	283.84	12.01

Contd.

Table 8. Continued

1	2	3	4	5	6	7	8	9	10	11
21	77.65	22.35	7.8	12.3	15.34	3.97	3.98	3.29	321.87	12.83
22	78.32	21.68	6.9	9.8	18.92	4.26	3.79	4.97	316.84	15.99
23	74.78	25.22	7.9	11.2	24.30	5.13	5.23	4.83	301.06	21.79
24	74.20	25.80	7.3	12.8	22.12	5.19	5.10	5.21	333.33	20.50
25	79.31	20.69	7.2	13.1	15.64	4.38	5.79	4.98	297.83	13.36
26	80.05	19.95	7.1	13.4	17.89	4.97	3.82	4.96	310.44	14.83
27	79.38	20.62	7.0	12.4	18.92	4.72	5.32	4.83	309.65	14.99
28	78.92	21.08	7.0	11.9	16.97	4.87	4.97	3.71	296.83	13.36
29	74.21	25.79	7.3	9.8	16.93	4.76	4.89	3.93	353.47	13.00
30	77.18	22.82	7.6	11.8	16.73	4.21	5.01	5.28	328.63	13.01
31	79.23	20.77	7.9	12.9	19.80	5.01	4.38	3.86	314.49	17.31
32	78.63	21.37	7.3	13.1	19.32	5.26	4.69	4.97	293.89	17.28
33	75.36	24.74	7.6	13.1	22.70	4.02	5.06	4.18	301.63	19.00
34	78.12	21.98	6.9	13.1	21.08	4.92	5.13	3.78	307.67	18.01
35	78.97	21.03	8.0	13.3	22.63	4.73	4.29	5.83	283.88	18.56
36	76.81	23.19	7.3	12.2	16.49	5.21	4.86	6.49	291.64	14.21
37	78.16	21.49	7.6	12.1	16.38	5.31	4.38	6.48	343.63	14.36
38	73.93	26.07	7.8	11.6	17.68	4.26	5.16	5.76	303.49	14.73
39	76.28	23.72	7.2	11.9	21.23	5.71	4.26	4.86	329.88	18.65
40	74.10	25.90	7.3	13.6	24.89	3.78	3.98	4.93	304.64	21.06
41	73.28	26.72	7.2	13.9	21.65	4.63	4.23	4.37	282.16	18.75
42	79.16	20.84	7.1	13.7	22.72	4.92	4.56	6.16	295.55	18.27
43a	72.13	27.87	7.4	14.1	19.75	4.73	4.78	5.23	307.31	17.01
43b	73.28	26.72	6.9	13.2	16.93	4.77	5.01	5.38	340.66	14.23
44	76.93	23.07	7.7	12.6	15.84	3.92	5.23	5.64	301.26	12.56
45a	71.83	28.17	7.4	10.5	18.34	5.70	4.97	6.98	310.10	15.21

Contd.

Table 8. Continued

1	2	3	4	5	6	7	8	9	10	11
45b	76.97	23.03	7.4	10.7	19.27	5.23	4.01	5.38	313.14	17.63
46	71.62	28.38	6.3	10.2	22.63	4.98	4.26	4.97	312.23	19.49
Total	3813.18	1186.00	371.0	624.6	945.50	239.95	239.70	256.05	15605.75	802.95
Aver-age	76.28	23.72	7.42	12.48	18.91	4.80	4.79	5.12	313.12	16.06
SEm±	0.304	0.231	0.042	0.073	0.189	0.100	0.059	0.079	1.043	0.111
CD	0.864	0.654	0.119	0.207	0.536	0.283	0.167	0.224	2.96	0.315

which was on par with AC. 40, 21, 22, 3 and 26. The average crude protein content of the 50 entries was 4.79 per cent.

4.1.4.2.5 Crude fat

Statistical analysis of the mean value of the crude fat content of 50 entries also revealed the existence of limited variability among the accessions and the range was found to vary from 3.52 per cent to 5.71 per cent. The highest value for fat content was noticed in the collection AC. 39 which was closely followed by AC. 9, 1, 4a, 5, 6, 8b, 3, 37 and 10. The minimum fat content of 3.52 per cent was noticed in the accession AC. 8a, collected from Thalikulam. There were a few other collections having minimum fat content of below 4.0 per cent like AC. 44, 12, 16, 21 and 40. The average crude fat content was 4.80 per cent.

4.1.4.2.6 Crude fibre

The data on the mean values of crude fibre content showed the presence of variability. The maximum value of 6.96 per cent was noticed in AC. 3, collected from Kariamparambu, which also had the highest rind TSS. This was closely followed by AC. 45 (6.87 per cent). A few other collections with crude fibre content more than 6.00 per cent were AC. 37, 18, 36, 42, 45a and 35. The lowest crude fibre content of 3.39 per cent was noticed in AC. 21, collected from Vatanappalli. There were also types with crude fibre content less than 4.0 per cent (AC. 29, 34, 28, 7 and 31). The average crude fibre was 5.12 per cent.

4.1.4.2.7 (-)-Hydroxy citric acid

A wide variation was noticed among the mean value of (-)-HCA content of 50 entries. The range was found to vary from 10.85 to 21.79 per cent. The

highest value of 21.79 per cent was recorded in AC. 23, collected from Kodungalloor, which was significantly different from all other entries. AC. 40 and AC. 24 were the only other types having (-)-HCA content of more than 20.0 per cent and both of which were on par with each other and significantly different from other entries except AC. 23. On the other hand, there were also accessions like AC. 21, 44, 20 and 8b having (-)-HCA less than 13.0 per cent. Of which the lowest value of 10.85 per cent was noticed in the accession 8b, collected from Thalikulam. The average (-)-HCA content was 16.06 per cent.

4.1.4.2.8 Total phenol

The statistical analysis of the mean values of the total phenol content of the different entries showed the existence of wide variability. The total phenol content ranged from 265.0 to 380.8 mg/100 g. AC. 4a recorded the maximum total phenol content of 380.8 mg/100 g, which was found to be significantly different from other entries. There were also collections with higher total phenol content of more than 330.0 mg/100 g like AC. 7, 4a, 8b, 5, 29, 15, 37, 43b and 24 . Accessions, namely, AC. 7, 86, 5, 29, 15, 37, 43b, 24, 39, 30, 8 and 21 had the total phenol content of less than 290.0 mg/100 g. Accession 12 collected from Nattika recorded the lowest total phenol content of 265.0 mg/100 g. The average value of total phenol content was 313.1 mg/100 g.

4.1.5 Correlation studies

The correlation matrix for the morphological characters of the fruits are presented in the Table 9. Significant correlation between number of segments with rind thickness and also with rind weight was observed. The correlation between number of segment and seed weight was found to be highly significant.

Table 9. Correlation matrix for the morphological characters of the fruit

Sl. No.	Weight	Length	Girth	Volume	No. of segments	Segment width	Rind thickness	Seed weight	Rind weight	Rind seed ratio	Fruit rind ratio
	1	2	3	4	5	6	7	8	9	10	11
1	1.0000										
2	0.3175**	1.0000									
3	0.0958	0.0067	1.0000								
4	0.8196**	0.3108**	0.1081	1.0000							
5	0.2047*	-0.0643	-0.0979	0.1955*	1.0000						
6	0.1973*	0.0079	0.0364	0.1906	0.1335	1.0000					
7	0.6012**	0.0607	0.1657	0.6220**	0.2389*	0.3144**	1.0000				
8	0.6695**	0.1864	0.0257	0.6065**	0.2613**	0.0574	0.2785**	1.0000			
9	0.9562**	0.2860**	0.1122	0.8066**	0.1951*	0.2117*	0.6721**	0.5385**	1.0000		
10	0.4377**	0.0480	0.1321	0.3633**	0.0141	0.2035*	0.5704**	-0.2804**	0.5885**	1.0000	
11	-0.3296**	-0.0720	-0.1869	-0.2636**	-0.0319	-0.1569	-0.3680**	0.2989**	-0.4610**	-0.8446*	1.0000

* Significant at 5 per cent level

** Significant at 1 per cent level

Correlation between fruit length and other fruit characters like rind weight and volume was found to be highly significant. No significant correlation was observed between fruit girth and other fruit characters.

Correlation between the fruit weight and other fruit characters like length, volume, rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio were found to be highly significant. Correlation between fruit weight and fruit rind ratio was found to be negative. Significant correlation was also observed for fruit weight with number of segments and segment width.

Significant correlation was observed between volume and other fruit characters like rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio. Among these, fruit rind ratio was negatively correlated with volume. Significant correlation was also observed between volume and number of segments.

Correlation between segment width and rind thickness was found to be highly significant. Rind weight and rind seed ratio had a significant correlation with segment width. Highly significant correlation between rind thickness and other fruit characters like seed weight, rind weight, rind seed ratio and fruit rind ratio was observed. Of these, correlation between fruit rind ratio and rind thickness was negative.

Highly significant correlation was observed between seed weight and other fruit characters like rind weight, rind seed ratio and fruit rind ratio. Of which rind seed ratio had negative correlation with seed weight. The correlation between rind weight and other fruit characters like rind seed ratio and fruit rind ratio were highly significant. Of which rind seed ratio had negative correlation. Fruit rind ratio was negatively correlated with rind seed ratio.

Table 10. Matrix of direct and indirect effects of fruit characters

Sl. No.	Weight	Length	Girth	Volume	No. of segment	Segment width	Rind thickness	Seed weight	Rind seed ratio	Fruit rind ratio
	1	2	3	4	5	6	7	8	9	10
1	0.7184	0.0044	-0.0006	0.0247	0.0005	-0.0020	0.0281	0.0667	0.1096	0.0063
2	0.2281	0.0139	0.0000	0.0094	-0.0002	-0.0001	0.0028	0.0186	0.1020	0.0014
3	0.0688	0.0001	-0.0063	0.0033	-0.0002	-0.0004	0.0077	0.0026	0.0331	0.0036
4	0.5888	0.0043	-0.0007	0.0301	0.0005	-0.0020	0.0290	0.0605	0.0950	0.0050
5	0.1471	0.0009	0.0006	0.0059	0.0024	-0.0014	0.0112	0.0261	0.0035	0.0006
6	0.1418	0.0001	-0.0002	0.0057	0.0003	-0.0103	0.0147	0.0057	0.0510	0.0030
7	0.4319	0.0008	-0.0010	0.0187	0.0006	-0.0032	0.0467	0.0278	0.1429	0.0070
8	0.4810	0.0026	-0.0002	0.0183	0.0006	-0.0006	0.0130	0.0997	-0.0702	-0.0057
9	0.3145	0.0007	-0.0008	0.0109	0.0000	-0.0021	0.0266	-0.0279	0.2504	0.0161
10	-0.2368	-0.0010	0.0012	-0.0079	-0.0001	0.0016	-0.0172	0.0298	-0.2115	-0.0191

4.1.6 Path analysis

The results of the path analysis of the morphological characters of the fruits are presented in Table 10. Fruit length did not influence rind weight directly or through any other parameters. The case was similar with fruit girth also. Fruit weight had a high influence on rind weight. The indirect positive effect of fruit weight on rind weight via. volume, rind thickness, seed weight and rind seed ratio was observed. The indirect effect of fruit weight and rind weight via. fruit rind ratio was negative.

Volume did not influence the rind weight directly or indirectly. Similarly, the number of segments, segment width, rind thickness and seed weight did not influence the rind weight either directly or indirectly. Rind seed ratio had direct influence on the rind weight. It also had indirect influence on rind weight via. fruit rind ratio.

4.1.7 Genetic diversity in kodampuli

As already seen, the analysis of variance indicated the existence of variability for all the above mentioned characters studied among the 50 entries. These data were consequently subjected to multivariate analysis utilising non-hierarchial euclidean cluster analysis.

The average inter-and intra-cluster D^2 values are aligned in Table 11. The cluster-wise composition of accessions are presented in the Table 12. The computed D^2 values varied from 0.00 to 6.468. On the basis of relative magnitude of D^2 values, all the 50 entries were grouped into 4 clusters so that the accessions within a cluster had smaller D^2 values among themselves than those belonging to different

Table 11. Average inter and intra cluster D^2 values

	I	II	III	IV
I	3.513	-	-	-
II	5.995	0	-	-
III	2.906	6.468	3.494	-
IV	5.035	5.575	4.230	4.135

Table 12. Composition of clusters based on D^2 statistic in kodampuli

Cluster No.	No. of entries in cluster	Accessions in the cluster
I	11	4a, 5, 6, 7, 11, 15, 26, 31, 34, 35, 42
II	1	3
III	21	1, 2, 86, 10, 12, 13, 17a, 17b, 20, 21, 22, 25, 27, 28, 30, 36, 43b, 44, 45b
IV	18	4b, 8a, 9, 14, 16, 23, 24, 29, 33, 34, 38, 39, 40, 41, 43a, 45a, 46

Table 13. Cluster means for different physical parameters of fruits

Cluster No.	Weight (g)	Length (cm)	Girth (cm)	Volume (cc)	No. of segments	Segment width (cm)	Rind thickness (cm)	Seed weight (g)	Rind weight (g)	Rind seed ratio	Fruit rind ratio
1	117.70	5.97	20.06	109.00	8.45	1.01	0.90	31.42	83.48	2.88	1.43
2	181.05	5.95	20.35	150.90	8.00	1.50	1.40	37.65	143.40	3.80	1.30
3	124.89	6.91	20.43	114.58	8.24	1.07	0.91	30.43	94.64	3.19	1.31
4	203.35	7.12	23.71	165.36	8.59	1.23	1.26	42.13	155.97	3.88	1.27

Table 14. Cluster means for different biochemical parameters of fruits

Cluster No.	Moisture (%)	TSS of rind (° brix)	TSS of mucilage (° brix)	Total acidity (%)	Crude fat (%)	Crude protein (%)	Crude fibre (%)	Total phenol (mg/100g)	(-)-HCA (%)
1	78.42	7.49	13.44	20.63	5.05	4.51	5.01	326.60	17.64
2	74.68	8.95	14.10	21.31	5.49	3.73	6.88	296.26	18.79
3	77.05	7.36	12.20	16.45	4.73	4.90	5.27	313.85	14.18
4	74.02	7.36	12.13	20.08	4.68	4.91	4.91	304.47	17.20

clusters. Eleven accessions were accommodated in cluster I, only one in cluster II, 21 in cluster III and 18 in cluster IV. Maximum divergence was observed between cluster II and cluster III which was followed by those between cluster II and I. The intra cluster divergence ranged from 3.491 to 4.135. Cluster III was having least intra-cluster divergence. Accessions collected from the same locality were distributed to different clusters. These results showed that geographical diversity might not necessarily be related to genetic diversity.

The cluster means for the physical parameters of the fruits are furnished in Table 13. Maximum values for fruit weight (203.35), length (7.12), girth (23.72), volume (165.36), number of segments (8.59), seed weight (42.13), rind weight (155.97) and rind seed ratio (42.13) were recorded in cluster IV. Cluster II recorded maximum values for segment width (1.5) and rind thickness (1.40). Maximum value for fruit rind ratio (1.43) was recorded in cluster I. Minimum values for fruit weight (117.7), girth (20.06) and segment width (1.01). Rind thickness (0.90), rind weight (83.48) and rind seed ratio (2.88) were recorded in cluster I. Cluster II recorded minimum values for length (5.95) and number of segments (8.00). Cluster III recorded minimum values for seed weight (30.43) and cluster IV for fruit rind ratio.

The cluster means for the biochemical parameters of the fruits are furnished in the Table 14. The maximum values for moisture content (78.42) was observed in cluster I. Cluster II recorded maximum values for rind TSS (8.95), mucilage TSS (14.10), total acidity (21.31), crude fat (5.49), crude fibre (6.88) and (-)-HCA (18.79). Cluster IV recorded maximum value for crude protein content (4.91). Maximum value for total phenol content was observed in cluster I. Minimum values for moisture content (74.02), crude fat (4.68), crude fibre (4.91), rind TSS (7.36) and mucilage TSS (12.13) were observed in cluster IV. Minimum values of rind TSS (7.36), total acidity (16.45) and (-)-HCA (14.18) were observed

in cluster III. Cluster II recorded minimum values for total phenol (296.26) and crude protein (3.13).

4.2 Rind quality under different drying conditions

The differences in the quality of the rind under different drying conditions, namely oven, sun and smoke are presented in the Table 15. The average moisture removal per cent of the rind dried in oven (78.41 per cent) was found to be higher than that of sun (77.35 per cent) and smoke (75.70 per cent) but statistically there was no significant difference in moisture content under different drying conditions.

Regarding the dried rind recovery, smoke drying recorded a maximum value (24.30 per cent) followed by sun (22.65 per cent) and oven (21.59 per cent). But analysis of variance did not revealed any significant difference under three drying conditions.

With respect to total acidity, the rind dried in oven had the lowest value (19.72 per cent) whereas those under smoke recorded the highest (21.33 per cent). Sun dried rind recorded an average total acidity of 20.6 per cent. But statistically all the treatments were on par.

Similarly, average amount of (-)-HCA under oven, sun and smoke were 17.10 per cent, 17.92 per cent and 18.90 per cent respectively. Here again no significant difference was noticed.

Crude fat content in the dried rind showed only very slight variations under different drying conditions. Oven dried rind had an average of 5.50 per cent

Table 15. Rind quality under different drying conditions

Sl. No.	Drying conditions	Moisture removal per cent	Dried rind recovery per cent	Total acidity (%)	(-)-HCA (%)	Crude fat (%)	Crude protein (%)	Crude fibre (%)	Total phenol (mg/100 g)
1	Oven	78.41	21.59	19.70	17.10	5.50	4.65	5.26	301.58
2	Sun	77.35	22.65	20.60	17.92	5.26	4.44	5.05	300.97
3	Smoke	75.70	24.30	21.33	18.90	5.03	4.23	4.83	300.35
	CD	NS	NS	NS	NS	NS	NS	NS	NS

which was closely followed by sun (5.26 per cent) and smoke (5.03 per cent) drying.

In terms of crude protein, the maximum value was recorded by oven dried sample (4.65 per cent) followed by sun (4.44 per cent) and smoke (4.23 per cent).

Crude fibre content of oven, sun and smoke dried rind was 5.26 per cent, 5.05 per cent and 4.83 per cent respectively. But all the treatments were on par statistically.

With respect to total phenol content also, the oven, sun and smoke dried did not show any significant variation. The average values were 301.58 mg/100 g, 300.97 mg/100 g and 300.35 mg/100 g respectively.

Texture wise differences were noticed in the rind under different drying conditions. Oven dried rind was hard and brittle. Under smoke, the rind was soft and flexible. Sun dried rind was intermediate in texture.

Regarding the colour of the dried rind, dark black colour was noticed in smoke dried rind whereas oven and sun dried ones were of brown and pale brown colour respectively.

With respect to appearance of the dried rind, smoke dried rind was far superior, since it was able to retain the original shape of the rind. Oven dried rinds could not retain the rind shape and showed shrunken appearance. Shape retention was intermediate in the case of sun dried ones.

4.3 Fruit development

Data on physical parameters of fruit at weekly intervals are presented in Table 16. It took 133 days from fruit set to ripening. The maximum length, girth, volume, fruit weight, rind weight, seed weight and rind thickness were attained by 112 days after fruit set with varying rate of growth at different periods (Fig. 1a and 1b).

The rate of increase in length (16.66 per cent), girth (14.75 per cent), volume (11.88 per cent) and fruit weight (22.52 per cent) was maximum between 35 to 42 days. Thereafter percentage increase showed a declining trend which continued upto 70 days after the set. The trend was found to be slightly increasing during the period of 70 to 91 days after fruit set which again showed a slight decrease and reached constant after 112 days after the fruit set.

Maximum increase in seed weight (11.96 per cent) and rind weight (18.55 per cent) occurred during first 42 days after the set. Then the rate of growth showed a declining trend during 42 to 70 days followed by an increase upto 91 days which again showed a slight decrease in growth rate and reached constant after 112 days after the fruit set.

Regarding the rind thickness, it increased gradually till 105 days after fruit set. Thereafter it became constant.

Data on the chemical composition of the rind at different developmental stages are furnished in the Table 17 (Fig. 2a and 2b).

Table 16. Physical changes of fruit during growth and development

Days after set	Mean length (cm)	Percentage increase in length	Mean girth (cm)	Percentage increase in girth	Mean volume (cc)	Percentage increase in volume	Mean fruit weight (g)	Percentage increase in fruit weight	Mean seed weight (g)	Percentage increase in seed weight	Mean rind weight (g)	Percentage increase in rind weight	Mean rind thickness (cm)	Percentage increase in rind thickness
7	2.3	0.00	5.8	0.00	11.5	0.00	8.60	0.00	1.8	0.00	6.8	0.00	0.2	0.00
14	2.9	6.25	6.8	7.81	14.5	3.52	11.60	4.79	3.4	6.18	9.2	6.54	0.2	0.00
21	3.3	8.33	7.9	9.01	18.5	4.70	16.30	7.51	5.3	7.34	13.6	8.72	0.3	20.00
28	3.8	10.41	9.1	10.16	24.0	7.05	23.60	11.66	7.4	8.10	18.3	12.81	0.3	0.00
35	4.5	14.58	10.5	11.4	32.7	9.64	32.70	14.54	10.5	10.04	23.2	13.35	0.3	0.00
42	5.3	16.66	12.3	14.75	42.8	11.88	46.80	22.52	14.1	11.96	30.0	18.55	0.4	20.00
49	5.6	6.25	13.7	11.4	49.5	7.85	52.00	8.31	16.9	10.80	34.7	12.81	0.4	0.00
56	5.8	4.17	14.7	7.81	55.5	7.06	56.60	7.35	18.5	6.18	37.1	6.53	0.5	20.00
63	5.9	2.08	15.3	4.92	60.5	5.88	58.40	2.87	19.4	3.47	39.0	5.18	0.5	0.00
70	6.0	2.00	15.5	1.63	65.7	6.12	59.40	1.60	20.1	2.70	39.5	1.36	0.5	0.00
77	6.2	4.16	15.9	3.27	71.0	6.30	61.10	2.56	21.0	3.47	40.7	3.27	0.5	0.00
84	6.5	6.25	16.4	4.10	77.8	8.00	64.00	4.63	22.3	5.02	42.0	3.44	0.6	20.00
91	6.9	8.33	17.0	4.92	87.0	10.80	67.00	4.79	24.7	9.26	43.9	5.03	0.6	0.00
98	7.2	6.25	17.4	3.28	92.5	5.41	69.30	3.67	25.3	6.18	44.5	1.63	0.6	0.00
105	7.3	2.08	17.7	2.45	95.9	4.00	70.40	1.76	26.5	4.63	44.5	0.31	0.7	20.00
112	7.4	2.08	18.0	2.45	96.5	0.70	71.20	1.29	27.7	4.63	44.6	0.00	0.7	0.00
119	7.4	0.00	18.0	0.00	96.5	0.00	71.20	0.00	27.7	0.00	44.6	0.00	0.7	0.00
126	7.4	0.00	18.0	0.00	96.5	0.00	71.20	0.00	27.7	0.00	44.6	0.00	0.7	0.00
133	7.4	0.00	18.0	0.00	96.5	0.00	71.20	0.00	27.7	0.00	44.6	0.00	0.7	0.00

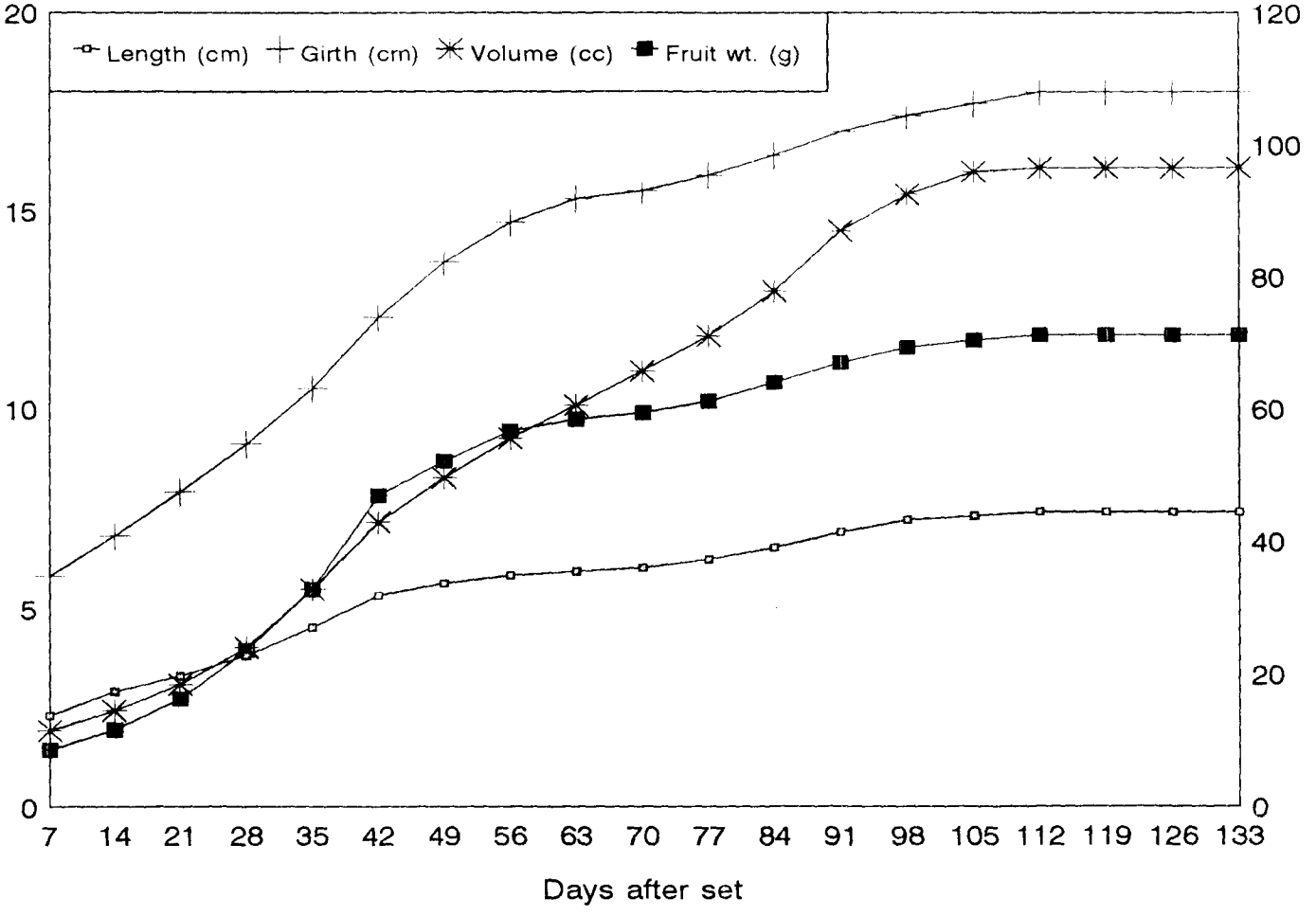


Fig.1a. Physical changes of fruit during growth and development

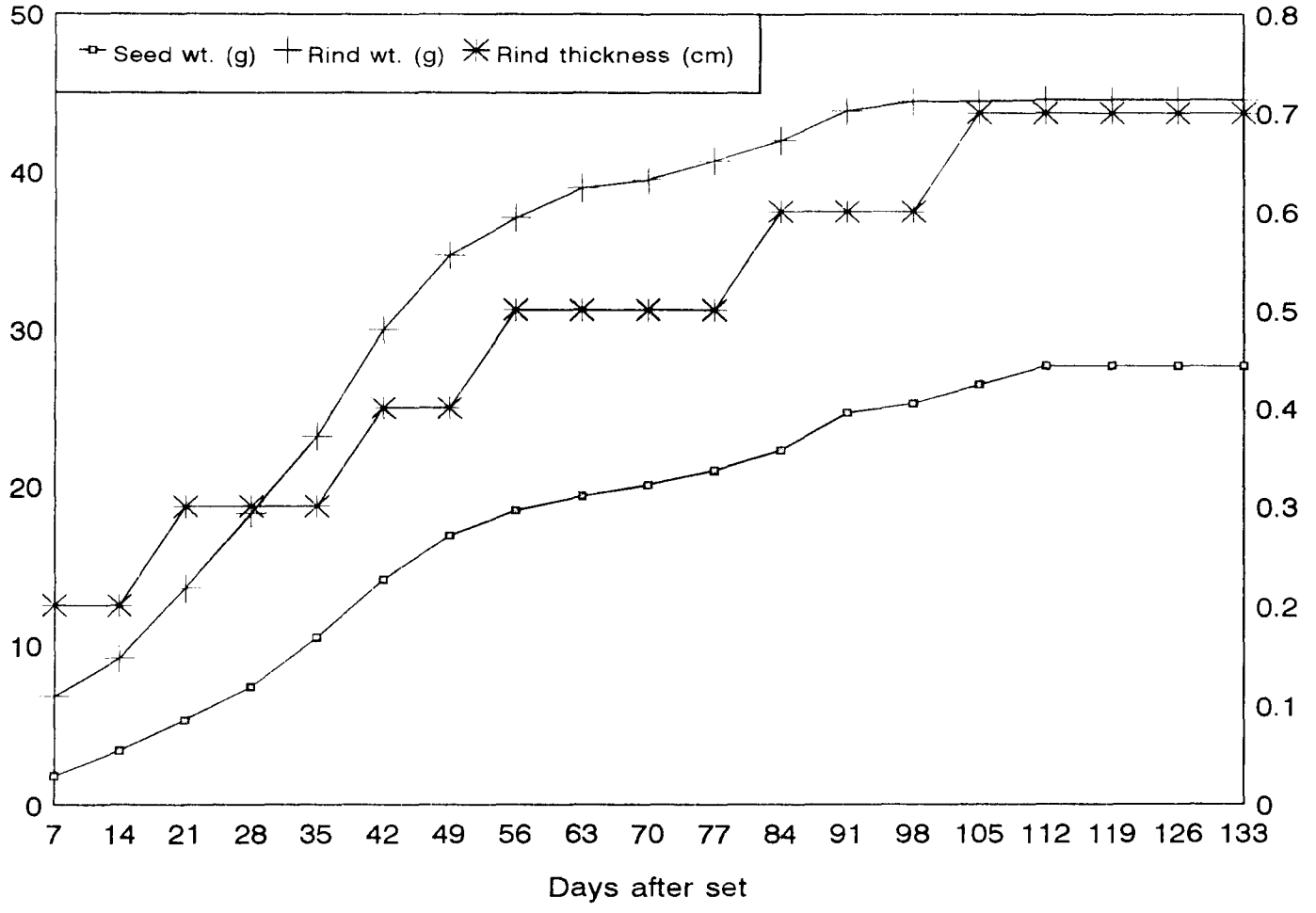


Fig.1b. Physical changes of fruit during growth and development

Table 17. Biochemical changes of fruit during growth and development

Days after set	Moisture (%)	Percentage increase in moisture	Total acidity (%)	Percentage increase in acidity	Crude fat (%)	Percentage increase in crude fat	Crude protein (%)	Percentage increase in crude protein	Crude fibre (%)	Percentage increase in crude fibre	(-)-HCA (%)	Percentage increase in (-)-HCA	Total phenol (mg/100g)	Percentage increase in total phenol
7	23.76	0.00	9.76	0.00	0.42	0.00	2.30	0.00	0.51	0.00	7.03	0.00	60	5.12
14	24.03	0.60	10.96	5.94	0.63	3.69	0.41	4.10	0.75	3.89	8.13	5.44	75	5.12
21	24.37	0.70	12.68	8.91	0.95	5.63	0.65	5.59	1.21	7.77	9.63	7.43	98	7.85
28	24.79	0.80	14.86	10.39	1.38	7.57	1.03	8.66	1.83	10.47	11.53	9.40	127	9.87
35	25.27	0.90	18.16	16.33	2.06	11.97	1.56	12.07	2.54	11.99	14.13	12.87	161	11.60
42	25.77	1.00	22.06	17.85	2.88	14.44	2.18	15.03	3.46	15.54	17.23	16.34	204	14.60
49	26.28	1.00	25.16	15.34	3.37	8.63	2.58	9.11	3.99	8.95	19.73	12.38	239	11.90
56	27.44	1.20	27.36	10.89	3.59	3.87	2.88	6.83	4.27	4.72	21.83	10.39	269	10.23
63	28.54	4.14	28.46	5.44	3.72	2.29	3.08	4.56	4.43	2.70	23.63	8.91	294	8.53
70	31.84	6.52	29.06	2.97	3.82	1.76	3.18	2.27	4.55	2.27	25.13	7.42	314	6.83
77	35.14	7.70	29.97	4.50	4.09	4.75	3.30	7.73	4.70	2.53	27.23	10.39	339	8.53
84	39.34	8.29	29.64	-1.48	4.45	6.34	3.58	6.37	5.00	5.97	26.33	-4.45	368	9.89
91	44.14	9.48	29.07	-2.96	4.85	7.04	3.90	7.29	5.45	6.93	24.83	-7.42	401	11.20
98	49.24	10.04	28.12	-4.70	5.53	8.50	4.38	10.93	5.93	8.78	22.70	-10.55	436	7.85
105	55.64	12.63	26.94	5.83	5.98	6.16	4.58	4.56	6.25	5.40	20.20	-12.38	416	-6.80
112	62.94	14.02	25.46	1.32	6.10	5.80	4.62	0.95	6.43	3.04	19.28	-4.55	387	-9.89
119	68.94	10.26	23.53	9.54	6.10	0.00	4.62	0.00	6.43	0.00	18.66	-3.06	354	-11.26
126	72.24	6.91	21.00	12.51	6.10	0.00	4.62	0.00	6.43	0.00	18.20	-2.27	329	-8.53
133	74.40	3.27	21.00	0.00	6.10	0.00	4.62	0.00	6.43	0.00	18.20	0.00	309	-6.83

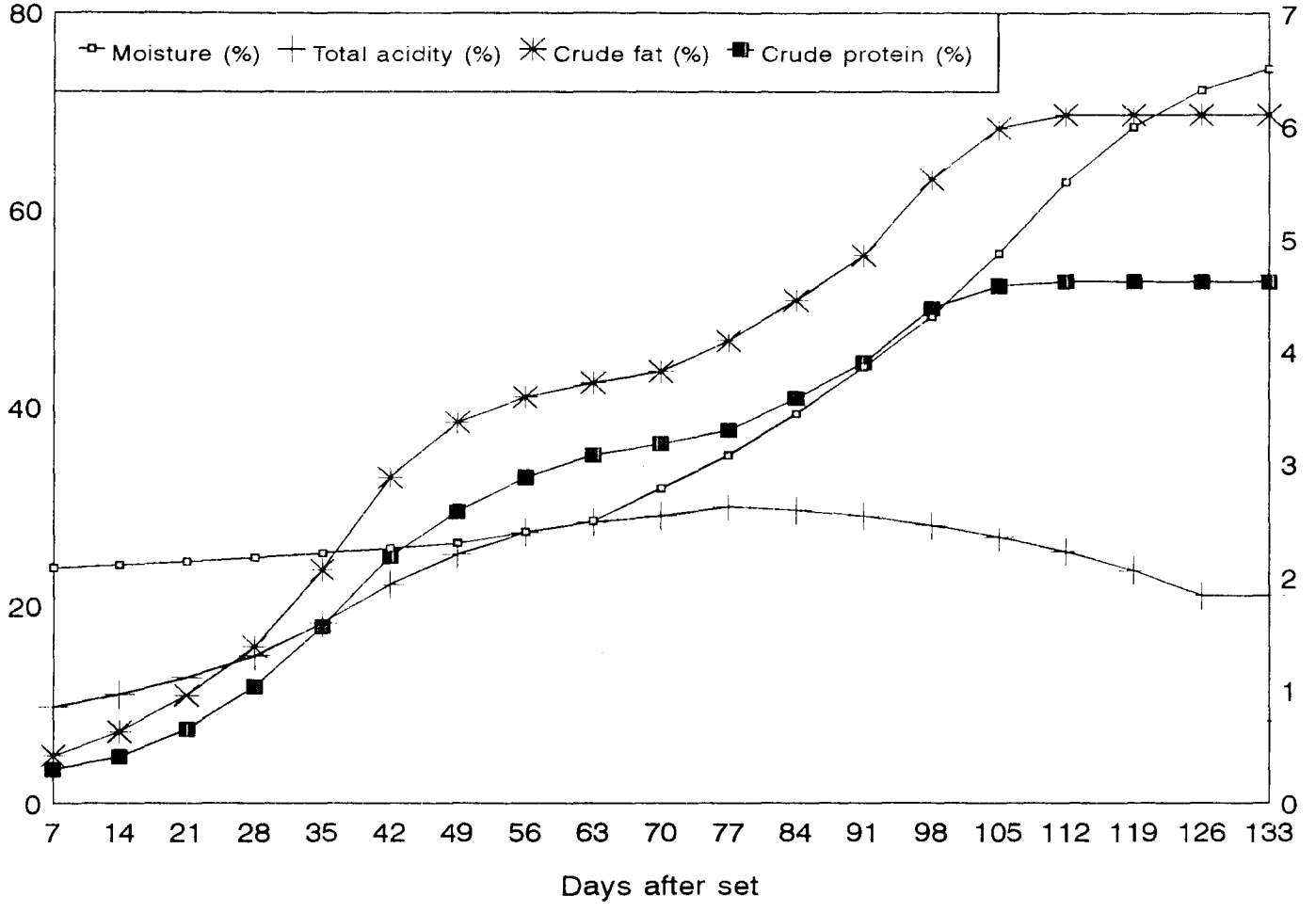


Fig.2a. Biochemical changes of fruit during growth and development

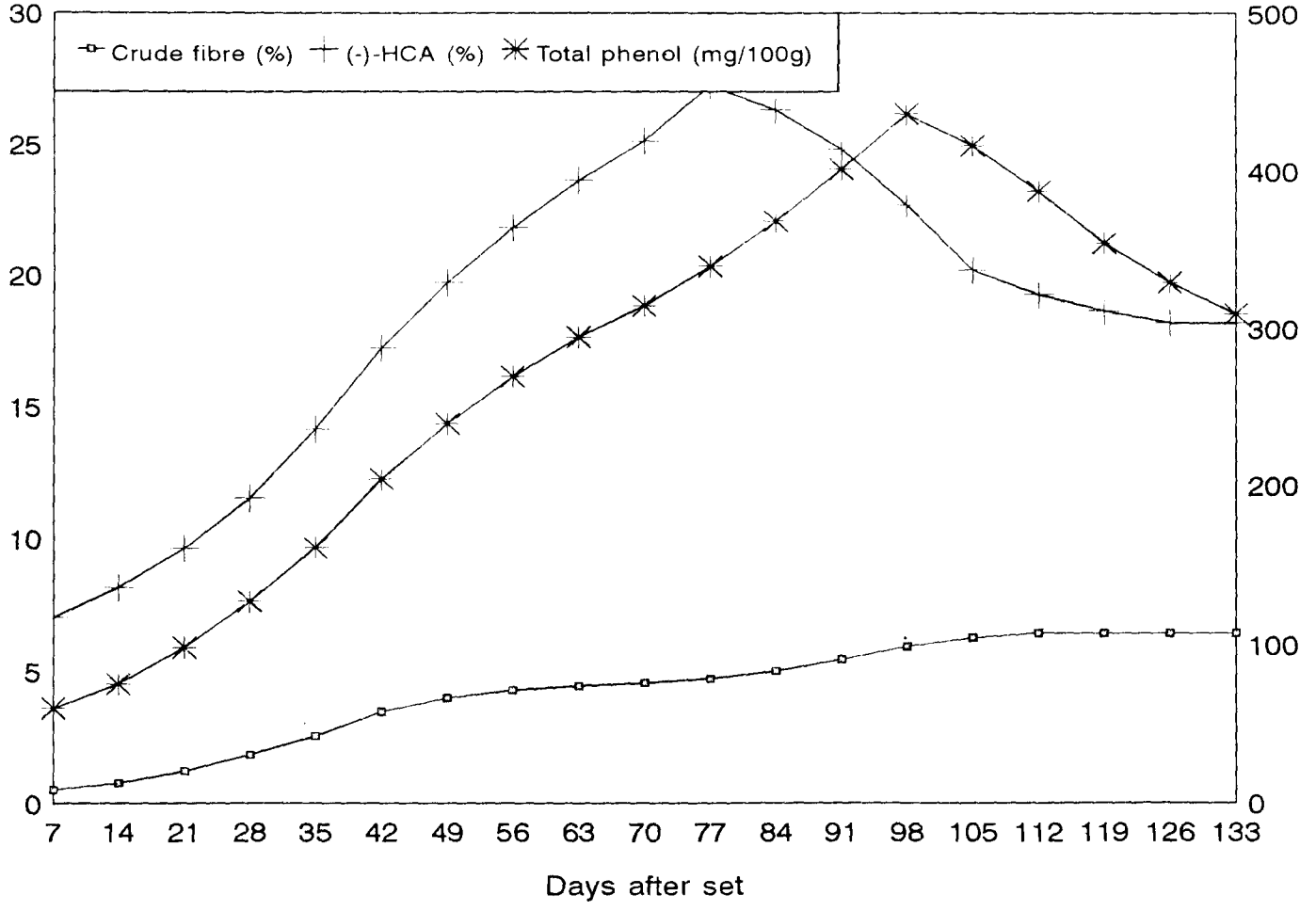


Fig.2b. Biochemical changes of fruit during growth and development

Moisture content increased from fruit set till harvest. The rate of increase was found to be slow upto 84 days, there after it increased rapidly reaching the maximum at 133 days after fruit set.

Regarding the total acidity and (-)-HCA content, there was an increase upto 77 days after fruit set and thereafter the content decreased till reaching a constant value after 126 days. Maximum rate of increase in total acidity (17.81 per cent) and (-)-HCA (16.34 per cent) was recorded during 35 to 42 days after the set. There after a declining trend was observed.

Increase in the content of crude fat, crude protein, and crude fibre took place upto 112 days after, which it attained a constant level. Maximum rate of increase in crude fat (14.44 per cent), crude protein (15.03 per cent) and crude fibre (15.54 per cent) was observed during 35 to 42 days and there after the rate gradually declined till 70 days. From 70 days onwards, the rate increased gradually till 112 days after fruit set, after which no further increase was noticed.

Total phenol content was found to increase till 98 days and thereafter, the level decreased till ripening. Regarding the rate of increase, maximum increase of 14.60 per cent was observed during 35 to 42 days and then decreasing trend was noticed till 70 days, after which, a gradual increase in the rate was observed upto 98 days. Thereafter a very steep decline was noticed till ripening.

4.4 Fruit drop

Fruit drop recorded at weekly interval showed that the drop was maximum during the first 30 days after set (Table 18). Thereafter the drop was negligible till 70 days and there was practically no drop from 70 to 119 days was noticed. During ripening negligible fruit drop was noticed.

Table 18. Fruit drop at weekly interval

Days after set	Mean Number of fruits observed per tree	Mean number of fruits dropped	Percentage fruit drop
7	200	20	10.00
14	180	16	8.00
21	164	13	6.50
28	151	10	5.00
35	141	4	2.00
42	137	1	0.50
49	136	1	0.50
56	135	1	0.50
63	134	1	0.50
70	133	1	0.50
77 to 119	132	0	0.00
126	132	1	0.50
133	131	0	0.00

The drop of ripened fruits from the trees varies with accessions. In some accessions, the fruits drop as soon as they started ripening. In certain others, only fully ripened fruits drop on the ground. In rare cases there was no drop even after complete ripening. In such cases the fruits reached the ground only in a rotten state, resulting in complete loss of the fruits.

4.5 Sex differentiation

4.5.1 Morphological characterisation

4.5.1.1 Plant characters

The data with regard to plant characters of male and bisexual plants of same age group are presented in the Table 19.

4.5.1.1.1 Plant height

The height of the male plant was found to range from 6.23 m to 9.20 m whereas in bisexual plants it varied from 5.90 m to 8.65 m. The average height of male and bisexual plants were 7.20 m and 7.15 m respectively. The analysis of variance indicated no significant difference in this character between male and bisexual trees and the values were found to be broadly overlapping.

4.5.1.1.2 Spread of the plant

The mean spread of male plants was observed to be 73.66 m^2 and that of bisexual was 72.58 m^2. The spread of male palnts varied from 66.36 m^2 to 85.93 whereas in bisexuals it ranged from 52.14 m^2 to 87.12 m^2. The difference in this character was not significant enough to discriminate between male and bisexual plants.

Table 19. Plant characters of male and bisexual trees

	Height of plant (m)		Spread (m^2)		Collar girth (cm)		Height at branching (cm)	
	Male	Bisexual	Male	Bisexual	Male	Bisexual	Male	Bisexual
Mean	7.20 ± (0.18)	7.15 ± (0.18)	73.66 ± (0.92)	72.58 ± (1.92)	103.98± (3.70)	108.97± (3.70)	80.26± (8.97)	80.70± (2.97)
Range	6.23 - 9.20	5.90 - 8.65	66.36 - 85.93	52.14 - 87.12	75.28 - 137.13	73.83 - 120.89	63.87 - 110.00	67.19 - 123.00

Table 20. Canopy shape and branching habit in male and bisexual trees

Sl. No.	Canopy shape		Branching habit	
	Male	Bisexual	Male	Bisexual
1	Conical	Pyramidal	Drooping	Spreading
2	Conical	Conical	Erect	Drooping
3	Round	Conical	Drooping	Drooping
4	Pyramidal	Conical	Drooping	Drooping
5	Conical	Round	Drooping	Erect
6	Dome	Conical	Spreading	Drooping
7	Conical	Round	Drooping	Drooping
8	Conical	Conical	Spreading	Spreading
9	Conical	Dome	Spreading	Drooping
10	Conical	Conical	Drooping	Drooping
11	Round	Pyramidal	Erect	Drooping
12	Dome	Conical	Drooping	Erect
13	Pyramidal	Dome	Drooping	Spreading
14	Conical	Round	Erect	Drooping
15	Pyramidal	Conical	Spreading	Spreading

4.5.1.1.3 Collar girth

Collar girth of bisexual plants was observed to range from 73.83 cm to 120.89 cm and that of male plants from 75.28 cm to 137.13 cm. The mean collar girth of bisexual plants was 108.97 cm and that of male was 103.98 cm. However, analysis of variance did not reveal any pronounced difference between male and bisexual plants.

4.5.1.1.4 Height at first branching

Eventhough wide variation was noted in the branching heights of the male and bisexual trees no distinguishable difference existed between males and bisexuals in this character. The branching height varied from 63.87 cm to 110.00 cm in males and 67.19 cm to 123.00 cm in bisexual. The mean branching height of male and bisexual plants were 80.26 cm and 80.70 cm respectively.

4.5.1.1.5 Canopy shape and branching habit

Male and bisexual plants did not show any difference in canopy shape and branching habit. Different canopy shapes like conical, pyramidal, round and dome were noticed in both male and bisexual trees (Table 20). With respect to the habit of branching, both male and bisexual trees showed all the three types of branching namely, horizontal, drooping and erect.

4.5.1.1.6 Colour of the young flush

Colours like green, pink and its shades were observed in both male and bisexual trees. But pink and pinkish shades were most widely prevelent in bisexual trees (Table 21 and Plate 23).

Table 21. Colour of the latex and young flush in male and bisexual trees

Sl. No.	Colour of the latex		Colour of the young flush	
	Male	Bisexual	Male	Bisexual
1	Yellow	Light yellow	Green	Pinkish green
2	Light yellow	Yellow	Green	Green
3	Light yellow	Dark yellow	Green	Pinkish green
4	Dark yellow	Yellow	Pinkish green	Pink
5	Yellow	Light yellow	Green	Greenish pink
6	Yellow	Yellow	Green	Greenish pink
7	Light yellow	Yellow	Green	Pink
8	Light yellow	Light yellow	Pinkish green	Green
9	Dark yellow	Dark yellow	Green	Pink
10	Yellow	Light yellow	Green	Green
11	Light yellow	Dark yellow	Pink	Green
12	Yellow	Light yellow	Green	Pinkish green
13	Dark yellow	Light yellow	Green	Greenish pink
14	Light yellow	Dark yellow	Green	Green
15	Yellow	Yellow	Greenish pink	Green

Table 22. Colour of the shoot bark and feeder roots in male and bisexual trees

Sl. No.	Colour of the shoot bark				Colour of the feeder roots	
	Male		Bisexual		Male	Bisexual
	Internal	External	Internal	External		
1	Cream	Brown	Cream	Brown	Cream	Light brown
2	Cream	Dark brown	Cream	Brown	Light brown	Cream
3	Cream	Brown	Cream	Dark brown	Cream	Light brown
4	Cream	Brown	Cream	Dark brown	Cream	Cream
5	Cream	Brown	Cream	Brown	Cream	Cream
6	Cream	Brown	Cream	Brown	Light brown	Cream
7	Cream	Dark brown	Cream	Dark brown	Cream	Light brown
8	Cream	Brown	Cream	Brown	Cream	Light brown
9	Cream	Brown	Cream	Dark brown	Light brown	Cream
10	Cream	Brown	Cream	Brown	Cream	Cream
11	Cream	Dark brown	Cream	Brown	Cream	Cream
12	Cream	Brown	Cream	Brown	Cream	Cream
13	Cream	Brown	Cream	Brown	Cream	Light brown
14	Cream	Dark brown	Cream	Brown	Light brown	Cream
15	Cream	Brown	Cream	Dark brown	Cream	Cream

4.5.1.1.7 Colour of the latex

There was no marked difference between male and bisexual trees with respect to the colour of the latex. Different shades of yellow colour was noticed in the latex of both male and bisexual trees (Table 21).

4.5.1.1.8 Colour of the bark

Male and bisexual plants did not show any marked difference with respect to colour of the bark. Different shades of brown were noticed externally on the bark in both sexes. Internally colour of the bark of the growing shoot was cream in both male and hermaphrodite (Table 22).

4.5.1.1.9 Colour of the feeder roots

Feeder roots showed different shades of brown and cream colour in both the sexes. No marked difference was noticed between male and bisexual trees with respect to the colour of feeder roots (Table 22).

4.5.1.2 Leaf characters

The observation with respect of leaf characters are presented in Table 23a and 23b.

4.5.1.2.1 Leaf length

The average length of leaves in male and bisexual trees was 9.37 cm and 9.70 cm respectively. The length of leaves in male plants ranged from 6.93 cm to

Table 23a. Leaf length, leaf width and length/width ratio of male and bisexual plants

	Leaf length (cm)		Leaf width (cm)		Length/width ratio	
	Male	Bisexual	Male	Bisexual	Male	Bisexual
Mean	9.37 ± (0.46)	9.70 ± (0.46)	4.91 ± (0.21)	5.38 ± (0.21)	2.84± (0.10)	2.92± (0.10)
Range	6.93 - 13.33	6.63 - 13.97	3.10 - 6.20	3.90 - 6.90	2.16 - 3.72	2.30 - 3.80

Table 23b. Leaf area, internodal length and petiole length of male and bisexual plants

	Leaf area (cm^2)		Internodal length (cm)		Petiole length (cm)	
	Male	Bisexual	Male	Bisexual	Male	Bisexual
Mean	49.48± (2.66)	52.18 ± (2.66)	5.58 ± (0.16)	5.57 ± (0.16)	0.87 ± (0.16)	0.86 ± (0.46)
Range	28.54 - 73.97	29.08 - 76.05	4.30 - 6.80	4.10 - 6.80	0.50 - 1.30	0.60 - 1.40

13.33 cm whereas in bisexual it was from 6.63 cm to 13.97 cm. This indicated no significant variation between both the sexes in terms of length of the leaf.

4.5.1.2.2 Leaf width

The average width of the leaves in males was 4.91 cm and that of in bisexuals was 5.38 cm. The width ranged from 3.10 cm to 6.20 cm in males. The corresponding range in bisexuals was 3.90 to 6.90 cm. But statistically there was no significant variation between males and bisexuals in terms of width of the leaf.

4.5.1.2.3 Length by width (L/W) ratio

Length by width ratio was found to range from 2.16 to 3.72 for males and 2.30 to 3.80 for bisexuals. The average L/W ratio of male and bisexual plants were 2.83 and 2.91 respectively. The analysis of variance indicated no significant difference in this character between male and bisexual trees.

4.5.1.2.4 Leaf area

Leaf area recorded in male plants ranged from 28.54 cm^2 to 73.97 cm^2. The corresponding range in bisexuals was from 29.08 cm^2 to 76.05 cm^2. The mean leaf area of bisexual plants was 52.18 cm^2 and that of males was 49.48 cm^2. Analysis of variance showed no significant difference between male and bisexual trees in terms of leaf area.

4.5.1.2.5 Petiole length

No pronounced difference in the petiole length was observed between male (0.87 cm) and bisexual (0.86 cm) plants.

4.5.1.2.6 Internodal length

No marked difference in the internodal length was observed between male (5.58 cm) and bisexual (5.57 cm) plants.

4.5.1.2.7 Leaf shape

The observation recorded with respect of leaf shape, nature of leaf tip and leaf base are furnished in Table 24. A variety of leaf shapes like oblong, elliptic, obovate, oblanceolate and lanceolate were noticed in both the sexes. Leaf apex namely acute, obtuse and accuminate were noticed in male as well as in bisexual trees. Both the sexes showed acute and acuminate leaf base. There was no marked difference between male and bisexual trees in terms of leaf shape.

4.5.2 Biochemical characterisation

The data regarding the biochemical characters of the leaves of male and bisexual plants were presented in the Table 25.

4.5.2.1 Essential oil content of leaf

Essential oil content of leaf in both male and bisexual plants ranged from 0.030 to 0.060 per cent. Mean oil content in male and bisexual plants were 0.047 per cent and 0.046 per cent respectively. Analysis of variance showed no signfiicant difference between male and bisexual plants.

Table 24. Leaf shape in male and bisexual trees

Sl. No.	Male			Bisexual		
	Leaf shape	Leaf base	Leaf tip	Leaf shape	Leaf base	Leaf tip
1	Obovate	Acute	Acute	Lanceolate	Acute	Acute
2	Oblong	Acute	Acute	Oblong	Acute	Acute
3	Lanceolate	Acute	Acuminate	Obovate	Acute	Acute
4	Elliptic	Obtuse	Acute	Oblong	Obtuse	Obtuse
5	Oblanceolate	Acute	Acute	Elliptic	Acute	Acuminate
6	Lanceolate	Acute	Acuminate	Oblanceolate	Obtuse	Obtuse
7	Elliptic	Obtuse	Obtuse	Elliptic	Acute	Acute
8	Oblong	Acute	Acute	Elliptic	Actue	Acute
9	Oblong	Acute	Acute	Lanceolate	Acute	Acuminate
10	Elliptic	Acute	Obtuse	Elliptic	Obtuse	Obtuse
11	Oblong	Acute	Acute	Lanceolate	Acute	Acute
12	Obovate	Acute	Acuminate	Lanceolate	Acute	Acute
13	Oblanceolate	Obtuse	Acuminate	Elliptic	Obtuse	Obtuse
14	Obovate	Acute	Acute	Oblong	Obtuse	Obtuse
15	Lanceolate	Obtuse	Acute	Lanceolate	Acute	Acuminate

Table 25. Essential oil content, total phenol and total acidity in leaves of male and bisexual plants

	Essential oil (%)		Total phenol (mg/100 g)				Total acidity (%)	
			Young		Mature			
	Male	Bisexual	Male	Bisexual	Male	Bisexual	Male	Bisexual
Mean	0.047± (0.00)	0.046± (0.00)	208.60± (7.07)	118.10± (7.07)	1397.82± (31.94)	794.53± (7.07)	0.57± (0.02)	0.59± (0.02)
Range	0.03 - 0.06	0.03 - 0.06	192.00 - 222.00	59.10 - 201.00	970.00 - 1567.00	520.30 - 987.90	0.48 - 0.77	0.48 - 0.78

4.5.2.2 Total acidity of leaf

The total acidity of leaf ranged from 0.48 to 0.77 per cent in male plants and from 0.48 to 0.78 per cent in bisexual plants. The average total acidity in male plants was 0.57 per cent and that of bisexual plants was 0.59 per cent. Analysis of variance showed no significant difference between male and bisexual plants in terms of total acidity in leaves.

4.5.2.3 Total phenol content of leaf

4.5.2.3.1 Mature leaf

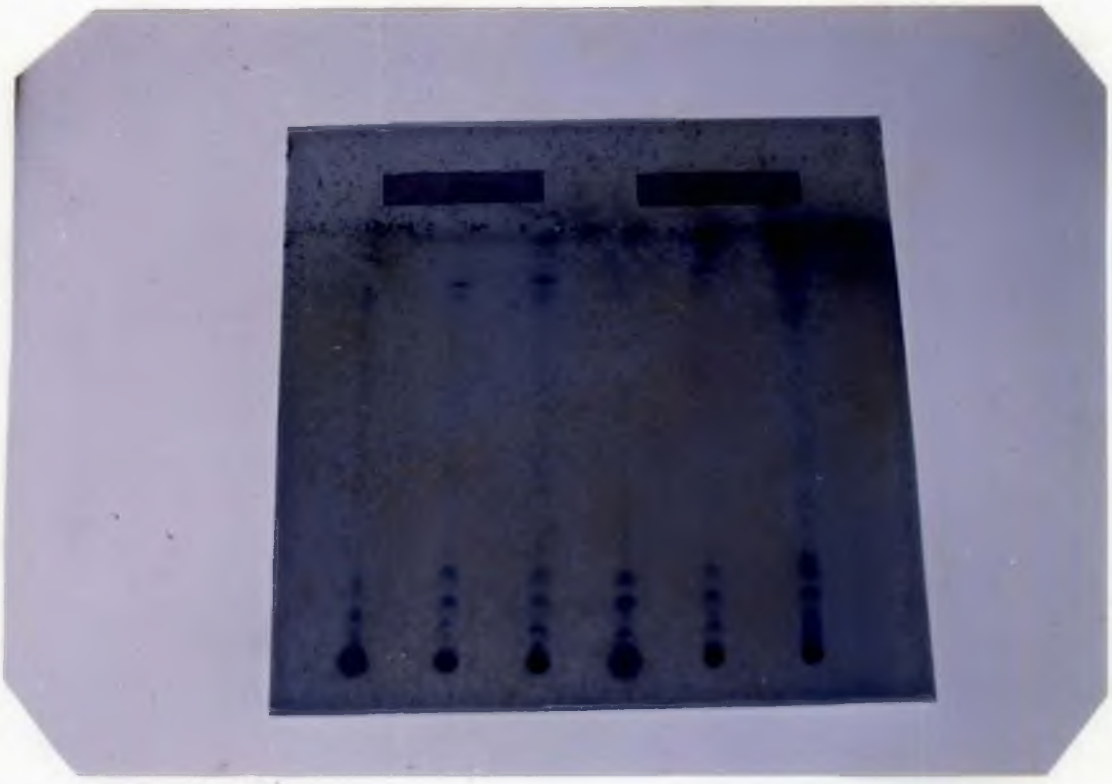
The total phenol content of mature leaf in male plants ranged from 970.00 to 1567.00 mg/100 g with an average of 1397.80 mg/100 g. In bisexual plants the total phenol content varied from 520.30 to 987.90 mg/100 g with a mean of 749.53 mg/100 g. Of the 15 male plants analysed, 13 plants had total phenol content of 1200 mg/100 g and above. On the other hand none of the fifteen bisexual plants showed a total phenol content of 1200 mg/100 g and above.

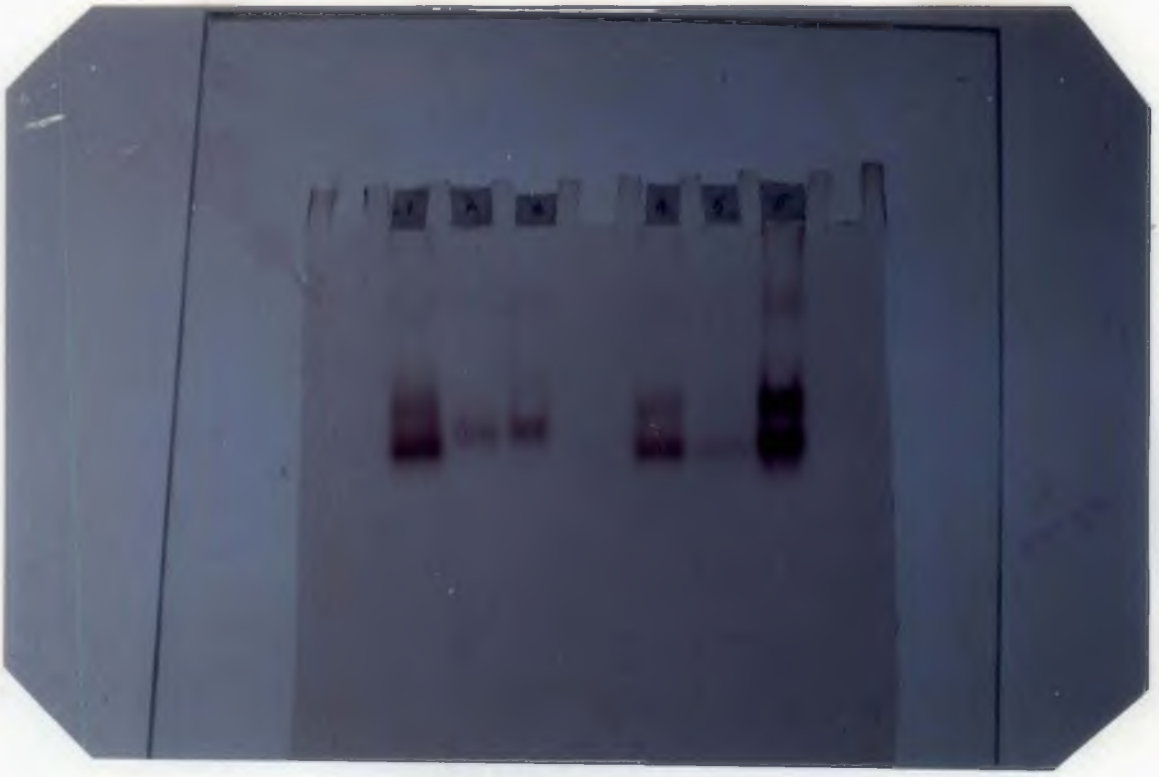
4.5.2.3.2 Young leaf

The total phenol content of young leaf ranged from 192.00 to 222.00 mg/100 g in male plants and 59.10 to 201.00 mg/100 g in bisexuals. The average total phenol content of young leaf was 208.60 mg/100 g in male and 118.10 mg/100 g in bisexuals. Out of fifteen male plants taken for analysis, ten plants had a total phenol content of 200.00 mg/100 g and above. On the other hand only one plant of the fifteen bisexuals showed a total phenol content of 200.00 mg/100 g above. The rest registered a lower total phenol content of below 200.00 mg/100 g. Analysis of variance showed a significant difference between

Plate 24. Thin layer chromatographic profile of phenolic extracts of male and bisexual trees

Plate 25. Peroxidase banding pattern in leaves of male and bisexual trees





males and bisexuals with respect to total phenol content of young as well as mature leaves.

4.5.2.4 Thin layer chromotography of phenolics

The profile of phenolic extract after acid hydrolysis showed five distinct spots with Rf values 0.055, 0.089, 0.137, 0.200 and 0.438 in male plants. In bisexual plants only four spots with Rf values 0.069, 0.131,0.193 and 0.401 were observed (Plate 24).

4.5.2.5 Isoenzyme analysis:

On staining with benzidine two bands showing peroxidase activity with Rm values of 0.46 and 0.41 were obtained for both male and bisexual plants (Plate 25).

Discussion

5. DISCUSSION

The results of the present investigation on variability in vegetative, floral, fruiting and biochemical characters of the fruit, a comparison on the quality of the rind under different drying conditions, pattern of fruit development and sex differentiation in terms of morphological and biochemical characters in Kodampuli (*Garcinia cambogia* Desr.) are discussed in this chapter.

5.1 Variability study

Variation manifested in kodampuli is due to its cross-pollinated, heterozygous nature. Moreover it is generally propagated through seed.

5.1.1 General tree characters

Trees surveyed were having round, dome, conical and pyramidal shapes. Dome shaped trees were very high yielding types. The reason for this may be that, such trees have more canopy area and receive more amount of sunlight, leading to the production of more fruiting branches. Branching habits like erect, drooping and horizontal were noticed. Trees with horizontal branches occupy a larger area resulting in higher yield. Both low headed and high headed trees were noticed among high yielders. Low headed trees may be preferred in order to overcome the harvesting difficulties.

Studies showed a protracted period of flowering in male trees of kodampuli over a period of four to five months whereas in hermaphrodite trees, it was comparatively shorter, confining to two to three months. The possible reason for the shorter duration of flowering in hermaphrodite trees may be that a good

amount of stored food is channelised for production of fruits in them. Since the male trees are unproductive, there is no channelisation towards the fruit production. The metabolites are hence used continuously towards the production of flowers for longer period of time.

The peak season of ripening was during June-July, coinciding with rainy season. George (1988) reported fruit ripening in kodampuli during the South-West monsoon. Heavy damage to the fruits in the form of rotting was noticed due to rain. Manual harvesting was difficult due to slippery nature of the tree as a result of rain. Drying of the rind was very difficult due to the limited hours of sunlight. Moreover, the general practice of smoke drying is very labourious and cumbersome. During the survey, early flowering accessions like AC.3 and 36, mid season flowering accessions like AC.1, 2, etc., late flowering accessions like AC.11, 21, 23, 37, 36, 38 and 46 and sporadic flowering accessions like AC. 8a, 9 and 13 were located. Early flowering (January-February) accessions can be selected as the fruits come to ripening well before the commencement of monsoon (May-June). Similarly very late flowering (March-April) accessions which ripens after the end of monsoon (July-August) may also chosen, which can help to solve the above problem to some extent. Attention should be given towards induction of flowering through growth regulators at an early period so that the harvesting and drying can be completed before heavy monsoon. Steps should also be taken to evolve types with very early flowering nature through breeding programmes.

Bearing capacity of the tree is determined by the genotype, age, climate and management practices. Variation in bearing capacity, namely, prolific bearing collections (AC.3, 8a, 9, 14, 36, 40, 42, 43b, 44, 45a and 46) giving an yield up to 500-600 kg of fresh fruits per annum and medium bearing accessions (AC.4a, 4b, 5, 6, etc.) yielding upto 200 kg of fresh fruits per year were located. There were also

poor yielding accessions (1, 2, 8b, 10, 12, 15, 17a, 17b, 21, 22, 25, 26 and 37) which yielded only less than 50 kg per annum. Regarding the age, there was a steady increase in yield up to 50 years, after which it remained almost stable. During the survey very high yielding trees above 95 years of age could also be located.

Irregular bearing nature was also noticed in this crop. Such trees bear one or more years of heavy crop followed by an year of poor crop. In general it was noticed that the yield of almost all the entries were comparatively higher during the year 1996-1997 than during 1997-1998. The poor yield during 1997-1998 may be due to the higher temperature and lesser rainfall prevailing during 1997-1998 (Appendix II and III). Singh (1990) reported that the potentiality of the shoots to form flower bud will depend on the floriferous condition of the tree, which, in turn, will be determined by the amount of crop load. Chacko and Ananthanarayanan (1982) suggested that the irregular bearing in mango might be due to the inability of plants to form flower buds under natural condition because of the lack of sufficient reserves and their possible hormone directed redistribution and mobilisation. So studies should be carried out in these lines to know the exact cause for the irregular bearing problem faced by the crop.

The most dreadful malady noticed in the crop was malformation, which reduced the fruit bearing capacity. Majumder *et al.* (1970) reported that the malformation of panicles and other vegetative parts in mango might be the outcome of the disturbances in the quantity and quality along with imbalance of the native growth substances. Mishra and Dhillon (1978) observed that malformed panicles of Dashehari variety of mango had lower level of inhibitary abscissic acid like substances and higher promotive activity than healthy panicles.

The occurrence of gamboge, a physiological disorder, was noticed in some of accessions as the fruits came to harvest during rainy season. The cause of this could be attributed to the quick expansion and cracking of the fruits due to sudden availability of moisture towards the end of fruit development. The sudden expansion of the rind resulted in exudation of an yellow gum from the rind which gradually penetrated into the fruit. Once it entered the fruit, the fruit pulp became yellow and gummy. The rind turned brown or black and bitter and it affected the quality of the dried produce. But the incidence of gamboge in early ripening types (AC. 3 and 36) was meagre. By selecting early ripening types or inducing the trees to flower earlier might overcome this problem to some extent.

Apart from minor incidence of leaf spot, leaf blight and fruit rot there were no serious pest and diseases in kodampuli unlike many other fruit crops. This may be due to the higher phenol content recorded in the leaves and the fruits of the tree. On an average young leaves of male tree recorded a total phenol content of 208.6 mg/100 g and in bisexual tree it was 118.1 mg/100 g. The total phenol content of mature leaves in male tree was 1397.8 mg/100 g and that of bisexual tree was 749.5 mg/100 g. Fruits had a total phenol content of 313.1 mg/100 g. Through genetic engineering, if the genes responsible for the production of higher amount of phenol in kodampuli, could be identified and transferred, there might be chances for incorporating disease and pest resistance in other fruit crops.

During the survey, it was interesting to see that the branches cut with knife showed drying symptoms within a short period. Farmers have a belief that iron knife is responsible for the drying of branches. Though it is scientifically yet to be proved, the possible reason for drying can be the deleterious effect of pruning.

Plate 26. Germinated seedlings from polyembryonic seeds of kodampuli

Another peculiar observation was the appearance of male flowers on one branch and bisexual flowers on the other of a single tree. In those cases the branching started right from the collar region. On examining a large number of seedlings it was found that about ten per cent polyembryony exist in this species. In such cases, production of two or three seedling occurred from a single seed. The seedling originating from zygotic embryo has a chance to segregate either to male or bisexual, and those arising from nucellar region might produce true to type ones resulting in bisexual trees. The above mentioned phenomenon might have resulted from the polyembryonic seedling (Plate 26). Duarte (1982) reported that seeds of mangosteen, a closely related species of kodampuli, were not zygotic and were formed from nucellar tissues of the carpel. Alex (1996) reported that ten per cent of the *Garcinia mangostana* seeds were polyembryonic in nature.

5.1.2 Leaf characters

Wide variation was noticed in leaf length (5.3 cm to 14.0 cm), leaf width (2.3 cm to 5.6 cm), length/width ratio (1.36 to 4.00) and leaf area (19.88 cm^2 to 64.46 cm^2). A variety of leaf shapes were noticed, namely, oblong, elliptic, obovate, oblanceolate and lanceolate. Majeed (1994) reported that the leaf shapes in kodampuli could be of elliptic, obovate-lanceolate or lanceolate-oblong.

5.1.3 Flower characters

5.1.3.1 Flower and sex types

Six flower types were identified, namely, type 1, 2, 3, 4, 5 and 6, varying in the function of pistil and stamen and the capacity to set fruit.

Flower type 1 was a typical flower of male trees. It had long as well as short pedicel with petal colour variation ranging from light yellow to dark yellow, cream and pink. Stamens ranged from 60 to 80 having the highest pollen viability of 94 per cent. Rudimentary pistil was absent.

Flower type 2 was also noticed n male trees. It had long as well as short pedicel with petal colour variation ranging from light yellow to dark yellow, cream and pink. Stamens ranged from 50 to 60 in number with a pollen viability of 83.2 per cent. Rudimentary structure, conical in shape was present in the place of pistil, in which the cross section had no ovary cells.

Flower type 3 was commonly found n male trees and also very rarely seen on bisexual trees. It had also long as well as short pedicel with petal colour variation ranging from light yellow to dark yellow, cream and pink. Stamens ranged from 40 to 50 in number with a pollen viability of 77.34 per cent. The rudimentary pistil showed further increase in size and the cross section showed no presence of ovary cells.

Flower type 4 was seen predominantly on male trees and rarely seen on bisexual trees. It had also long as well as short pedicel with similar petal colour variation as that of the above types. Stamen number varied from 35 to 40 with a pollen viability of 60.50 per cent. Stigmatic surface makes its full appearance with cross-section showing ovary cells. The fruit setting percentage was very low.

Flower type 5 was seen predominently on male trees and to some extent in bisexual trees. It was also having similar variation in pedicel length and petal colour as that of type 1. Stamens varied from 30 to 35 in number with a pollen viability of 54.23 per cent. Stigmatic surface with prominent tubercles can be

noticed. The cross-section of pistil showed presence of slightly bigger ovary cells than type 4. The fruit setting percentage was low.

Flower type 6 was noticed only on bisexual trees with similar pedicel length and petal colour variation as that of type 1. Stamen number ranged from 8 to 30 with a pollen viability of 22.94 per cent. This was the normal bisexual flower with very prominent stigmatic surface. Cross-section of pistil showed higher number of well developed ovary cells. This type was having maximum capacity for fruit set.

Based on the preponderance of a particular type of flower and bearing tendency of individual tree, the trees observed during survey could be divided into two types namely male and bisexual tree. Male tree bears predominently flower types of 1, 2 and 3, and to some extent type 4 and 5, either individually, or in combinations, with other types in varying proportions. They are mostly incapable of producing fruits. Bisexual tree bears predominantly type 6 flowers with profuse fruit setting capacity. Very rarely there were also bisexual trees with majority of type 4 and 5 flowers along with type 1, 2 and 3 but the fruit setting capacity was very low. Vajravelu (1990) reported the presence of pistillate and staminate flowers in separate trees. This in contradiction to the present observation. The present study was in agreement with the observation of George (1992) and Sherly (1994) of the presence of male and hermaphrodite flowers in kodampuli.

Attempts should be made to examine the process of sex reversal in kodampuli. Sex reversal is the process of conversion of unproductive male plants in due course of time into productive female plants. Sex reversel has been noticed in nutmeg, another dioecious crop. Sastri (1962) reported that occasionally male trees

after a number of years produce female flowers and may eventually become females.

If attempts are made to induce more number of type 6 flowers in tree type 1, it will be a great break through in kodampuli cultivation.

Gunjate *et al.* (1984) reported the presence of 11 flower types with varying function of pistil and stamen and the capacity to set fruit in *Garcinia indica*. They also reported the presence of three tree types, namely, male, bisexual and female. There are chances for the existences of female trees in kodampuli too. During the survey no such purely female tree was located. In the evergreen forest of Western Ghats, the centre of origin of kodampuli, there exists a large variability. Surveys are to be conducted in those areas to locate the purely female kodampuli trees.

5.1.3.2 Variability in morphology and fertility of flowers on bisexual and male trees

Number of flowers per cluster varied from 1 to 4 in bisexual and 5 to 15 in male trees. Anderson (1875) observed 1 to 3 flowers per cluster in bisexual trees and 1 to 7 flowers per cluster in male trees. The mean pedicel length of the flowers seen in male trees varied from 0.20 to 1.80 cm and those in bisexual trees, it varied from 0.20 to 0.90 cm. Colours like pink, cream, pinkish cream, creamish pink and yellow were noticed in the petals of the flowers seen in male and bisexual trees. Mean petal length of the flowers seen in bisexual tree varied from 0.30 to 0.80 cm and those in the male trees varied from 0.30 to 0.50 cm. Flowers seen in male trees had the mean weight ranging from 0.11 to 0.38 g while in bisexual trees, it varied from 0.38 to 0.69 g.

Mean number of the stamen of the flowers seen in bisexual tree varied from 9 to 35 while those in the flowers of male tree varied from 41 to 83. George *et al.* (1992) reported numerous two celled anthers with short filaments in male flowers and 6 to 20 stamens in bisexual flowers. The percentage pollen fertility and germinability of the flowers seen in male trees ranged from 47.63 to 94.50 per cent and 41.28 to 90.18 per cent, respectively. The pollen fertility and germinability of the flowers seen in bisexual tree had the range from 13.10 to 38.10 per cent and 10.12 to 35.12 per cent, respectively.

5.1.4 Fruit characters

5.1.4.1 Morphological characters

Colour of the fruit varied from light yellow to dark orange. No correlation was observed between colour of the fruit and other fruit characters like yield, fruit size, rind thickness, etc. From the marketing point of view also, colour is not an important criteria because once the rind is dried, it loses its original colour and attains black, brown or pale brown colour.

Round, oblong, oval, cordate, pear and napiform shapes were noticed in kodampuli fruits. George (1988) reported the presence of ellipsoid, ovoid and spherical shapes in kodampuli fruits. There was no correlation between fruit shape and other yield parameters. Rind is sold in the form of two halves and hence shape may not be an important character to be considered while selecting good accessions.

Fruits with assymmetrical shapes were also noticed, with well developed segments and seeds on one side, and poorly developed segments and undeveloped seeds on the other side. Seeds being a rich source of auxin may be responsible for

the well developed portion of the fruit. Presence of poorly developed seeds resulting in the insufficient amount of growth hormones might be the possible reason for the assymetrical development of the fruit. Such assymmetrical shaped fruits have been reported in jack and mango due to poor development of seed (Singh, 1990).

Number of segments varied from 6 to 11. AC. 8b recorded a maximum of 11 segments per fruit. On considering the character associations, it was found that the number of segments was positively correlated with fruit weight and thickness of the rind. So the trees with fruits having larger number of segments per fruit can be made use of in breeding programmes. Variation in segment number has also been reported by Beddome (1978) and George (1988).

Statistically wide variation was noticed among the collections in terms of segment width. The range was from 0.40 cm (AC. 20) to 1.80 cm (AC. 33). Correlation between segment width and rind thickness was found to be highly significant. It was also significantly correlated with rind seed ratio and fruit rind ratio. Hence, while selecting superior accessions, segment width should be considered as an imporant criteria.

A wide variability in the fruit length was noticed among the accessions, ranging from 4.50 cm (AC. 5) to 9.00 cm (AC. 34) and the fruit length was significantly correlated with volume which in turn was correlated with other fruit characters like rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio. Hence, fruit length has to be considered as a criteria for selection of trees for commercial cultivation or for breeding purposes.

Statistically very wide variation was noticed in terms of fruit girth ranging from 15.00 cm (AC.13) to 28.00 cm (AC. 45a). Significant correlation was not

observed between girth and other fruit characters. Hence fruit girth need not be considered as a selection criteria.

Mean fruit weight in all the 50 entries showed a wide variation ranging from 60.00 g in AC. 35 to 260 g in AC.46. Accessions like 40, 45a, 41, 38, 9, 43a, 43b, 18, 8a, 24, 33, 4a, 29, 4b, 3, 16 and 14 were also having higher fruit weight of above 150.0 g. Highly significant correlation was noticed between fruit weight and other fruit characters like length, volume, rind thickness, seed weight, rind weight and rind seed ratio. Significant correlation with number of segments and segment width was also noticed. With fruit rind ratio, it was negatively correlated. Since the fruit weight has got correlation with so many other fruit characters, it has to be considered as the most important selection criteria for arriving at superior types for commercial cultivation and for incorporating in breeding programmes.

Wide variations was also observed in the fruit volume. Maximum of 220.00 cc was noticed in AC.38. AC.46, which topped the list in fruit weight, had a volume of 218.70 cc, ranking second. This indicates fruits with higher fruit weight need not have higher volume. The reason for this may be that AC.46 having higher rind thickness of 1.80 cm was having lower cavity diameter. Volume was significantly correlated with rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio, of which, fruit rind ratio had negative correlation. Significant correlation was observed with number of segments. Hence,volume should also be considered as another important selection criteria.

Very high rind thickness of 1.80 cm (AC.46) and very low rind thickness of 0.40 cm (AC.36) was recorded among the 50 collections showing wide variation. Significant correlation between rind thickness and other fruit characters like seed weight, rind weight and rind seed ratio was observed. With fruit rind ratio, the

correlation was negative. Therefore rind thickness should also be considered as an important selection criteria.

Maximum seed weight of 65.00 g (AC.33) and minimum of 20.00 g (AC.35) revealed the existence of significant variability in terms of seed weight among the collections. Significant correlation with fruit weight, rind weight, rind seed ratio and fruit rind ratio was observed, of which the correlation was negative with fruit rind ratio. The significant positive correlation of seed weight with fruit weight and rind weight can be explained in terms hormonal activity of the seeds towards the development of the fruit. Singh (1990) reported that size of the seed may contribute to the size of the fruit through hormonal activity.

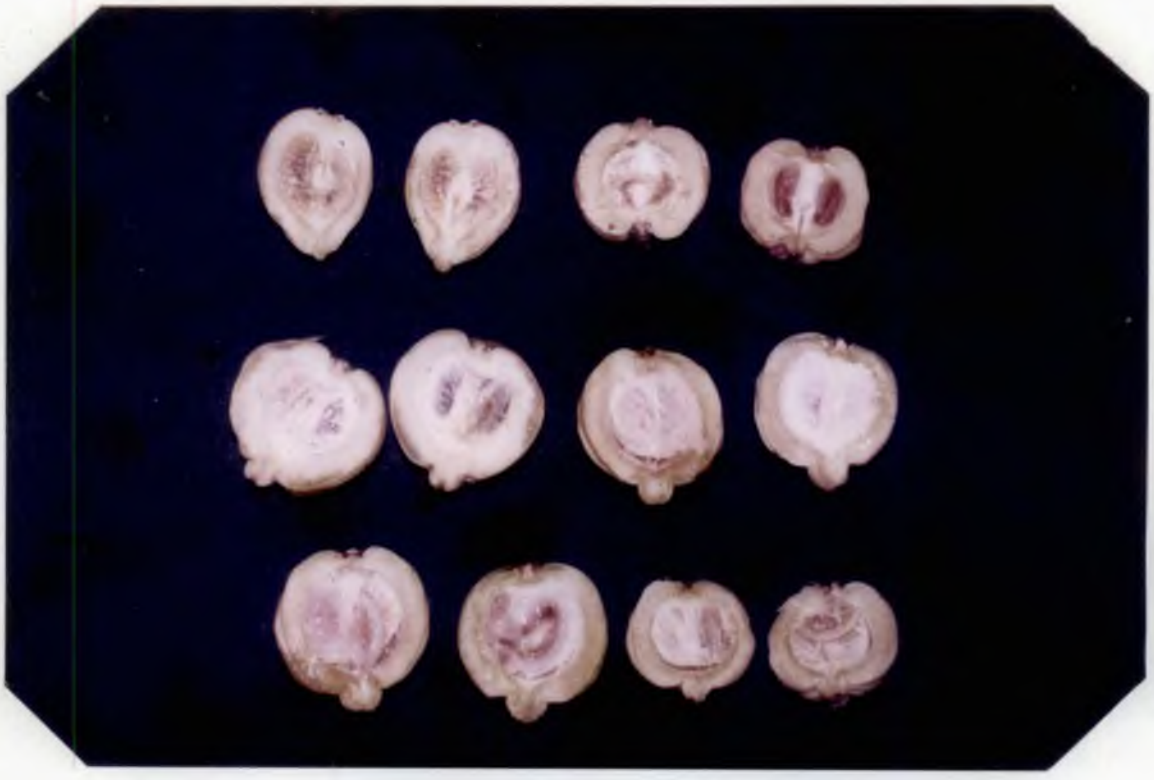
Both developed and undeveloped seeds were noticed in the fruits. The number of developed seeds ranged from one (AC.39) to nine (AC.32) and the number of undeveloped seeds range from one (AC.6, 8a, etc.) to seven (AC.37) indicating the existence of wide variability. Presence of undeveloped seeds in a fruit results in assymetrical shape of the fruit which in turn affects the yield. The undeveloped seeds in a fruit also results in the reduction of the size of the fruit (Plate 27). Therefore collections having fruits with more number of undeveloped seeds may not be preferred for commercial cultivation or for breeding purposes.

Rind weight, an important yield contributing factor, had a great diversity among the 50 entries. AC.46 recorded the highest rind weight of 218.7 g and the AC. 35 the lowest of 40.30 g. Correlation between rind weight and rind seed ratio was highly significant.

Wide variability was also observed in fruit rind ratio (1.13 to 1.77) and in rind seed ratio (1.45 to 5.29). Selection should be made in accessions with higher rind seed ratio and lower fruit rind ratio.

Plate 27. Fruits with undeveloped seeds showing reduction in size

Plate 28. Cross-section of the fruits showing muscilage along with seeds



5.1.4.2 Biochemical characters

Moisture content is one of the important criteria which is closely associated with dried rind recovery. Rinds with lower moisture content results in higher dried rind recovery and *vice versa*. In the present study variability in moisture content ranged from 71.62 per cent (AC.46) to 81.46 per cent (AC.2). Collections like AC. 16, 43a, 14 and 46 were having lower moisture content of below 72.00 per cent and higher dried rind recovery of above 28.00 per cent were noticed.

TSS of the rind ranged from 6.3°brix (AC.13) to 8.9°brix (AC.3). The rind with higher TSS may be preferred as it does not leave any bitter taste and also it can be used as such in cooking even before drying. Accessions like AC. 3, 18, 7, 8a, 20, 35, 16, 10 were having higher TSS of 8.00°brix and above.

TSS of the mucilage ranged from 9.8°brix (AC.22 and 29) to 14.3°brix (AC.8b). Accessions like AC. 5, 8b, 7, 3 and 43a were having higher TSS of more than 14.00°brix. In spite of having higher TSS, the mucilage (Plate 28) does not find any valuable use so far. Attempts should be made to exploit the mucilage in making consumer attractive, processed items like squash, syrup, canned products, etc. In *Garcinia indica*, a related species of kodampuli, the mucilage is utilised on a commercial scale for the preparation of kokam syrup which is a popular drink of Maharashtra State. In *Garcinia mangostana*, another related species of kodampuli, canned segments are very popular. So the feasibility of utilising the sweet mucilage on a commercial scale has to be worked out.

Wider variation was noticed among the collections in terms of total acidity and (-)- HCA. The total acidity was found to vary from 14.76 per cent (AC.20) to

24.89 per cent (AC.40). Sherly (1994) reported 6.68 per cent total acidity in fresh fruits. Accessions like AC.39, 23, 4a, 35, 33, 6, 46, 42, 24, 43, 39 and 17 were also having higher total acidity level of more than 20.00 per cent. (-)-HCA content ranged from 10.85 per cent in AC.20 to 21.79 per cent in AC.23. Lewis *et al.* (1964) reported 30 per cent (-)-HCA. None of the collections under study recorded 30 per cent (-)-HCA. Accessions having high (-)-HCA content of above 18.00 per cent were AC.25, 39, 40, 24, 6, 4a, 33, 15, 42, 35, 45, 5 and 39. Most of the accessions with higher total acidity were also having higher (-)-HCA content.

Rind with higher total acidity and (-)-HCA are preferred in the market as it reduces the quantity of the rind to be added to the preparations. Owing to the medicinal importance of (-)-HCA, there is a great demand for (-)-HCA based formulation in the internal as well as in the external market. Higher total acidity and (-)-HCA content is the most important quality parameter to be considered while making the selections for commercial exploitation as well as for breeding purposes.

Limited amount of variability was noticed among the trees surveyed in terms of crude protein, crude fat and crude fibre content. Crude protein content ranged from 3.32 (AC.11) to 5.91 per cent (AC.8b). Crude fat ranged from 3.52 (AC.8a) to 5.71 per cent (AC.39) and crude fibre, from 3.39 (AC.21) to 6.96 per cent (AC.3).

Statistically a very wide variation was noticed among the accessions with respect to total phenol content and the range was varied from 265.00 mg/100 g (AC.14) to 380.80 mg/100 g (AC.4a). It was found that bitter types were having higher total phenol content of more than 330.00 mg/100 g (AC.4a, 7, 8b, 5, 29, 15, 37, 43b and 24) and hence lacks market preferences. Types with lower total phenol

content (AC.16, 35, 20, 14, 41, 8a and 14) of less than 290.00 mg/100 g could be utilised for commercial cultivation or for breeding purposes.

In general, compared to the morphological characters of the fruit, variability observed in biochemical characters were limited.

5.2 Rind quality under different drying conditions

No significant differences were observed in the biochemical characters of the rind under different drying condition. At the sametime, slight variations in the visual characters were noticed.

Among the three drying conditions, percentage moisture removal was found to be highest under oven followed by sun and smoke. Dried rind recovery was more under smoke than under sun and oven. This may be because of higher amount of heat prevailing under oven compared to sun and smoke.

Regarding the percentage of total acidity and (-)-HCA, smoke dried rind recorded the highest value followed by sun and oven dried ones. This may be probably because of thermo-oxidation of acid due to prevailing higher temperature condition under oven than under sun and smoke.

Crude fat, crude protein, crude fibre and total phenol content were slightly higher in oven dried rind followed by sun and smoke.

Texture wise, oven dried rind was hard and brittle and smoke dried rind was soft and flexible. Sun dried rind was intermediate in texture. More amount of

moisture removal at higher temperature at a faster rate could be the probable reason for the hard and brittle texture of oven dried rind.

Smoke dried rind was dark brown or black in colour, whereas oven and sun dried rind was brown, and pale brown respectively. Deposition of carbon particles over the rind may be the reason for the dark brown or black colour in smoke dried rind.

Smoke dried rind was able to retain the shape of the rind whereas oven and sun dried rind was not able to retain its shape due to higher removal of moisture at faster rates leading to the shrunke and curved nature of the rind.

Consumer proference is for rinds with higher acidity, softness and flexiblity, shiny black colour which retains its shape. Smoke drying satisfies all these characters and therefore, refined methods have to be identified for smoke drying at a faster rate.

5.3 Fruit development

The fruits took 133 days from fruit set to ripening. The maximum length, girth, volume, fruit weight, rind weight, seed weight and rind thickness were attained by 112 days after fruit set with varying rate of growth at different periods. The rate of increase in length (16.66 per cent), girth (14.75 per cent), volume (11.88 per cent), fruit weight (22.52 per cent), seed weight (11.96 per cent) and rind weight (18.55 per cent) occurred during the first 42 days after the set. Thereafter the rate of growth showed a declining trend till 70 days. The trend was found to be slightly increasing during the period from 70 to 98 days after set, which again showed a

slight decrease and reached constant after 112 days after set. Rind thickness increased gradually till 112 days and thereafter it remained constant.

The peak period of growth of fruit was found to be directly associated with the peak growth period of seed. This is supported by the observation of Chacko *et al.* (1970) that in mango the period of rapid growth was associated with the period of maximum activity of auxin and gibberellin like substances in the seed. Singh (1990) reported that size of the seed also contribute to the size of the fruit. This rapid development of fruit may be due to rapid development of seed and a decrease in growth may be due to the lignification and development of endocarp as it results in competition for food substances in the formation of endocarp and fleshy part of the fruit. The increase in weight during the maturity in guava was attributed to an increase in both cell size and volume of intercellular space in flesh which enabled maximum possible accumulation of food substances (Dhillon *et al.*, 1987).

Chemical analyses showed that moisture content increased from fruit set till harvest. The total acidity and (-)-HCA content increased upto 77 days after set and thereafter the content decreased till it reached a constant value after 126 days. Crude fat, crude protein, crude fibre increased upto 112 days and then became constant. Total phenol content increased till 98 days after set and thereafter, the level decreased till ripening.

Physical characters reached the highest values by 112 days and remained constant. The case was not similar with respect to biochemical characters especially acidity and (-)-HCA content. These findings throw light on the fact that the fruits of kodampuli need not be retained on the tree till its normal ripening stage. The fruits can very well be harvested at an early date by 112 days by which time they have reached their physical maturity along with the required biochemical qualities.

Therefore, for large scale extraction of (-)-HCA, harvesting of kodampuli can be practiced at full maturity stage. But for cooking purpose fully ripened rind tastes better in fish curries, as the unripened dried rind imparts a slight bitter taste due to the yellow resin.

5.4 Fruit drop

The total fruit drop observed was 35.5 per cent, of which, 29.5 per cent of the drop occurred during first 28 days of fruit development and thereafter, fruit drop was found to be negligible.

Since the fruit drop was confined mainly to the early periods of development, the probable reason for the drop may be lack of fertilisation or improper fertilisation. Chadha (1963) attributed the competition between young developing fruits as the main cause of fruit drop, especially in the early stages in mango. He opined that this early fruit drop is essential as the plant cannot carry all set fruits to maturity. The production of large number of flowers might lead to competition among the young developing fruits resulting in shedding of the fruits. The fruit drop may be the result of an abscission mechanism as reported by Addicot and Lynch (1955), Chadha and Singh (1963) and Randhawa (1971) in different crops.

However, Baradwaj (1975) suggested the imbalance between various plant growth regulators as the possible reason for fruit drop. According to him, the auxins and giberellins produced in the seed and the abscissin in the pericarp might be transported to interact at the abscission zone located at the base of the pedicel. If auxin and giberelline were not available in sufficient amounts to neutralise the

effect of abscissin, the flower or fruit shed. Further detailed studies may have to be taken up to determine the exact cause of high initial drop in kodampuli.

The occurrence of drop was also noticed at the beginning of fruit ripening in some trees. At the same time in other cases fruits did not fall down even after reaching complete ripening. Drop during beginning of ripening was useful in case of tall trees where harvesting was found to be difficult and laborious and also at the same time fruit reached the ground before attaining rotten stage. But the drop during end of ripening led to heavy damage as the fruit reached the ground only in the rotten state. This may be due to weak pedicel attachment in the first case and strong pedicel attachment in the second case.

Accessions like AC.1, 2, 3, etc. were having fruits with pedicel detachment at the beginning of ripening. While selecting trees care should be taken to select high yielding types with easy pedicel detachment at the beginning of ripening, so that harvesting may be less cumbersome.

5.5 Sex differentiation

5.5.1 Morphological characterisation

There were no significant differences between male and bisexual plants in terms of morphological characters like plant height, plant spread, collar girth, height at first branching, canopy shape and branching habit, colour of the feeder roots, latex and bark. Regarding colour of the young flush, green, pink and shades of pink were noticed in both male and bisexual trees. But pink and shades of pink were most widely prevalent in bisexual trees. Sherly (1994) observed that the colour of emerging leaves had marked difference among the male and hermaphrodite trees. In male trees, the emerging leaves were light green in colour while they showed a

pinkish red colour in hermaphrodite trees. In this investigation, bisexual trees with green flush and male trees with pink flush were noticed exceptionally. So colour of the flush may be reliable for sex differentiation in kodampuli.

With respect to leaf characters like length, width, length/width ratio, area and shape of the leaves, petiole length and internodal length, the male and bisexual trees did not show any marked differences.

5.5.2 Biochemical characterisation

With respect to biochemical characters in terms essential oil content and total acidity of leaves, there were no significant differences between male and bisexual trees. Thomas (1997) reported the presence of higher amount of essential oil in leaves of male nutmeg plants than female ones.

Significant differences between male and bisexual plants were noticed with respect to the total phenol content of young and mature leaves. On an average young leaves of male recorded a higher total phenol content of 208.6 mg/100 g when compared with 118.1 mg/100 g in bisexual. The total phenol content of mature leaves of male recorded 1397.8 mg/100 g when compared with 749.53 mg/100 g in bisexuals. Thomas (1997) reported the presence of higher total phenol content in the leaves of male nutmeg trees than in female ones. This observation has to be confirmed with kodampuli seedlings.

The TLC profile of phenolic extract displayed different patterns in male and bisexual plants. One additional spot was observed in male than in bisexual. Packiyasothy *et al.* (1991) reported two additional phenolic spots in the profile of male plants than that of female plants in nutmeg. Presence of more phenolic groups

and high concentration of phenolics in the male plant indicate that synthesis and accumulation of phenolics have a direct relation in the sexuality and fruit setting of kodampuli plants. Electrophoresis revealed similar banding pattern for peroxidase enzyme in both male and bisexual plants.

Summary

6. SUMMARY

The present investigation on variability analysis in kodampuli (*Garcinia cambogia* Desr.) was undertaken in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 1996-1998. The trees grown in the homesteads of Pathanamthitta and Thrissur districts and also in the research plots of College of Horticulture, were utilised for the study.

The objectives of the study were to

1. To study the variation in vegetative, floral and fruiting characters
2. To select high yielding quality types
3. To select early flowering and early ripening types
4. To compare the quality of the rind under different drying condition
5. To study the pattern of fruit development
6. To make a comprehensive study to differentiate the sex of kodampuli through morphological observations and biochemical analyses.

The following conclusions were made based on the present investigation.

Variation was noticed in the canopy shape, viz., round, dome, conical and pyramidal and in branching habits viz., horizontal, drooping and erect.

Flowering was noticed in male trees from November to July with a peak from December to March. In bisexual trees, flowering was noticed from January to April with a peak period from February to March. Early flowering (January-February) was noticed in the genotypes AC. 3 and 36 and late flowering (March-April) was noticed in AC. 21, 23, 37, 38 and 46. Sporadic flowering was noticed in AC. 8a, 9 and 13.

Peak season of ripening was during June-July. Early flowering types came to ripening by May-June and very late flowering type by July-August.

Accessions 3, 8a, 9, 14, 40, 42, 43b, 45a and 46 were prolific bearing, giving an yield of more than 350 kg fresh fruits per annum. Irregular bearing tendency was commonly noticed in most of the collections. Incidence of malformation, gamboge and fruit rot were prevalent.

Six flower types were identified with varying functions of stamen, pistil and fruit setting capacity. Flower type 1, 2, 3, 4 and 5 were predominantly seen in male trees. Of these types 1, 2 and 3 did not set any fruit. Type 4 and 5 rarely set fruits. Type 6 flower was noticed in bisexual trees with the capacity to set fruits profusely.

Number of flowers per cluster, length of pedicel, number of stamens and percentage of pollen viability and germination were higher in the flowers of male trees. Whereas, weight of the flower, petal length and size of the ovary were more in the flowers of bisexual trees.

Wide variation was noticed in the morphological characters of the fruit. Colour of the fruit ranged from light yellow to dark yellow. Varied fruit shapes, namely, round, oblong, oval, cordate, pear and napiform were noticed. About 25 per cent of the fruits were of assymmetrical shape with many undeveloped seeds.

Maximum number of segments per fruit was noticed in AC. 8b but it was bitter in taste with higher total phenol content. Maximum segment width was recorded in AC.33 (1.80 cm) and the minimum in AC. 20 (0.40 cm). The collection having longest fruit was in AC. 34 (9.00 cm) and the shortest one was AC. 5

(4.50 cm). AC. 45a stood top in terms of girth by recording 28.00 cm which was also having higher fruit weight and rind thickness.

AC. 46 recorded maximum fruit weight of 260.00 g and rind thickness of 1.80cm, which also had higher girth, volume, rind weight, and seed weight. The lowest fruit weight of 60.00 g and rind thickness of 0.40 cm were noticed in AC. 35 and AC. 36, respectively.

AC. 33 ranked first with respect to seed weight (65.00 g) which was closely followed by AC. 4b (63.00 g). Number of developed seeds ranged from 1 (AC. 39) to 9 (AC. 32) and the undeveloped seeds ranged from 1 to 7.

Maximum rind weight (218.70g) was recorded by AC. 46, which was closely followed by AC. 45a (217.60 g). The lowest rind weight of 40.30 g was observed in AC. 35, which also had minimum fruit weight.

Fruit rind ratio ranged from 1.13 (AC. 17a) to 1.77 (AC. 7) and rind seed ratio ranged from 1.45 (AC. 5) to 5.29 (AC. 46).

Regarding biochemical characters, variation was noticed among the collections in terms of moisture content, rind TSS, mucilage TSS, total acidity, (-)-HCA content and total phenol. Variability was very less in terms of crude fibre, crude fat and crude protein among the collections.

AC. 2 had the maximum moisture of 81.46 per cent and the minimum of 71.62 per cent was in AC. 46. Maximum rind TSS of 8.9° brix was recorded in AC. 3 and minimum of 6.3° brix in AC. 13. AC. 8b had the highest mucilage TSS of 14.3° brix and the lowest of 9.8° brix was seen in AC. 29 and 22. With respect to the total acidity, the highest value of 24.89 per cent was recorded by AC. 40 which

was closely followed by AC. 23 (24.30%). The lowest value of 14.76 per cent was observed in AC. 20.

Crude protein, crude fat and crude fibre content had the variation ranging from 3.32 to 4.91 per cent, 3.52 to 5.71 per cent and 3.39 to 6.87 per cent, respectively.

Among the 50 collections, AC. 23 had the highest value of 21.79 per cent for (-)-HCA and was closely followed by AC. 40 and AC. 24. The lowest value of 10.85 per cent was noticed in AC. 8b, which recorded the highest mucilage TSS. Total phenol content was maximum in AC. 4a (380.80 mg/100 g) and the minimum in AC. 14 (265.0 mg/100 g).

While locating lines with high yield and good quality, it was not possible out of the kodampuli under study to select one which had high fruit weight, rind thickness, rind TSS, total acidity, (-)-HCA, crude protein coupled with low values for moisture, total phenol, crude fat, and crude fibre. However, lines with individual quality character could be selected and utilised for further breeding programmes.

The present study clearly indicated the existence of variability among the collections in morphological and biochemical character and showed the potentialities of AC. 46, 45a, 8a, 14 and 3.

Correlation between the fruit weight and other fruit characters like length, volume, rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio were highly significant. Significant correlation (at 5 per cent) was also observed for fruit weight with number of segments and segment width. Fruit volume had significant correlation with rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio. Highly significant correlation (1 per cent) was also observed

between segment width and rind thickness which in turn was correlated with fruit characters like seed weight, rind weight, rind seed ratio and fruit rind ratio. Similarly seed weight showed correlation with other characters like rind weight, rind seed ratio and fruit rind ratio. Fruit rind ratio was negatively correlated with rind seed ratio.

Path analysis showed that fruit weight had a high influence on rind weight. The indirect positive effect of fruit weight via volume, rind thickness, seed weight and rind seed ratio was observed. The indirect effect of fruit weight and rind weight via fruit rind ratio was negative. Fruit length, volume, number of segments, segment width, rind thickness and seed weight did not influence the rind weight directly or indirectly.

Rind seed ratio had direct as well as indirect influence on the rind weight.

Non hierarcheal euclidean cluster analysis showed the existence of genetic divergence. The computed D^2 value varied from 0.00 to 6.468. On the basis of relative magnitude of D^2 values all the 50 types were grouped into 4 clusters. Considerable diversity within and between clusters was noticed. Accessions collected from the same locality fell in different clusters while those from different locations came in the same cluster. This showed that geographic diversity might not have a direct association with genetic diversity.

On comparing the rind quality under different drying conditions statistically, there were no significant differences in the biochemical characters. But slightly higher total acidity, (-)-HCA and dried rind recovery was noticed under smoke drying. Further, the smoke dried rind was soft and flexible, shiny black in colour with shape retaining capacity, satisfying the consumer preference.

The fruits took 133 days from fruit set to ripening. The maximum length, girth, volume, fruit weight, rind weight, seed weight and rind thickness were attained by 112 days after fruit set with varying rate of growth at different periods.

Regarding biochemical composition, moisture content increased from fruit set till harvest. The total acidity and (-)-HCA content increased upto 77 days after set and thereafter it decreased till ripening. Crude fat, crude protein and crude fibre increased upto 112 days and then became constant. Total phenol content increased upto 98 days and thereafter the level decreased till ripening.

The total fruit drop observed was 35.5 per cent, of which, 29.5 per cent of the drop occurred during first 28 days of fruit development and thereafter, fruit drop was found to be negligible.

There were no significant differences between male and bisexual plant in terms of morphological characters like plant height, plant spread, collar girth, height at first branching, canopy shape, branching habit and colour of the feeder roots, latex and bark. Regarding colour of the young flush, pink and shades of pink were most widely prevalent in bisexual trees than in male trees. With respect to leaf characters like length, width, length/width ratio, leaf area and shape, petiole length and internodal length, the male and bisexual trees did not show any marked differences.

With respect to biochemical characters in terms of essential oil content and total acidity of leaves, there were no significant differences between male and bisexual trees. Significant difference between male and bisexual trees was noticed with respect to total phenol content of young and mature leaves. On an average young leaves of male recorded a higher total phenol content of 208.6 mg/100 g when compared with 118.1 mg/100 g in bisexual plants. The total phenol content of

mature leaves of male recorded 1397.8 mg/100 g as against 749.5 mg/100 g in bisexuals.

The TLC profile of phenolic extract displayed different pattern in male and bisexual plants. One additional spot was observed in male, as compared to bisexual plants. Isozyme studies revealed the existence of similar banding pattern in both male and bisexual plants, with respect to peroxidase enzyme.

References

REFERENCES

Addicot, F.T. and Lynch, R.S. 1955. Physiology of abscission. *Ann. Rev. Pl. Physiol.* **6**:78-82

Alex, A. 1996. Vegetative, floral and fruit characters in mangosteen (*Garcinia mangostana* L.). M.Sc. (Hort.) Thesis, Kerala Agricultural University, Vellanikkara, Thrissur

Al-Jibouri, A.A.M. 1988. Pollen isozyme analysis of male cultivars of date palm (*Phoenix dactylifera* L.). *Date-Palm J.* **6**:341-358

Anderson, T. 1875. Guttiferae. *Flora of British India*. Vol.I. (Ed. J.D.L. Hooker), Reer & Co., Convent Garden, London, pp.259-276

A.O.A.C. 1980. *Official Methods of Analysis*. Association of Official Analytical Chemists 13th edn. Washington, p.218

Baradwaj, S.N. 1975. Boll shedding in cotton. *Indian J. Pl. Physiol.* **18**(2):9-13

Beddard, R. 1969. Study of genetic variance in strawberry. *Second Res. Rep.* University of Larcel, Quebec **48**:50

Beddome, R.H. 1978. *The Flora Sylvatica of Southern India*. Vol.I. Periodical Expert Book Agency, Delhi. p.85

Bhagwat, N.R. 1984. Studies on flowering and fruiting in karonda (*Carissa carandas* L.). M.Sc. (Agri.) thesis, Konkan Krishi Vidyapeeth, Dapoli.

Bhat, K.V., Bhat, S.R. and Chandel, K.P.S. 1992. Survey of isozyme polymorphism for clonal identification in Musa, Esterase, acid phosphatase and catalase. *J. Hort. Sci.* **67**:501-507

Billau, W., Buchloh, G., Geiger, F. and Hartmannh, D. 1987. HPLC - analysis of phenolic compounds in storage roots of white asparagus (*Asparagus officinalis*) during the vegetative period. *Asparagus Res. Newslett.* **4**(1):18-19

Chacko, E.K., Kachru, R.B. and Singh, R.N. 1970. Changes in the level of natural growth promoters during fruit development in Dashchari mango (*Mangifera indica* L.). *J. Hort. Sci.* **45**:341

* Chacko, E.K. and Ananthanarayanan, T.V. 1982. Accumulation of reserve substances in *mangifera indica* L. during flower initiation. *Z. Pflanzenphysiol* **106**:281-85

Chacko, E.K. 1984. Physiology of vegetative and reproductive growth in mango. *Proc.First Australian Mango Res. Workshop*, Caions, Queensland, Nov. 1984. Australia, p.54-70

Chadha, K.L. and Singh, K.K. 1963. Studies on fruit drop in mango. *Indian J. Hort.* **20**:17-85

Chadha, K.L. and Singh, K.K. 1964. Fruit drop and its relation to fruit growth. *Indian J. Hort.* **21**(3&4):197-201

Chandler, W.A. 1925. *Fruit Growing.* Houghton Miffin, London, p.177

Chandrarathna, M.F. 1948. Garcinia in Ceylon. *Trop. Agriculturist.* **103**:34-37

Chen, P.K., Fan, C.J., O'-Brien, W. and Venketeswaran, S. 1985.Preflowering sex determination : an aid to jojoba propagation. *Proceedings of the Sixth International Conference on Jojoba and Its Uses.* Ben-Gurion University of the Negor:1 Beersheve. p.243-251

Chopra, S.L. and Kanwar, J.S. 1978. *Analytical Agricultural Chemistry.* Kalyani Publishers, Ludhiana

Cobley, L.S. 1956. *An Introduction to the Botany of Tropical Crops.* Longmans Green, London

CSIR. 1956. *The Wealth of India* (*Raw Materials*). Vol.IV. Publications and Information Directorate, CSIR, New Delhi, p.99-100

Darwin, C.R. 1859. *On the Origion of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.* Modern Library (Giant series), New York

Deng, Y.H., Shangyuan, X.X., Zhou, Z.Y. and Cao, J.M. 1982. A preliminary report of studies on the identification of male and female vines of *Actinidia chinensis*. *Acta Hort.* **9**(2):63-66

Dhillon, B.S., Singh, S.N. and Gill, S.S. 1987. Developmental physiology of guava. *The Punjab Hort. J.* **27**(1/2):28-34

Duarte, O. 1982. *Proc. 21st Int. Hort, Cong.*, Hamburg, **1**:415-424

Durham, R.E., Moore, G.A. and Sherman, W.B. 1989. Isozyme banding patterns and their usefulness as genetic markers in peach. *J. Am. Soc. hort. Sci.* **112**:1013-1018

Dutt, P.K. and Mazumdar, B.C. 1989. Studies on the protein content of male and female papaya plants. *South Indian Hort.* **37**(5):295

* Dyurdevich, L., Chulafich, L., Kozhomara, B., Kof, E. and Kefeli, V. 1992. Content of phenolic compounds in relation to sex expression in the dioecious plant sorrel. *Fiziologiya Biokhimiya kul'turnyth Rastanii.* **24**:64-68

Farmahan, H.L. and Pandey, R.M. 1978. Studies on some morphological characters and translocation of ^{14}G-glucose in grape berries at different stages of their development. *South Indian Hort.* **26**:151-156

* Flach, M. 1966. Nutmeg cultivars and sex problems. *Eng. Summ. Meded. Landb. Hogesh.* **66**:1

George, S. 1988. Garcinia - a neglected acid fruit of Kerala. *Indian Cocoa Arec. Spices J.* **11**(3):101-103

George, S.T., Latha, A.K.B., Mathew, K.L. and Geetha, C.K. 1992. Pattern of flowering and flower development in Kodampuli. *Indian Cocoa Arec. Spices J.* **16**(2):68-70

Gokhale, A.V. and Kanitkar, V.K. 1951. Fruit drop in Alphonsa mango and its control. *Proc. Indian Sci.* **38**(3):151

Gunjate, R.T., Karnik A.R. and Limaya, V.P. 1982. Flower and sex forms in kokum. *Indian Cocoa Arec. Spices J.* **8**(2):32-37

Jackson, M.L. 1958. *Soil Chemical Analysis*. Asia Publishing House, New Delhi, p.498

Jacob, K. 1992. Kodampuli Krishiye murano. Spice India (Malayalam). **10**:9-10

* Jaiswal, V.S., Narayanan, P. and Lal, M. 1984. Activities of acid and alkaline phosphatases in relationship to sex differentiation in *Carica papaya Biochemie and Physiologie der Pflanzen* **179**(9):799-801

* Janse, J.M. 1898. De mootmuskatcultuvr inde Minahasa en op de Bande Cilanden. *Med's Lands Plantent.* **28**:1-233

Jauhari, O.S. and Singh, R.D. 1971. Bael - A valuable fruit. *Indian Hort.* **6**:9-10

Joseph, T. and Kumaran, K. 1996. Fruit set, fruit development and fruit drop in hard and soft flaked types of Jack (*Artocarpus heterophyllus* Lan.). *J. trop. Agric.* **34**:21-24

Joshi, G.D., Pradhudesai, V.G. and Salri, M.J. 1986. Physico-chemical characteristics of Karonda (*Carissa carandas* L.). *Maharastra J. Hort.* **3**:39-44

Kerala Agricultural University. 1991. *Research Report 1987-90.* Directorate of Research, KAU, p.109

Kohorn, L.U. 1994. Shoot morphology and reproduction in jojoba: advantages of sexual dimorphism. *Ecology* **75**:2384-2394

Khan, M.A.A., Rahman, M.A., Vadin, M.N. and Hussain, M.Z. 1982. Observation in amino acid contents in male and female papaya plants. *Bangladesh Hort.* **10**(2):27-29

*Kotaeva, D.V., Chkhubianishvili-El, Kezeli, T.A. 1982. Leaf mesophyll in dioecious representatives of the Moraceae in relation to questions of sex differentiation. *Bull. Acad. Sci. Georgian SSR.* **108**:149-152

Krishnamoorthy, S., Rao, V.N.M. and Ravoof, A.A. 1964. A note on the flower and floral biology in mangosteen (*Garcinia mangostana* L.). *South Indian Hort.* **12**(3/4):99-101

Krishnamoorthy, B., Zachariath, J.J., Ravindran, P.N. and Gopalan, A. 1992. Identification of sex of nutmeg seedlings based on morphological and chemical characters. *J. Pln. Crops* (Supplement) **20**:194-199

* Lacombe, J.P. 1980. Sex discrimination from early vegetative characters in dioecious hemp (*Cannabis sativa* L.). *Physiologie Vegetatle.* **18**:419-430

Lewis, Y.S., Neelakantan, S. and Anjanamurthy, S. 1964. Acid in Cambogia. *Curr. Sci.* **33**(9):32-33

Machon, N., Deletre, L.B.V. and Rarneau, L. 1995. Quantitative analysis of sexual dimorphism in Asparagus. *Can. J. Bot.* **73**:1780-1786

Maestri, E., Rastivo, F.M., Marziani, L.G.P., Falagigna, A. and Tassi, F. 1991. Isozyme gene markers in the dioecious species, *Asparagus officinalis* L. *Theor. Appl. Genet.* **69**:305-311

Majeed, M. 1994. Citrin - *A revolutionary, Herbal Approach to Weight Management.* New Editions Publishing Co., Burlingame, p.8-14

Majumder, P.K., Sinha, G.C. and Singh, R.N. 1970. Effect of exogenous application of alpha-naphthyl acetic acid in mango (*Mangifera indica*). *Indian J. Hort.* **27**:130

Market, C.L. and Moller, F. 1959. Multiple forms of enzymes, tissue, ontogenetic and species specific patterns. *Proceedings of the National Academy of Sciences*, USA, **45**:753-763

Mathew, L., George, S.T. and Krishnan, S. 1996. Estimation of leaf area in *Garcinia cambogia* (Kodampuli) through linear measurements. *J. trop. Agric.* **34**:61-62

Mazumdar, B.C. 1975. Physico-chemical analysis of some types of bael (*Aegle marmelos* Correa.) fruit growing in West Bengal. *Indian Agric.* **19**:295-98

Mishra, K.A. and Dhillon, B.S. 1978. Level of abscisic acid - like substances in the healthy and malformed panicles of mango (*Mangifera indica* L.). *Sci. Cult.* **44**:419-20

* Munoz, S., Lima, H., Peroz, M. and Roderiguez, O.L. 1982. Use of the peroxidase enzyme system for the identification of sex in *Carica papaya. Ciancia Y lecnica en la Agricultura Citricos Y Otros Frutalos* **5**(4):39-48

Musahib-ud-Din and Dinsa, H.S. 1946. The floral count and fruit set studies in some of the North Indian mangoes. *Punjab Fruit J.* **10**(37):35-42

Nand, D. 1970. Flowering and bearing behaviour of carambola (*Averrhoa carambola* L.). *Indian J. Hort.* **27**:145-152

Nauriyal, J.P. 1955. A study of premature fruit drop in citrus. *Indian J. Hort.* **2**(2):39-52

Nazeema, K.K. 1992. Standardisation of softwood and epicotyl grafting in *Garcinia cambogia* Desr. M.Sc.(Hort.) thesis, Kerala Agricultural University, Vellanikkara, Trichur

NBPGR. 1986. *Annual Report.* National Bureau of Plant Genetic Resources, New Delhi

NBPGR. 1987. *Annual Report.* National Bureau of Plant Genetic Resources, New Delhi

NBPGR. 1988. *Annual Report.* National Bureau of Plant Genetic Resources, New Delhi

Nizon, R.W. and Carpenter, J.B. 1978. *Agricultural Information Bulletin.* USDA. p.63

Nyong'O, R.N., Cabbinath, J.R. and Appiah, K.J. 1994. Flowering and fruiting patterns in *Milicia excelsa* and *Milicia regia*. *Ghana J. Forestry* **1**:19-29

Oliver, J.L. and Zapater, J.M.M. 1985. A genetic classification of potato cultivar based on allozyme pattern. *Theor. appl. Genet.* **69**:305-311

* Oyama, K. 1990. Variation in growth and reproduction in the neotropical, dioecious palm, *Chamedorea tepejilote J. Ecol.* **78**:648-663

Packiyasothy, E.V., Janz, E.R. and Dharmadara, H.M. 1991. Studies on some chemical components of nutmeg (*Myristica fragrans* Houtt.) leaf directed at determination of sex of seedlings. *J. Natural Sci. Coun. Sri Lanka* **19**:91-97

Pal, P., Ghosh, S.K. and Sen, S.K. 1987. Determination of maturity standard in mango (*Mangifera indica* L.) cv. Fazli. *Haryana J. hort. Sci.* **16**(1&2):40-44

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers*. 4th ed. ICAR, New Delhi

Pareek, O.P. and Panwar, H.S. 1981. Vegetative, floral and fruit characteristic of two phalsa (*Grewia subinequalis*) types. *Ann. Arid Zone.* **20**:281-90

Pareek, O.P. and Vashishtha, B.B. 1983. Delicious ber varieties of Rajasthan. *Indian Hort.* **28**:13-16

Pareek, O.P. and Sodagar, N.N. 1986. Date palm groves of kachchh. *Indian Hort.* **31**:21

Pollard, J.E. and Biggs, R.H. 1969. Relation of callulose to abscission of citrus. *Pl. Physiol.* **44**:31-35

Prasad, V.V. and Iyengar, E.R.R. 1982. Physiological differences in the male and female plants of jojoba (*Simmondsia chinensis*). *Curr. Sci.* **51**(21):1034-40

Prestoe. 1948. Sex of nutmeg trees. *Gardeners Chron.* **148**(1):135

Purseglove, J.W. 1969. *Tropical Crops - Dicotyledons*. ELBS and Longman, London, p.83-85

Randhawa, S.S. and Singh, J.P. 1962. Nature of fruit drop in mandarin (*Citrus reticulata* Blanco.). *Indian J. Hort.* **20**:191-199

Randhawa, G.S. 1971. *Use of plant growth regulators and gibberellins in Horticulture.* ICAR, New Delhi

Ranganna, S. 1977. *Manual of Analysis of Fruits and Vegetable Products.* Tata Mc Graw-Hill Publishing Company, Ltd., New Delhi p.1-3

Richards, A.J. 1990. Studies in Garcinia, dioecious tropical fruit trees: the origin of mangosteen (*Garcinia mangostana* L.). *Bot. J. Linn. Soc.* **103**:301-308

Sadasivam, S. and Manikam, A. 1992. *Biochemical Methods for Agricultural Sciences.* Wiley Eastern Limited and Tamilnadu Agricultural University, Coimbatore

Saldanha, J.C. and Nicolson, H.D. 1978. *The Flora of Hassan District, Karnataka.* Amerind Publishing Co., New Delhi p.124-126

Sasidharan, N. and Sivarajan, V.V. 1996. *Flowering Plants of Thrissur Forest (Western Ghats, Kerala, India).* Scientific Publishers, Jodhpur p.52-53

Sherly, R. 1994. Growth, flowering, fruit set and fruit development in Kodampuli (*Garcinia cambogia* Desr.). M.Sc.(Hort.) thesis, Kerala Agricultural University, Vellanikkara, Trichur

Shuang-Xi, F. and Xue-Feng, S. 1995. Relationship between sexual performance and isozymes of peroxidase in asparagus plants. *Acta Agriculturae Boreali Sinica.* **10**:67-71

Singh, D. 1963. Kamrakh - Sweet and vitamin rich. *Indian Hort.* 7:8

Singh, L.B. 1965. Mango in India - Problems and achievements. *Advances in Agricultural Science and Their Applications.* (Ed. Krishnamurthi, S.). Agricultural College and Research Institute, Coimbatore, p.444-445

Singh, R.N. and Jindal, K.K. 1974. Studies on sex determination in papaya seedlings at nursery stage. *Proceedings of the XIX International Horticultural Congress. I Section VII. Fruits* (Ed. Antiszewski, R., Harrison, L. and Zych, C.C.). International Society for Horticultural Science, Warsaw, Poland, pp.457-542

Singh, R.N. 1978. *Phal Vigyan*. ICAR, New Delhi

Singh, R.N. 1990. *Mango*. ICAR, New Delhi, p.49

*Sosrodharjo, S. 1980. *Bull. Penelitian Hortikultura* **8**:11-17

Sastri, B.N. 1962. *The Wealth of India*. Vol.6, Council of Scientific and Industrial Research, New Delhi

Srinivasan, K. 1970. Muttam Varikka - A promising jack fruit variety. *Agric. Res. J. Kerala* **8**:51-52

* Sriprasertek, P., Burikam, S., Attathom, S. and Piriyasurawong, S. 1988. Determination of cultivar and sex of papaya tissues derived from tissue culture. *Kasetart J. nat. Sci.* **22**(5):24-29

Sturtevant, S. 1919. *Notes on Edible Plants*. J.B. Lion Co., Abbany, p.285

Suganuma, H. and Iwasaki, F. 1983. Sex identification of dioecious plants by the isozyme method in date palm (*Phoenix dactylifera* L.) *Japanese J. tropic. Agric.* **27**:275-78

Thimmaraju, K.R., Reddy, M.A.N., Samy, N. and Sullaadmath, V.V. 1977. Studies on floral biology of tamarind (*Tamarindus indica* L.). *Mysore J. agric. Sci.* **11**:293-98

Thomas, C.A. 1965. Kodapuli - Little known but pays much. *Indian Fmg* **15**(5):33-35

Thomas, P. 1997. Dioecy in nutmeg (*Myristica fragrance* Hutl.). M.Sc.(Hort.) thesis, Kerala Agricultural University, Vellanikkara, Thrisur

Trimen, H. 1893. *A Handbook of the Flora of Ceylon.* Dulal & Co., London p.95

Vajravelu, E. 1990. *Flora of Palghat Including Silent Valley National Park, Kerala.* Botanical Survey of India, p.70-71

Vashishtha, B.B. and Pareek, O.P. 1989. Identification key for the cultivars of Indian jojuba (*Zizyphus mauritiana* Lamk.). *Indian J. Hort.* **46**:183-188

Veeraghavathatham, D. and Balashanmugam, P.V. 1989. *Botany of Fruit Crops.* A.E. Publications, Coimbatore, p.26

Verghese, J. 1991a. *Garcinia cambogia* Desr. - Kodampuli. *Indian Spices* **28**(1):19-20

Verghese, J. 1991b. Kodampuli (*Garcinia cambogia*). *Spice India* **6**(8):20-21

Verghese, J. 1996. The world of spices and herbs. *Indian Spices* **34**(1&2):11-12

Wilkinson, J. and Beard, J.B. 1972. Electrophoretic identification of *Agrostis paelustris* and *Poa pratensis* cultivars. *Crop Sci.* **12**:833-834

Xia-Renxue and Xia-Rx. 1997. Sex differentiation and its identification at the early stages of growth in fruit trees. *J. Fruit Sci.* **14**(1):52-56

*Originals not seen

VARIABILITY ANALYSIS IN

Garcinia cambogia Desr. (Malabar Tamarind)

By

P. MUTHULAKSHMI

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF POMOLOGY AND FLORICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 654

KERALA, INDIA

1998

ABSTRACT

The present investigation on variability analysis in kodampuli (*Garcinia cambogia* Desr.) was undertaken in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 1996 to 1998. Major objectives of the study were to explore the variability in vegetative, floral, fruiting and biochemical characters of kodampuli, to compare the quality of the rind under different drying conditions, to study the pattern of fruit development and to differentiate the sex in terms of morphological and biochemical characters.

Surveys were conducted in the homesteads of Pathanamthitta and Thrissur districts to study the variability.

A wide variation in tree characters like shape of the tree (dome, round, conical and pyramidal) and branching pattern (erect, spreading and drooping) was noticed. Early flowering (AC. 3 and 36), late flowering (AC. 11, 21, 23, 37 and 46) and sporadic flowering types (AC. 3a, 9 and 13) were identified.

Prolific bearing types (AC. 3, 8a, 9, 14, 40, 42, 43b, 45a and 46), giving an yield of above 350 kg fresh fruits per annum, could be located. Most of the collections showed irregular bearing tendency. Incidences of gamboge, malformation and fruit rot were widely noticed. Though scientifically yet to be proved, pruning seems to be deleterious.

A wide variation was noticed in leaf characters. Among the trees surveyed, six different flower types were identified. The first five flower types were widely prevalent on male trees and the sixth one was common only on bisexuals. The first three did not set any fruit, four and five set fruits rarely and the sixth one set fruits profusely. Male trees had more number of flower per cluster, higher

petiole length, more stamens per flower, higher pollen viability and germination. Flowers in bisexual trees had higher flower weight, petal length and ovary size

Variation in fruit colour (light yellow to dark orange) and shape (round, oblong, oval, cordate, pear and napiform) was recorded. There were fruits with papilla (size ranged from 0.1 to 1.5 cm) and without papilla.

Some of the entries recorded higher number of segments of more than 10 (AC. 8b, 7, 24, 4b, 6, 43a, 40 and 46). Higher width of the segment of more than 1.40 cm was seen in AC. 20, 13, 25, 9, 39 and 3. Accessions with length of the fruit above 8.00 cm namely, AC. 46, 1, 21, 20, 43b, 40 and 36 and girth of the fruit above 25.00 cm like AC. 45a, 46, 41 and 22 were noticed. Some of the accessions (AC. 46, 45a, 14, 4b, 9, 33, 38, 43a and 41) were outstanding in fruit weight by recording above 200.00 g. There were also accessions with higher rind thickness of above 1.50 cm (AC. 46, 43a and 45a). Collections with higher rind seed ratio of above 1.4 were AC. 46, 8a, 23, 16, 25, 39, 43a, 45a, 45b, 17a, 9, 4a and 6.

Biochemical analysis recorded variability in terms of moisture content, rind and mucilage TSS, total acidity and (-)-HCA. Collections with total acidity of above 22.00 per cent (AC. 2, 40, 23, 4a, 35, 33, 6, 46, 42 and 24), (-)-HCA of above 20.00 per cent (AC. 23, 40 and 24) and total phenol content of below 290.0 mg/100 g (AC. 7, 12, 86, 5, 29, 15, 37, 43b, 24, 39, 30, 8 and 21) were identified.

Fruit weight and other fruit characters like length, volume, rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio were highly correlated. Path analysis showed that fruit weight had a high influence on rind weight. The indirect effect of fruit weight and rind weight via., fruit rind ratio was negative.

Non-hierarchial cucleadian cluster analysis revealed the existence of genetic diversity in kodampuli. The 50 entries collected could be grouped into four clusters.

On comparing the quality of the rind under different drying conditions namely oven, sun and smoke, no significant difference was noticed. However, the rind from smoke drying was soft and flexible, shiny black in colour with good shape retaining capacity and consumer appeal.

It took 133 days from fruit set to ripening. The physical parameters like length, girth, etc. attained its maximum by 112 days after fruit set with varying rate of growth at different periods. Moisture content increased from fruit set till harvest. The total acidity and (-)-HCA increased upto 77 days and then decreased till harvest. Crude fat, crude protein and crude fibre increased upto 112 days and then remained constant. The phenol content increased upto 98 days and thereafter decreased.

The total fruit drop observed was 35.5 per cent. The drop during the first month of development was 29.5 per cent.

There were no significant differences between male and bisexual trees in terms of morphological characters. Pink and different shades of pink were more prevalent in the emerging flushes of bisexual trees, as compared to male trees. Significant difference between male and bisexual trees was noticed with respect to total phenol content of young and mature leaves. The TLC profile of phenolic extract showed one additional spot in male than in bisexual plants. Electrophoresis revealed similar banding pattern for peroxidase enzyme in both male and bisexual plants.

Appendices

Appendix I. ANOVA for morphological and biochemical parameters of fruits from different accessions

Source	Degrees of freedom	Mean sum of squares										
		Weight	Length	Girth	Volume	No.of segments	Segment width	Rind thickness	Seed weight	Rind weight	Rind seed ratio	Fruit rind ratio
		1	2	3	4	5	6	7	8	9	10	11
Treatment	49	4396.290	3.010	12.953	2382.220	2.286	0.147	0.145	208.525	2984.150	1.646	0.023
Error	50	0.672	0.014	0.163	0.827	0.000	0.003	0.001	0.501	6.272	0.016	0.002

Mean sum of squares								
Moisture content	TSS		Total acidity	Crude fat	Crude protein	Crude fibre	Total phenol	(-)-HCA
	Rind	Muscilage						
12	13	14	15	16	17	18	19	20
13.320	0.501	2.990	14.015	0.564	0.600	1.386	1177.990	12.978
0.304	0.042	0.073	0.189	0.100	0.059	0.079	1.043	0.111

Appendix II . Weather data of Thrissur at monthly intervals during October 1996 - July 1997

Weather parameters	Oct 96	Nov 96	Dec 96	Jan 97	Feb 97	Mar 97	Apr 97	May 97	Jun 97	Jul 97
Maximum temperature (°C)	30.7	31.5	30.5	32.0	33.9	35.7	35.2	34.4	31.2	28.6
Minimum temperature (°C)	22.9	23.6	21.8	22.9	21.8	24.0	24.5	24.5	23.0	21.8
Rainfall (mm)	219.3	22.7	60.4	0	0	0	8.2	63.0	720.5	979.2
Rainy days	12.0	2.0	2.0	0	0	0	1.0	4.0	18.0	28.0
RH 1	93.0	84.0	80.0	78.0	82.0	82.0	83.0	87.0	93.0	95.0
RH 2	70.0	59.0	55.0	45.0	39.0	37.0	50.0	57.0	71.0	84.0
Sunshine hours	6.0	7.1	6.8	9.6	9.3	9.6	9.6	6.7	5.9	1.9

Appendix III. Weather data of Thrissur at monthly intervals during October 1997 - July 1998

Weather parameters	Oct 97	Nov 97	Dec 97	Jan 98	Feb 98	Mar 98	Apr 98	May 98	Jun 98	Jul 98
Maximum temperature (°C)	32.2	31.6	31.7	33.1	34.4	36.2	36.5	34.1	30.2	29.2
Minimum temperature (°C)	23.6	23.2	23.8	22.8	23.6	23.6	25.6	25.2	23.3	23.6
Rainfall (mm)	194.7	209.7	66.7	0	0	11.0	61.4	203.0	809.3	752.9
Rainy days	12.0	7.0	2.0	0	0	1.0	4.0	9.0	24.0	28.0
RH 1	88.0	88.0	83.0	78.0	77.0	86.0	86.0	90.0	94.0	96.0
RH 2	65.0	67.0	61.0	49.0	51.0	47.0	50.0	63.0	79.0	80.0
Sunshine hours	7.3	5.3	7.5	9.3	9.6	10.0	9.0	7.6	3.4	3.3