GROWTH, FLOWERING, FRUIT SET AND FRUIT DEVELOPMENT IN KODAMPULI

(Garcinia cambogia Desr *)*

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Horticulture

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DECLARATION

I hereby declare that this thesis entitled Growth, flowering, fruit set and fruit development in 'kodampuli' (*Garcinia cambogia* Desr) 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 any other similar title of any other university or society

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CERTIFICATE

Certified that the thesis entitled **Growth, flowering, fruit set and fruit development in 'kodampuli' (Garcinia cambogia Desr)** is a record of research work done independently by Miss Sherly R under my guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship to her

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CERTIFICATE

We the undersigned members of the Advisory Committee of Ms Sherly R is a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled **Growth, flowering, fruit set and fruit development in 'kodampuli'** (*Garcinia cambogia* Desr) may be submitted by Ms Sherly R in partial fulfilment for the degree

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

1 INTRODUCTION

The kodampuli *Garcinia cambogia* Desr is one of the economic fruit trees yielding fruits having much commercial potential as condiment and at the same time having high medicinal value The tree is supposed to have originated in the Western Ghats of South India and occurs commonly in the evergreen forests at altitudes from 1 300 to 6 000 m above MSL In Kerala it occurs throughout the State even in the low lands of Kuttanadu and is very popular in the Central Travancore areas Though common in Kerala its potential remains unexploited as the tree is not generally cultivated at an orchard level andisoften seen neglected as a miscellaneous tree crop in the backyards of home steads

Kodampuli is androdioecious in nature with separate male and hermaphodite plants It flowers during the summer and fruits ripen during the rainy season The tree possesses great economic value as almost all parts of the tree are useful for one purpose or other However the fruit is the most important part of the tree The dried slices of rind imparts a special flavour and taste to the preparations It is used as a substitute for tamarind in Indian cookery and in indigenous medicines It is extensively used in Kerala in culinary preparations involving fish The medicinal properties of rind further

increases its economic importance Since acidic in nature the fruit possesses marked antiseptic properties also The deccotion is useful in rheumatism bowel complaints disorders in womb in the cure of piles etc The fruit is also employed in veterinary medicine as a rinse for mouth disease in cattle The timber which is not good for construction work is used for manufacturing matches and splints The seeds of kodampuli yield 31 per cent of edible fat rich in oleic acid and resembles kokam butter The yellow gum resin occurring in the barks makes a good varnish The dried rind of the fruit is used as a substitute for acetic acid in polishing gold and silver

Though kodampuli has such immense potential no serious attempt has been made so far on the improvement of the crop 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 Scientific cultivation of the crop is, however not practiced anywhere

The long pre bearing period dioecious nature the wide variability in the production potential and fruit characters among the progenies difficulty in drying the rind due to coincidence of peak harvest season with monsoon are some of

the important problems which needs immediate attention Further farmers are generally reluctant to retain these trees due to the assumption that the crop is a heavy feeder that interferes with the growth of economic crops standing nearby

Appropriate cultural practices based on a thorough understanding of the growth and flowering behaviour of the tree under normal environmental conditions may minimise the irregularities of production to the extend of a commercially profitable venture Identifying or evolving an ideal plant type with short stature year round fruiting and desirable fruit characters like edible pulp seedlessness etc through breeding can bring about a radical change in Kodampuli cultivation The floral biological studies forms the basic data for any crop improvement programme through breeding The present investigations have, therefore, been undertaken with a view to understand the following

1 Growth and flowering pattern of the tree

2 Floral biology

3 Fruit set fruit development and fruit drop

Review of Literature

2 REVIEW OF LITERATURE

Garcinia Linn is a large genus of trees which belongs to Guttiferae the family named from the many species producing resinous juice Anderson (1875) reported that the family is tropical with 24 genera and 250 species commonly found in Asia and America and rare in Africa Bentham and Hooker (1894) described 5 tribes clusiae Moronobeae Garciniae Calophyllus and Qucineae in the family Guttiferae They described 36 species including Garcinia cambogia under the tribe Garciniae Whitemore (1973) opined that the genus Garcinia Linn originated in the old world tropics especially in Asia and described it as the biggest genus in the family with about 400 species

Several workers like Anderson (1875) Brandis (1906) and Gamble (1935) described Garcinia cambogia and other species of Garcinia found in India Gamble (1935) reported that Garcinia cambogia is commonly found in the Western Ghats from Coorg to Travancore and upto 6000 ft in the evergreen and lower Shola forests

Being regarded as a minor fruit till recently not much studies have been conducted in this crop on different aspects viz growth flowering fruit set fruit development etc Literature pertaining to these aspects in other crops which are relevant to the present investigation and the available reports in Garcinia are reviewed here

2 1 Growth Studies

The importance of growth studies in relation to flowering and fruiting of deciduous fruit trees was evident from the earlier works of Gustafon (1926) Reed (1929) Barnard (1932) and Mc Munn (1939)

Later the relationship between vegetative growth and fruiting were studied in different tropical and subtropical tree crops like mango jack guava sapota annona citrus nutmeg etc

In mango a number of workers have studied the pattern of growth flushes Singh and Khan (1939) Naik and Rao (1942) Roy (1953) Singh (1959) Krishnamurthi et al (1961) and Reddy (1983) have reported different periods of primary and extension growth depending upon the variety and environmental conditions under which they are grown Naik and Rao (1942) and Krishnamurthi et al (1961) have described the growth behaviour of mango as cyclic with a period of growth alternated with a period of quiescence They reported five cycles of growth during the course of one year Among the five flushes March flush was more important both in intensity and duration Paulas (1964) studied the growth and flowering of different classes of shoot in a number of mango varieties and observed that flowering occurs in past seasons shoot and early cessation of growth was found to be necessary for a successful flower

crop in the following season Nakasone et al (1955) reported that flushes occurring in summer are more likely to flower than flushes appearing earlier in the year However Reddy (1983) reported that in cv Banganapally shoots produced blooms irrespective of the time of their emergence and single and double flush shoots were more fruitfull than triple flush shoot

Halma and Compton (1936) Krishnamurthi et al (1960), Randhawa and Sinha (1963) and Singh and Ghose (1965) had given a detailed account of the cyclic growth behaviour of citrus shoot root and radial growth

Sundararajan (1961) reported that the growth in sapota commences with the onset of monsoon rains in June and ceases in early summer

Growth studies were undertaken in detail in many guava varieties Two definite seasons of growth flushes and flowering was reported by Aravindakshan (1960) Three classes of shoots were recognised in Guava viz shoots which produced flowers and ceased growth shoots which continued producing flowers and shoots purely vegetative

The investigations carried out in bael (Aegle marmelos) showed only one flush of growth each year vegetative and reproductive shoots emerged simultaneously in the second half of May after leaf fall (Singh 1986)

In Garcinia mangostana a closely related species of kodampuli three vegetative flushes were reported from Malagasy republic (Bourdeaut and Moreuil 1970) So far no systematic work has been undertaken on the pattern of growth of kodampuli or its related species

2 2 Sex forms

Mangosteen Garcinia mangostana is reported to be unisexually dioecious (Purseglove 1969) The existence of male and hermaphrodite flowers was reported by Cobley (1956) But female trees with fertile staminodes only were reported by Krishnamurthi et al (1964)

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

Garicinia cambogia was reported to be dioecious in nature with male and hermaphrodite plants separate (Chandrathna 1948 CSIR 1956 George 1988 KAU 1991 and Nazeema 1992) George et al (1992) described Garcinia cambogia as androdioecious since the male and bisexual flowers occur in separate trees

Nutmeg Myristica fragrans (Hout) is an economically important dioecious crop where three types of flowers viz male normal female and abnormal female were reported (Nazeem and Nair 1981) The flowers resembled each other externally but differed internally

2 3 Flower production and blossom studies

Very little work has been done on flower characters and floral biology of kodampuli However detailed investigations in these aspects were carried out in fruit trees like mango (Singh 1958 1960) jack (Sinha 1975 Joseph 1983) sapota (Patil and Narwadkar 1974 Nalwadi et al 1977) guava (Seth 1962 Sehgal and Singh 1967 Ojha et al 1986 Kahlon et al 1987 and Sandhu et al 1987) nutmeg (Nazeem et al 1981 Amstrong and Drummond 1986) tamarind (Thimmaraju et al 1977) and cashew (Shivanandam et al 1986) The literature pertaining to the investigations undertaken in kodampuli (Garcinia cambogia) and its related species are reviewed in detail below

2 3 1 Flowering pattern and floral biology

Two main seasons of flowering were reported to Garcinia livingstonei (Devivedi and Bajpai 1974) and Garcinia mangostana (Krishnamurthi et al ,1964) The seasons were April to May and October to November in mongosteen and March and November in G livingstonei Garcinia

morella another important species of Garcinia flowers in May (Chandrarathna 1948) and kokam' (Garcinia indica), flowers from November to February (Karnik and Gunjate, 1984) The flowering season of kodampuli' (G cambogia) was reported to be Feburuary by Thomas (1965) Other reports show the flowering period of both male and bisexual trees to be from January to April (Varghees, 1991 Jacob, 1992 and George et al , 1992)

In 'kokam', the flowers were reported to be terminal or fascicled having 2 to 8 buds (Gunjate et al , 1982) The flowers occur singly or in pairs usually at the ends of branchlets of over two years old in mangosteen (Krishnamurthi, et al , 1964, Purseglove, 1969) In kodampuli', Trimen (1935) reported that male flowers occur singly or in groups of 1-3 from the axils The flowers are reported to be axillary, seessile or pedicellate and solitary or in groups (CSIR, 1948) However, Jacob (1992) reported that flowers in clusters of 10-30 in numbers occur in leaf axils and shoot tips The sequence of flower opening was similar to that of a cymose inflorescence with the central bud opening first followed by the one on the sides

The flowers of kokam , Garcinia indica were described as tetramerous and hypogynous (Gunjate et al , 1982) The calyx is sepaloid consisting of four sepals arranged in

decussate pairs the inner pair being broader than the outer one The corolla consists of four petals slightly larger than sepals and yellow to pink dorsally and dark pink ventrally The male flowers of Garcinia indica generally have long pedicel and have numerous stamens forming short capitate column or collected in a ring surrounding the rudimentary pistil Anthers are oblong sessile on short thick filaments adnate four celled and very rarely in two tufts around the pistil Stigma is sessile radiate each ray with two lines of tubercles Ovary is two to eight celled and the placentation is axile The bisexual flowers has long pedicel four tufts of stamens surrounding the pistil The stigma of bisexual flower is sessile or subsessile The bisexual flower is morphologically similar to female flower

Based on their preliminary observations George et al (1992) reported the flowers of both male and bisexual trees of G cambogia with four sepals and petals each arranged imbricately In male flower numerous two celled anthers were seen on short filaments In the case of bisexual flower 6 20 stamens often sterile were found surrounding the ovary which was two celled with 6 10 stigmatic lobes

2 3 1 1 Anthesis and Anther dehiscence
i

The anthesis time of both male and female flowers of Garcinia indica was reported to be between 06 00 hr and

08 00 hr (Karnik and Gunjate 1984) Anther dehiscence in Garcinia indica occurs 15 20 minutes before anthesis

2 3 1 2 Stigmatic receptivity

The characteristic of angiosperm stigma was studied in detail by Heslop and Shivanna (1977) including about 1000 species of plants Two major type stigmas described by them are stigmas which dry at maturity having no free flowing secretion and those which remain wet bearing such a fluid in the receptive stage Sporophytic self incompatibility was reported to be associated with dry papillate stigma Trinucleate pollen not readily germinated in vitro tend to be associated with dry stigma while wet stigma forms tend to have binucleate pollen easily germinated in liquid or semisolid media

Stigmatic receptivity was maximum on the day of anthesis in Garcinia indica (Karnik and Gunjate 1984) No work has been reported on stigmatic receptivity of Garcinia cambogia

2 3 2 Pollen studies

The science of pollen and spores has attracted the attention of research workers due to its great significance in palynological studies to taxonomist and paleontologists It also helps on the elucidation of radiation effect (Brewbaker 1959) facilities classification of angiosperms

(Wodehouse 1935) helps in identifying the disputed varieties or species (Nair 1960 Nair and and Mehra 1961) and can provide evidence for distinguishing the amphidiploid and amphihapolid interspecific hybrids (Hossain et al 1990) The storage and germination of pollen grains play an important role in assisted pollination and hybridisation programme

2 3 2 1 Pollen production

The amount of pollen produced per blossom or anther varies between variety to variety (Nair et al , 1964) The exact measurement of the amount of pollen produced per anther is essential to evaluate the worth of a variety as a pollinator more accurately Oberle and Geortzen (1952) demonstrated a method for determining the number of pollen grains per anther with the aid of haemocytometer a technique adopted in clinical field The accuracy of haemocytometer in estimating the pollen production was further confirmed and modified by the work of Rao and Khader (1962) in fruit crops like papaya pomegranate and sapota

Pollen production studies had been reported in fruit crops like Guava (Nair et al 1964) in sapota papaya and pomegranate by Rao and Khader (1962) and in varikka and koozha types of jack by Joseph (1983)

In kokam Garcinia indica the pollen grain production per anther was estimated to be 3640 in male and 3603 in hermaphrodite flowers (Karnik and Gunjate 1984)

2 3 2 2 Pollen morphology

Morphological characters of pollen has been used as an important tool in studying the floral biology interpreting the taxonomic relationship between plants and origin of plants

Very little work has been done on the pollen morphology of tropical fruit crops Nair and Mehra (1961) had described the pollen grains of citrus species Rao and Khader (1960) made investigation on pollen morphology of six fruit plants namely papaya jack guava sapota pomegranate and grapes Singh and Misra (1979)studied the characteristic of the pollen of three species of Zyzyphus Studies on the pollen morphology of jack were carried out by Prasad and Trivedi (1978) and Joseph (1983) Moti et al (1973) carried out investigations on the morphological characters of 101 mango varieties

2 3 2 3 Pollen viability

The extent of pollen viability is of vital importance in hybridization work Stanley and Linskens (1974) suggested various methods for testing the viability of pollen grains including both germination and non germination assays

a Stain test

Stains which give colour to viable pollen is often used as indices of viability Zirkle (1937) described the method of mounting pollen grains in acetocarmine The pollen grains which stained well and well shaped were taken as fertile and unstained shrivelled ones as non viable or sterile Stanley and Linskens (1974) mentioned some other stains as aniline blue potassium iodide and methyl green etc for indicating viability

Balasubramanyam (1959) in guava Nirmalendunath and Randhawa (1959) in pomegranate Singh (1961) and Moti et al (1973) in mango Singh (1962 b) in Litchi Nalawadi et al (1975) in Annona and Nalawadi et al (1977) in sapota had followed the acetocarmine test to find out the percentage fertility

b Germination tests

Germination tests are reported to be more accurate than stain test in assessing the pollen viability Sugar solutions are commonly used as media for pollen germination Sugar is reported to control the osmotic concentration during germination of pollen (Brink 1924 O kelly 1955 Vasil 1958) Brink (1924) observed that when pollen was cultured in sugar or sugar agar medium the pollen tubes were as long as or even longer than those found in nature

Adams (1916) reported good pollen germination at various concentrations of cane sugar for different crops viz 2 5 to 10 per cent for apple four to eight per cent for pear six per cent for black currants Pollen germination was reported in 16 per cent sucrose and 0 7 per cent agar for sapota (Rao and Khader 1960) 25 per cent sucrose and 0 5 per cent agar for mango (Singh 1961) 30 per cent sucrose for cashew (Damodaran et al 1966) 12 per cent sucrose for annona (Sulikeri et al 1975) 15 per cent sucrose for cocoa (Ravindran 1977) 10 per cent sucrose for jack (Prasad and Trivedi 1978 Joseph 1983 Gopinathaan et al 1983) four per cent sucrose for nutmeg (Nazeem 1979) and five per cent sucrose for nutmeg (Bavappa and Banda 1981)

2 3 2 4 Effect of boric acid and calcium nitrate in pollen germination

Schumucker (1932) discovered that boric acid at concentration ranging from 1 to 10 ppm was a stimulant to pollen germination and tube growth in Nympheae and in many other species Boron was found to occur in the tissues of the pistil of the species studied The role of boric acid and boron in germination and pollen tube growth was studied by many workers Thompson and Batjer (1950) in their studies on the pollen of different species of fruit trees found that boron or boric acid in low concentrations such as 25 to 40 ppm stimulated pollen germination and pollen tube growth

Resnik (1956) in citrus reported a 10 to 15 per cent increase in pollen germination by the addition of boric acid at concentrations ranging from 10 to 100 ppm Munzer (1960) revealed that 1 to 10 per cent boric acid stimulated pollen germination and pollen tube growth in more than 60 species of angiosperms

Beneficial effect of boric acid on the germination of pollen grains was reported in many other crops like sapota (Rao and Khader 1960) Mango (Singh 1961 Wet et al 1989) Cocoa (Ravindran 1977) nutmeg (Nazeem 1979) jack (Joseph 1983) Cashew (Subbaiah 1984) However Parmer (1978) reported that sucrose media containing agar or boric acid had no special effect on pollen germination when added with sucrose

The influence of calcium nitrate on pollen germination and tube growth was reported by various workers Brink (1924) has mentioned it as an inhibitor of pollen germination Kwack and Brewbacker (1963) Kwack (1965) Ravindran (1977) Nazeem (1979) etc have revealed the essential role of calcium in pollen germination and tube growth The enhancing effect of calcium was attributed to the non metabolic incorporation of it with pectic substances of the pollen wall (Jose and Nagnoon 1972)

2 3 2 5 Pollen storage

Storage of pollen is of great significance in plant breeding especially when the two parents involved in a cross do not synchronize in flowering or when long distance shipment from one place to another is desired The maintenance of pollen viability is dependent on the conditions of storage especially temperature and relative humidity

a Storage by controlling temperature and humidity

King and Hesse (1938) studied the pollen storage requirement of as many as 16 deciduous fruits and found that the optimum temperature for storing pollen was 30°F Nebel (1939) was able to store the pollen of apple pear plum peach and apricot for 2 to 5 1/2 years in desiccator over sulphuric acid with 50 per cent R H at 28°C

Pollen longevity studies were conducted in relation to temperature and humidity in papaya (Traub and O Rork 1936 Cohen et al 1989) in mango and litchi by Singh (1962 a b) in grapes by Nagarajan et al (1965) in jack by Sinha (1972) and Joseph (1983) and in nutmeg by Nazeem (1979)

b Storage by freezing

Griggs et al (1953) successfully stored the pollen of plum peach almond apple, pear cherry and olives without much difference in the germination percentage for one to three years in home refrigerator at -18°C Singh (1962a) has reported that mango pollen can be stored for more than a year under freeze conditions Similar reports were available in case of litchi (Singh 1962 b) citrus (Sachan and Patro 1970) Kagzi lime (Shukla and Misra 1975) papaya (Cohen et al 1989) Lyophilization or freeze drying of pollen is reported to be one of the efficient method of pollen storage (Stanley and Linkskens 1974 Nair 1977)

2 4 Pollination studies

Riabove (1930) have given a most comprehensive survey of literature on the pollination of trees containing about 800 references He stressed the possible influence of environment on modes of pollination and physiological conditions of plant on fruit set

Inadequate pollination or conditions existing after pollination were reported as one of the main reasons responsible for poor fruit set in mango (Mukherjee 1953) in annona and jack (Krishnamurthi and Rao 1965) and in apple (Teskey and Shoemaker 1972) A male female ratio of 1 10 is reported to be required for successful pollination

in nutmeg as dioecious in nature (Cruickshank 1973) Perrl (1938) reported parthenocarpic development of fruits where as Flach (1966) was of the view that cross pollination in nutmeg is obligatory He also suggested that the progenies of freely pollinated bisexual trees will be more female than that of freely pollinated female trees He explained the reason for the higher progenies by the fact that in case of monoecious trees the chances of self pollination was more than that of dioecious plant The chances of such self pollination increased in case of monoecious nature of male flowers resulting in less production but with more female progeny The reverse was true in case of monoecious trees with more female flowers

2 5 Fruit set and development

High flower production could not be taken as an index for estimating the final crop in most of the horticultural crops The fruit set and not the flower production was found to have a great bearing upon the yield in most crops

Mukherjee (1949) and Singh (1954) have reported the ultimate set in mango as one per cent Factors like high percentage of male flowers defective pollination adverse weather conditions and vegetative growth were reported as the causes of low fruit set in mango (Singh 1964) In jack Saha (1970) found that the age of branch affected fruit set

Fruit development was reported to be parthenocarpic in Garcinia mangostana Fruit ripening in kodampuli is reported during the South West monsoon season (George 1988) Jacob (1992) reported that the fruits take about four months to ripen Detailed study on the fruit set and fruit development is lacking in Garcinia cambogia or its related species

2 6 Fruit drop

Eventhough fruit drop is observed only to a little extent in kodampuli it has not so far been reported as a major problem affecting the yield Several reports were available in a variety of other fruit crops viz citrus (Nauriyal 1955 Pollard and Biggs 1969) mango (Chadha and Singh 1963 1964 Singh 1965)

The abscission of fruits subsequent to bloom or those have developed partially occur in definite waves Chandler (1925) recognised three waves of abscission in deciduous trees as (1) at blooming time or shortly after following pistil abortion (2) two weeks after flowering following failure of fertilization (3) June drop following competition for nutrients and failure of embryo development Chadha and Singh (1964) recorded 3 waves of drop in mango i e pin head drop post setting or April

drop and unripe fruit drop or May drop Randhawa (1971) recorded three waves of drop in citrus The waves were during the month following full bloom the June drop and pre harvest drop Formation of abscission mechanism as reason for abscission was supported by various workers like Addicott and Lynch (1955) Chadha and Singh (1963) and Randhawa (1971) Among the external factors controlling the mechanism, reports have been mostly on temperature and moisture status of soil Later the imbalance between hormones like Giberellins and abscisin was suggested as the cause of premature drop (Addicott and Lynch 1955 Bardwaj 1975)

2 7 Chemical composition of fruits

CSIR (1956) reported that kodampuli contains tartaric acid (10 6 per cent) reducing sugar (15 00 per cent) and phosphoric acid (1 52 per cent) Chandarathna (1948) reported that 90 per cent of the acids in the rind are not volatile and consist almost completely of tartaric acid He also reported a variation in the acid content of the rind in fruits of different locality Lewis (1964) reported the major acid in the dried rind of Garcinia cambogia as hydroxy citric acid and its concentration comes to about 30 per cent in the dry weight basis George (1988) reported 10 6 per cent tartaric acid and 4 15 per

cent reducing sugars in the rind of kodampuli Mannan *et al* (1986) reported the major acid in the seed oil of *Garcinia* as oleic and linoleic acid and the total content comes to 90 per cent

2 8 Yield

Thomas (1965) reported that a full grown tree yields 127 kg to 254 02 kg of green fruit On drying a loss of 75 per cent fresh weight was reported

Materials and Methods

3 MATERIALS AND METHODS

The investigations were conducted on the trees maintained as a germplasm collection at the orchard Department of Pomology and Floriculture College of Horticulture during the period of eighteen months commencing from March 1993 to September 1994 The orchard is located on a levelled land of laterite soil with a pH range of 5 0 to 5 5

The studies on different aspects of growth flowering and fruit development were taken up on hermaphrodite and male trees Three mature bearing hermaphrodite trees and four flowering male trees of kodampuli of seven years age were selected for the present study The trees (seedling progenies) were receiving uniform cultural practices throughout the period of investigation

On each tree the canopy was arbitrarily divided for convenience into four quadrants considering each aspect viz East West North and South as a quadrant From each such quadrants 100 shoots were selected randomly for taking up the following observations

1 Extension growth of shoots for a period of one year
2 Flowering and floral characters
3 Fruitset fruit development and fruit drop

3 1 Growth Characteristics of 'kodampuli' in terms of shoot growth and leaf development

3 1 1 Extension growth of shoots

One hundred lateral shoots on each quadrant were selected at random on three hermaphrodite trees (T_1 to T_3) and four male trees (T_4 to T_7) The shoots were tagged and numbered serially during March 1993 The extension growth was measured in cm scale at fortnightly intervals for a period of one year

3 1 2 Leaf emergence growth and development

Twentyfive vegetative buds were tagged at random on the shoots of individual trees to observe the growth pattern of leaves of kodampuli from emergence to maturity Linear growth measurements were recorded from the protruberance stage to mature stage at three days interval without detaching the leaves

3 2 Flowering and floral characters

3 2 1 Pattern of flowering

Pattern of flowering in male and hermaphrodite trees was studied by observing 100 shoots selected at random on each tree Observations on the number of shoots flowered and the number of inflorescence or flower per flowered shoot were made

3 2 2 Flower bud development

Periodic examination of the shoots tagged for extension growth studies were made during the flowering season to find out the exact time of visual emergence of flower buds Progressive stages of flower bud development was studied by labelling and closely watching 100 buds randomly selected on each tree Tagging of buds were done soon after the emergence of buds as a light green protruberance with bilobed tip Observations were made on the developmental stages colour changes length and girth of the bud at three days interval The developing buds were examined and drawings and photographs were made at different stages

3 2 3 Floral biology

Studies on various aspects of floral biology viz anthesis anther dehiscence stigma receptivity and pollen characters were carried out separately on staminate and bisexual flowers The flowers were described and drawings made

3 2 3 1 Anthesis

Preliminary observations showed that flower opening take place in the evening hours In order to know the exact time of anthesis 25 mature buds were tagged on male and hermaphrodite trees separately in the morning and observations were made at half hourly intervals from 15 00

hours The maturity of the buds was determined from the colour of perianth parts The experiment was repeated over a period of one week

3 2 3 2 Anther dehiscence

The period of anther dehiscence was studied by tagging 25 buds of uniform size having yellow perianth parts Observations were made twice daily in the morning and evening examining the anther for dehiscence using a hand lens Preliminary observations indicated that the anther dehiscence occurs in the early morning hours on the day of flower opening Later observations were repeated on mature buds at half hourly intervals from 06 30 hours onwards

3 2 3 3 Stigma receptivity

The receptivity of stigma was judged by the fresh creamy white colour and shiny appearance of stigmatic surface This was further confirmed by controlled pollination and observing the fruit set Mature buds were emasculated and covered for this purpose They were later pollinated with pollen collected from dehisced male buds using a camel hair brush Pollination was done at six hourly intervals starting from one day prior to anthesis and continued till one day after anthesis Twenty five buds were utilized for these studies at different stages

3 2 4 Pollen studies

Pollen studies with respect to pollen morphology fertility germination and pollination aspects were taken up The pollen for the studies were collected between 10 00 and 11 00 hours from mature buds on the day of opening Maturity of the buds were judged initially by the dome shape and orange yellow colour of the perianth Later the pollen was collected from the dehisced anthers only Opened flowers were excluded from pollen collection to avoid pollen loss The details of procedures adopted for studying each aspect are furnished below

3 2 4 1 Morphology and fertility

Twenty five well shaped mature buds were selected from male and hermaphrodite trees for the study Pollen from each bud was 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 the 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 The experiment was repeated by <u>in vitro</u> germination method using 4 per cent sugar + 0 5 per cent agar as the medium

The diameter of the pollen grains was measured using an ocular micrometer The diameter of 100 normal sized well stained and well shaped pollen grains was recorded at random from each slide and the average was worked out

3 2 4 2 Estimation of pollen production

The number of pollen per flower was estimated using haemocytometer as suggested by Rao and Khader (1962) Orange yellow flower buds of staminate and bisexual flowers were collected separately just prior to anther dehiscence Perianth parts were carefully removed and the anther column was observed under a handlens for non-dehiscence Hundred such anthers which were almost mature but not dehisced were gathered in small vials and stored in a desiccator over calcium chloride for 4 to 6 hours to facilitate dehiscence After dehiscence, 2 5 ml of water containing 0 05 per cent Teepol was added and the contents were stirred thoroughly in order to obtain even dispersion of the pollen grains in the suspension A drop of the suspension drawn in a fine pipette was transferred to each of the two counting chambers of a Spencer Bright Line Haemocytometer Each chamber has an area of nine square millimeter ruled into smaller divisions Each of the four corner square millimeter area is ruled into 16 areas while the five square millimeter areas are ruled into smaller divisions The counting chambers

are 0 1 mm in depth so that the volume over one mm^2 is 0 1 mm^3 On this basis the number of pollen grains per flower can be derived as follows

The contents of 100 anthers are suspended in 2 5 ml of solution Thus the contents of each anther are suspended in 0 025 ml of the solution or 25 mm^3

IF N = average number of pollen grains counted per corner square and

X number of pollen grains per anther

N X - 0 1 25

0 1 X = 25 N

X 250 N

The pollen grain in each of the four corner squares of each counting chamber were counted using low power (10 x) objective of the microscope

Accordingly for every male and hermaphrodite trees ten counts were made examining 50 flowers in each case

3 2 4 3 In vitro pollen germination

a Effect of sucrose and agar on pollen germination

Since the optimum medium for pollen germination in kodampuli had not yet been reported earlier different

concentrations of sucrose ranging from 5 to 50 per cent with 0 5 per cent agar was tried initially Germination was observed in 5 and 10 per cent concentrations only In order to find out the optimum concentrations of sucrose the experiment was repeated with different levels of sucrose such as 0 2 4 6 8 and 10 per cent with 0 5 per cent agar

The effect of different levels of agar on germination of pollen grains was assessed by observing the germination at different levels of agar such as 0 5 1 0 and 1 5 per cent with 2 4 6 8 and 10 per cent sucrose concentrations

b Effect of boric acid on pollen germination

Effect of boric acid on pollen germination was tested at different levels of sucrose with 0 5 per cent agar The different levels tried were 0 2 4 6 8 and 10 per cent in case of sucrose and 25 50 75 and 100 ppm in case of boric acid

Pollen germination was ascertained by examining pollen tube growth to a length atleast double that of the diameter of the pollen 24 hours after inoculation On an average 500 pollen grains from 10 microscopic fields were counted Measurements of 100 pollen tubes were recorded for tube length and expressed in µ Germination was expressed in percentage with the average worked out from 500 observations

3 2 4 4 Pollen storage

In order to understand the optimum storage conditions for the pollen grains mature buds from male trees were collected and subjected to different treatments The storage of pollen grains were tried using staminal column with pollen grains intact and by using separated pollen grains alone The various storage conditions included in the study were

i) keeping at room temperature without any treatment
ii) Keeping over calcium chloride in a desiccator at room temperature
iii) keeping in refrigerator at 4°C
iv) Keeping over calcium chloride in desiccator under refrigerated condition at 4°C

The viability was recorded for each treatment at daily interval in four per cent sucrose + 0 5 per cent agar media after five hours incubation in moist chamber

3 2 5 Pollination studies

3 2 5 1 Pollinating agents

To study the agents helping in pollination of kodampuli male and hermaphrodite trees were closely observed during flowering season To trap the insects visiting the flowers during flower opening the

inflorescence on male trees in one squaremetre area was sprayed with 0 1 per cent Sumicidin at 13 00 hours (Nazeem 1979) A muslin cloth was tied below the flowering branches of the tree and suspended to collect the insect which might fall down Observations were made just after spraying and next day morning This treatment repeated on different aspects of the canopy of both male and hermaphrodite trees during flowering season

In order to assess the extent of air born pollen slides covered with cellophane tape with the sticky side exposed were suspended at different sites near male and hermaphrodite trees at 15 00 hours Slides were collected next morning and examined under microscope for kodampuli pollen and foreign matters Observations were recorded as percentage of pollen grains to the total number of particles observed

3 2 5 2 Mode of pollination

To ascertain the precise mode of pollination fruit set by four modes of pollination was studied All the studies were taken up utilising 100 flowers for each experiment Observations on fruit set was recorded 10 days after pollination (DAP)

a Natural/open pollination

In order to know the extent of pollination under natural conditions individual flower buds were selected and tagged before anthesis These were later examined for fruit set and extent of natural pollination was worked out

b Self pollination

For knowing the extent of self pollination taking place in kodampuli trees individual flowers were selected and covered one day prior to anthesis for preventing any pollen contamination from outside Then covers were removed one day after flower opening and fruit set was recorded

c Natural cross pollination

The extent of natural cross pollination was studied on selected bisexual flowers Flowers were emasculated one day prior to anthesis and left for natural pollinating agents Natural cross pollination as manifested by the extent of subsequent fruit set was determined by noting down the number of flower setting fruit

d Hand pollination

Flowers were emasculated and covered one day before opening These flowers hand pollinated on the next day by dusting the pollen collected from male flowers on the stigmatic surface Pollinated flowers were tagged and observed for fruit set

3 3 Fruit set fruit development and fruit drop

3 3 1 Fruit set

To assess the percentage of natural fruit set 25 flowers were tagged on each aspect of the tree so that a total of 100 flowers were observed on each tree Observations made at weekly intervals for a period of one month

Twentyfive flowers each on hermaphrodite trees were emasculated covered and left unpollinated to study whether there is any apomictic fruit development in kodampuli

For knowing the effect of assisted pollination on fruit set the bisexual flowers were artificially pollinated with pollen from male flowers collected during flower opening The pollinated flowers were tagged and observations made at weekly intervals for a period of one month

3 3 2 Fruit development

3 3 2 1 Physical changes during fruit development

Young fruits of 10 to 15 days old were tagged for studying the developmental stages of the fruit Hundred fruits were tagged on each tree and observations on length and girth were made using a scale and non elastic twine The observations were taken at weekly interval and continued upto harvest stage

In order to study the changes with respect to physical parameters such as total weight volume weight of rind weight of seed etc fruit samples were picked at 20 days interval commencing from fruit set till harvest and observations were made

3 3 2 2 Chemical changes of rind associated with fruit development

Fruit samples were drawn at 20 days interval from fruit set to harvest and subjected to analysis in order to know the chemical composition of the rind during the different stages of fruit development The methodology followed for the analysis of chemical characteristics are given below

(a) T S S

T S S was determined using a hand refractometer and expressed as ° Brix

(b) Acidity

Acidity was determined by titration with standard NaOH solution and expressed as percentage of citric acid

(c) Ascorbic acid

Ascorbic acid was determined by titrating the fruit samples against the dye 2 6 Dichloro phenol Indophenol and expressed in mg/100g of sample

(d) Reducing sugar

Reducing sugar was estimated as per AOAC (1980)

(e) Moisture

Moisture was determined by drying in hot air oven at 60 to 70 °C for 16 18 hours (Ranganna 1977)

(f) Dryage under conventional method of drying

Samples were weighed and subjected to conventional processing The rind after removal of kernel was cut into halves and dried in sun for 3 to 7 days and they were smoked on a raised platform over the fire place for another three to four weeks The smoking was continued till the rind is black in colour and almost all the moisture is removed Weight of sample after drying was noted and expressed as percentage

3 3 3 Fruit drop

In order to assess the extent of post set drop young fruits of 10 15 days old were tagged and observed at fortnightly interval and fruit drop was recorded in 100 fruits selected at random for these observations

3 4 Yield

Number of fruits obtained from each tree during each harvest and the corresponding fruit weight was recorded to arrive at the total yield from individual trees

Statistical analysis

The data were subjected to statistical analysis wherever it was found necessary as per Panse and Sukhatme (1985)

Results

4 RESULTS

The results of the detailed studies on the growth pattern flowering fruit set and fruit development in kodampuli are presented in this chapter

4 1 The growth characteristics of 'kodampuli' in terms of shoot growth and leaf development

4 1 1 Shoot growth

The data on the shoot growth measured as mean monthly extension and percentage of shoots that showed growth at a time for a period of one year in male and hermaphrodite trees are presented in table 1 In both male and hermaphrodite trees shoot growth was observed throughout the year However the increment in growth recorded varied from month to month The maximum extension in growth was observed during the month of April both in male (2 52 cm) and hermaphrodite trees (2 29 cm) This mean growth accounted for 24 80 per cent and 26 50 per cent of the total growth in male and hermaphrodite trees respectively

Statistical analysis of the data showed that the mean extension growth differed significantly among the months Mean monthly extension growth was found to be significantly higher during the period from February to May compared to the rest of the year Although growth was also observed growth during the period from June to January the rate was low and there was no significant difference in mean monthly

extension of growth The growth was minimum in the month of August in male (0 16 cm) and hermaphrodite (0 03 cm) trees Statistical analysis of the mean extension growth of shoots of male and hermaphrodite trees showed significant difference between the two types at five per cent level of significance (Table 1)

The percentage of shoots which showed growth in different months also followed the same pattern as that of mean extension growth (Fig 1) Maximum percentage of shoots showed growth in the month of April in both male (72 40) and hermaphrodite (51 50) trees Growing shoots were minimum in the month of August both in male (13 05 per cent) and hermaphrodite (6 55 per cent) trees

The mean shoot extension of individual trees and percentage shoots showed growth over a period of one year are presented in table 2 Statistical analysis of the data showed significant difference between the mean shoot growth of individual trees The mean shoot growth was found to be maximum in male trees T_7 and T_5 followed by the hermaphrodite tree T_2 The minimum shoot growth was found in male tree T_4 which was about 1/3 of that observed in male tree showing maximum growth The percentage shoots showing growth during the period also varied significantly among individual trees The percentage shoots which showed growth during the period was maximum for male tree T_7 (95 00)

Table 1 Mean monthly growth and percentage of growing shoots in male and hermaphrodite trees

Month		Male tree		Hermaphrodite trees		Percentage shoots showing growth			
		Mean extension growth (cm)	percentage contribution towards growth	Mean extension growth (cm)	percentage contribution towards growth	Male		Hermaphrodite	
1993	April	2 52	24 80	2 29	26 50	72 4	(58 12)	51 50	(45 86)
	May	1 58	15 57	1 27	14 72	53 25	(46 83)	24 00	(29 33)
	June	0 54	5 32	1 46	16 92	13 56	(21 56)	16 17	(23 73)
	July	0 33	3 25	0 11	1 27	8 06	(16 43)	5 42	(13 44)
	August	0 16	1 58	0 03	0 34	5 18	(13 05)	1 33	(6 55)
	September	0 67	6 60	0 22	2 54	6 75	(15 12)	3 20	(10 30)
	October	0 63	6 20	0 19	2 20	9 38	(17 85)	3 00	(9 97)
	November	0 94	9 26	0 16	1 85	16 25	(23 81)	5 20	(13 18)
	December	0 62	6 10	0 05	0 58	13 75	(21 72)	2 83	(9 63)
1994	January	0 79	7 78	1 23	14 25	23 50	(29 00)	23 50	(29 00)
	February	1 37	13 40	0 47	5 44	38 00	(38 06)	32 75	(34 94)
	March	1 44	14 18	1 54	13 37	47 90	(43 80)	41 80	(40 28)
Total			100 00		100 00	100 00		100 00	
F Value		6 65**	3 77**						
CD		0 61	0 51						
t value		1 38*				4 01**			

(to compare male and hermaphrodite plants)

** Significant at 1° level * Significant at 5° level

Figures in parentheses denote transformed values

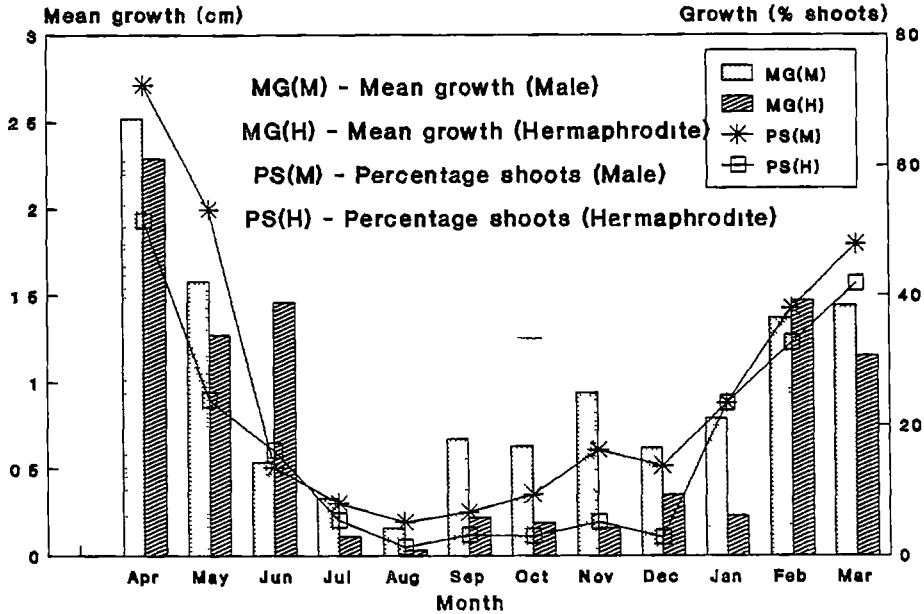


Fig 1 Mean extension growth and percentage of growing shoots over a period of one year in male and hermaphrodite trees

Table 2 Annual growth of shoots in different trees

Sl No	Tree No	Mean annual shoot growth (cm)	Percentage shoots showed growth
1	T_1(♀)	7 25	90 00
2	T_2(♀)	13 99	92 00
3	T_3(♀)	7 01	84 00
4	T_4(♂)	5 26	84 00
5	T_5(♂)	15 40	84 50
6	T_6(♂)	9 87	91 00
7	T_7(♂)	15 87	95 00

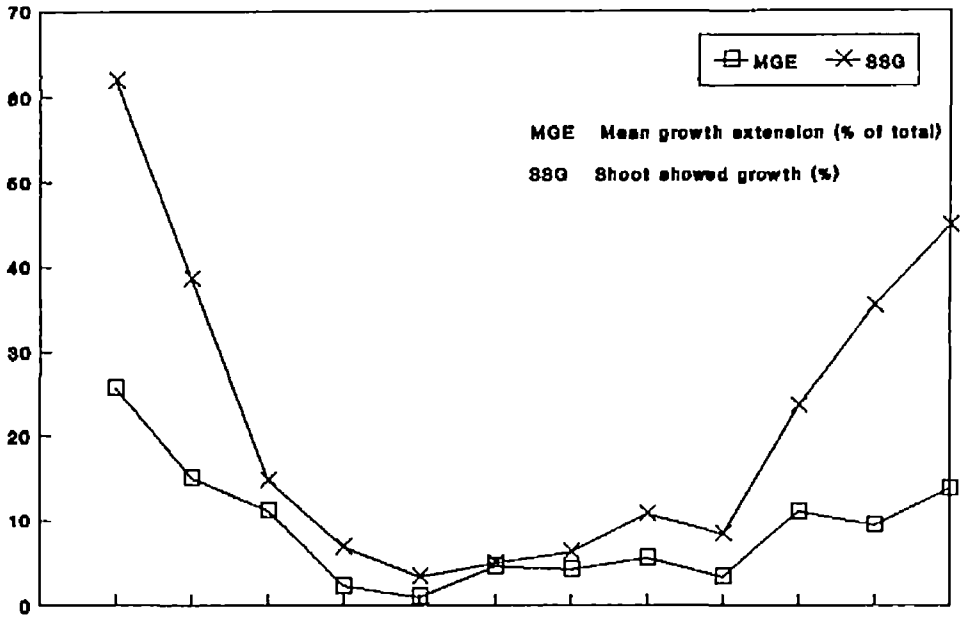
F value 4 57

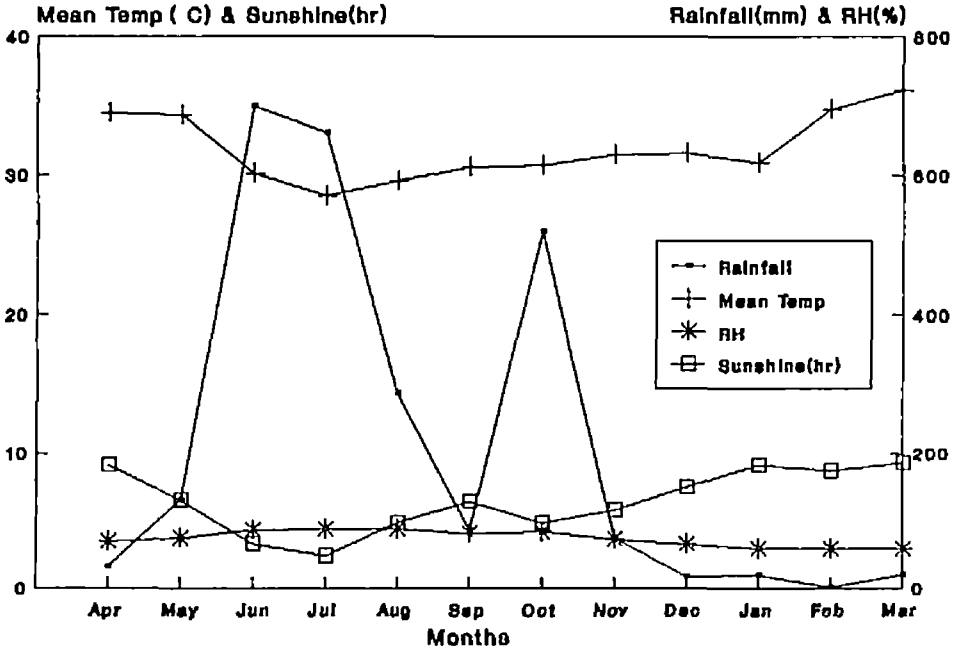
CD 3 07

followed by hermaphrodite tree T_2 (92 00) followed by the male tree T_6 and hermaphrodite tree T_1 (90 00)

The weather data pertaining to the period 1993 94 are presented in Appendix I Weather data collected indicated that the maximum and minimum monthly mean temperature ranged from 28 5°C to 36 2°C and 22 6°C to 24 8°C respectively with the maximum temperature in March and minimum in January A total rainfall of 4796 9 mm was recorded during the period of 14 months with the main rainfall in the month of June July and October

During the peak period of growth (February March) the maximum temperature ranged between 34 4°C and 36 2°C and the total rainfall recorded was 284 0 mm The growth was found to be maximum during the hotter months of the year The relative humidity ranged between 58 00 per cent and 74 00 per cent during the peak period of growth During the period of minimum growth the maximum temperature ranged between 28 5°C and 31 6°C and the total rainfall recorded was 2305 0 mm The relative humidity during this period ranged between 58 00 and 87 00 per cent The effective sunshine hours recorded was low (2 4 to 7 5 hours) during the period of minimum growth compared to the period of maximum growth (6 5 to 9 3 hours) The pattern of growth of shoots in relation to climatic parameters such as rainfall temperature sunshine hours and relative humidity is presented in Fig 2


MGE
SSG
MGE Mean growth extension (% of total)
SSG Shoot showed growth (%)
70
60
50
40
30
20
10
0


Mean Temp (C) & Sunshine(hr)
Rainfall(mm) & RH(%)
Rainfall
Mean Temp
RH
Sunshine(hr)
40
30
20
10
0
800
600
400
200
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Months

4 1 2 Leaf emergence and development

The data on leaf development in both types of the trees are presented in table 3 It took 25 to 27 days for the development of leaves from emergence to apparently mature dark green stage The emerging leaves were found to be pinkish red in colour in hermaphrodite trees while light green flushes were observed in male trees (Plate I) The pinkish red colour of the leaves turned to light green colour in six days and remained as such for the next 15 days changing to dark green finally in hermaphrodite trees (Plate II) In male trees the light green colour of emerging leaves changed to dark green after 21 days (Plate III The leaves showed no significant difference in size among the male and hermaphrodite trees but some difference observed among the individual trees

The leaves were simple, opposite and glabrous with broad acute base acuminate tip entire margin and prominent veins in both types of the trees

4 2 Flowering and floral characters

4 2 1 Pattern of flowering

Results from the studies on flowering in individual male and hermaphrodite trees are presented in table 4

Table 3 Changes in linear measurement and colour during development of leaves

Tree Number	Length									Girth									Colou								
	Days after emergence									Days after emergence									At emergence	Days after emergence								
	3	6	9	12	15	18	21	24	27	3	6	9	12	15	18	21	24	27		3	6	9	12	15	18	21	24	27
$T_1(♂)$	0 40	1 09	2 49	3 23	4 34	6 82	7 30	7 30	7 30	0 20	0 36	1 27	1 67	2 13	2 74	2 90	2 90	2 90	Pinkish red	Pink ish red	Red light	light green	light green	light green	Light green	Light green	Turning to Dark green	Dark green
$T_2(♀)$	0 36	0 85	1 08	2 16	0 28	4 75	5 90	7 50	7 50	0 20	0 60	0 95	1 06	2 80	3 40	3 80	4 20	4 20	,,	,	,	,,	,	,	,	,	,	
$T_3(♀)$	0 41	0 98	1 40	2 56	4 00	4 80	5 43	6 13	6 13	0 10	0 20	0 43	0 90	1 67	2 13	3 53	4 50	4 50	,,	,		,			,			
$T_4(♂)$	0 40	1 24	1 48	2 60	4 14	6 42	7 50	7 88	7 88	0 20	0 58	0 60	0 99	1 80	2 20	3 40	3 80	3 80	Light green	Light green	Light green					Turning dark green	,	
$T_5(♂)$	0 40	0 62	0 46	2 40	4 50	6 33	7 56	7 96	7 96	0 20	0 60	0 78	1 20	1 20	3 40	3 60	4 00	4 00	,,	,		,,	,	,,	,	,	,,	
$T_6(♂)$	0 41	0 98	1 40	2 56	4 00	4 80	5 43	6 13	6 13	0 12	0 20	0 43	0 90	1 67	2 13	3 53	4 50	4 50	,		,			,			,	
$T_7(♂)$	0 31	0 50	1 10	1 50	2 67	5 15	7 20	7 52	7 52	0 20	0 21	0 51	0 89	1 23	1 56	2 50	3 40	3 40	,	,	,		,		,	,	,	

PLATE I Colour of emerging leaves of kodampuli


Hermaphrodite
Male
Colour of emerging leaves

PLATE II Colour change of developing leaves of hermaphrodite trees

PLATE III Colour changes of developing leaves of male trees


Colour change of developing leaves
Hermaphrodite


Colour change of developing leaves -
Male tree

In male trees the percentage of shoots that flowered ranged from 74 00 to 78 00 while in hermaphrodite trees flowering was observed only in 50 00 per cent of the shoots

Visual emergence of flower buds in male trees commenced from the month of November onwards Flower opening was found to progress steadily thereafter with a peak flowering period observed during January April months Almost 76 25 per cent of the shoots putforth flowers during this period (Table 5) In hermaphrodite trees visual flower bud emergence commenced from the month of December onwards Flower opening progressively increased and the peak blooming was observed during February March period

Studies revealed a protracted period of flowering in male trees of kodampuli extending over a period of four to five months whereas in hermaphrodite trees it was comparatively shorter confining to two to three months

In male trees the flowers appeared in clusters on inflorescences with a mean number of 4 96 inflorescence per shoot having 4 56 flowers per inflorescence (Table 4) In hermaphrodite trees usually bisexual flowers were borne singly and rarely in pairs or groups of three to five The mean number of inflorescence per shoot was 3 46

The data on the percentage of shoots flowered on different aspects of the tree showed no significant difference (Table 6)

Table 4 Extent of flowering of individual trees

Tree No	Male			Tree No
	Percentage shoots flowered	Mean number of inflorescence per shoot	Mean number of flower per inflorescence	
$T_4(\delta)$	78 00	4 8	4 8	$T_1(\varphi)$
$T_5(\delta)$	77 00	5 9	4 9	$T_2(\varphi)$
$T_6(\delta)$	74 00	4 4	3 9	$T_3(\varphi)$
$T_7(\delta)$	76 00	4 7	4 6	
Mean	76 25	4 96	4 56	

Hermaphrodite	
Percentage shoots flowered	Mean Number of flower per shoot
55 00	3 5
43 00	3 3
48 00	3 4
48 66	3 46

Table 5 Pattern of flowering in male and hermaphrodite trees

	Month of visual flower bud emergence	Period of maximum flowering	Flowering intensity (% shoots flowered)
Male tree	November	January April	76 25
Hermaphrodite tree	December	February March	48 66

Table 6 Extent of flowering in different aspects of the tree

Aspect	Percentage of shoots flowered		Number of flowers per shoot	
	Male	Hermaphrodite	Male	Hermaphrodite
East	74 00	48 00	23 92	3 64
West	73 00	48 00	21 89	2 90
South	83 00	50 00	21 50	2 90
North	75 00	50 00	22 49	4 30

$$x^2 = 0\ 82$$

4 2 2 Flower bud development

After visual emergence flower buds passed through a series of morphological changes to reach the anthesis stage The whole period of flower bud development was divided into seven arbitrary stages (Plate IV and VI) in male and bisexual flowers The chronological order of these developmental stages and the mean size of the bud in these stages were studied in male and bisexual flowers and the data are summarized in table 7 The different stages are diagramatically represented in Plate V and VII and the description is given below

Stage 1

The bud of male and hermaphrodite trees appeared more or less similar in shape and were light green in colour The buds had a bilobed tip and were 0 10 cm in length and 0 80 cm in girth in male flowers The bisexual flower buds at this stage were 0 15 cm in mean length and 0 95 cm in girth This stage continued for three days in male flowers and two days in bisexual flowers

Stage 2

The male buds were 0 20 cm in length and 1 00 cm in girth Bisexual flower buds were slightly larger than male buds with 0 29 cm length and 1 05 cm girth In this stage two small projections appear on the sides and develop in to

Table 7 Durat on and size of the bud at different stages of bud development

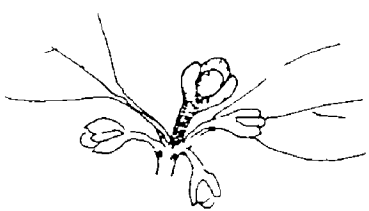
Type of flowe	Number of buds obse ved	Mean size of the bud at different stages of developaent													Duration of each stage (days)							Number of days from eaergence to opening
		Length (ca)							Girth ca)													
		stage							Stage							Stage						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
Male	100	0 10	0 20	0 83	1 03	1 05	1 45	1 50	0 80	1 00	1 55	1 60	1 83	2 19	2 5	3	10	3	6	3	2	5	32
Bise ual	100	0 15	0 29	0 6o	0 92	1 04	1 22	1 33	0 90	1 05	1 53	2 37	2 63	2 90	3 15	2	7	4	3	3	7	2	28

PLATE IV Stages of male flower development


Stages of mak flower development

1

2



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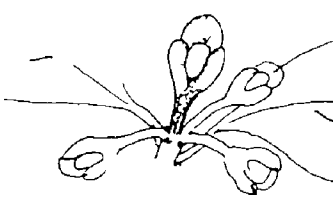

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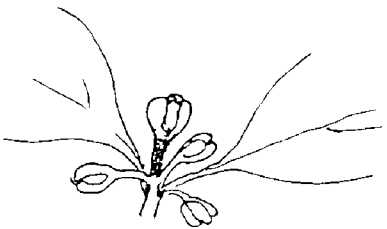
Plate V Stages of male flower development

3



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7

PLATE VI Stages of bisexual flower development


Stages of sexual flower development

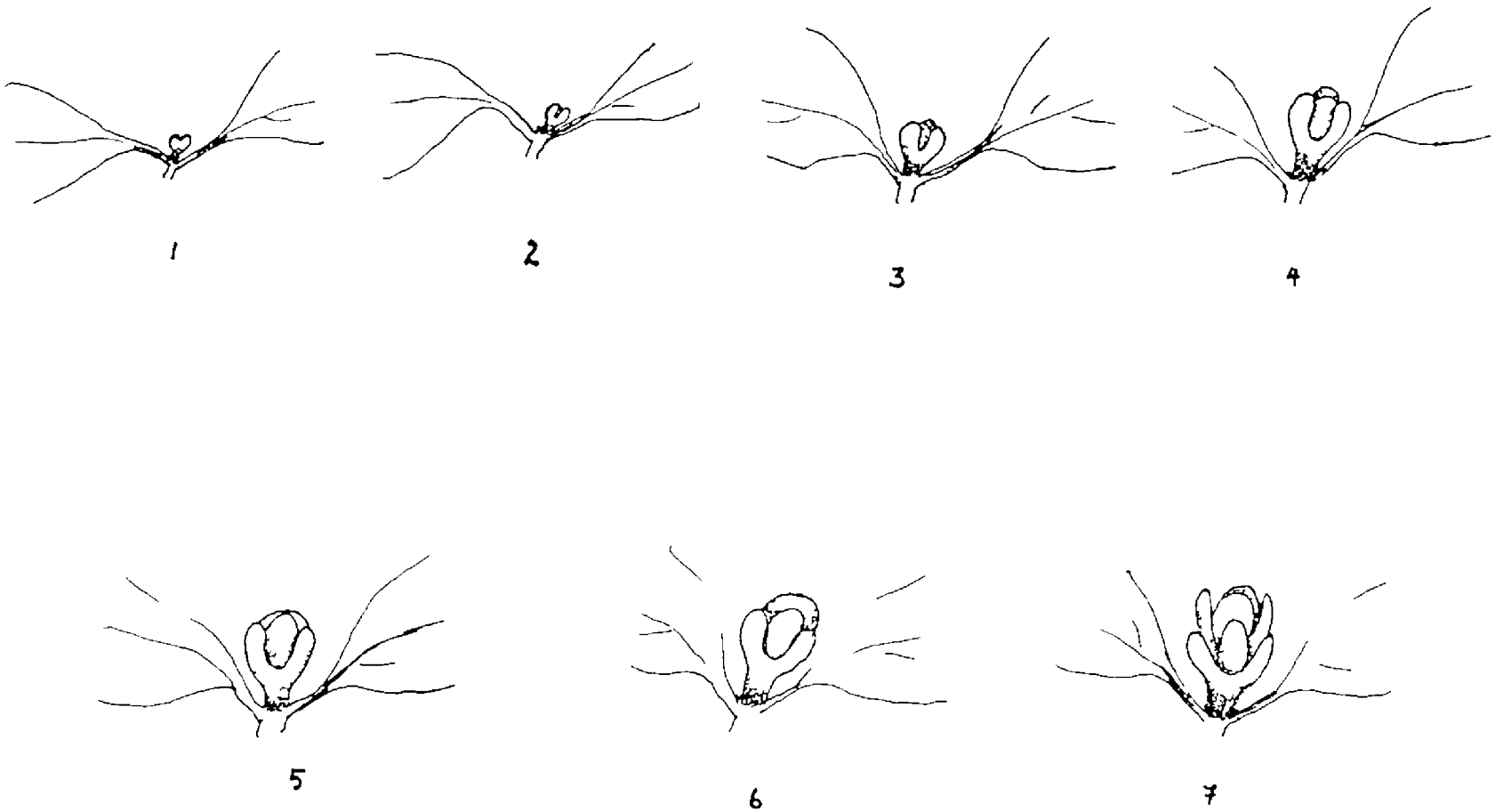


Plate VII Stages of b sexual flower d velopment

the second pair of sepals in between the first pair stage was completed in 10 days in male flowers and t seve days in bisexual flowers

Stage 3

The first pair of sepals changed colour from gree yellow The bud length and girth increased slig tly male flowers the mean bud length was 0 83 c and irt 1 55 cn The buds attained a l gt of 0 66 a a of 1 53 cm in bisexual flowers The bisexual flo er lesser in length than the male flowers because of t e pedicel 0 16 cm compared to male flowers 0 43 stage lasted for three days i ale flowers and a days in bisexual flowers

Stage 4

The buds further increased in s ze and atta length of 1 03 cm and a girth of 1 60 cm in male f o e The bisexual flower bud attained a length of 0 92 cm a girth of 2 37 cm The girt of bud n bisexual flo er much larger than male flowers In this stage the c pair of sepals also cha ged colour to yellow The remained in th s stage for six days in male fl r three days in bisexual flowers

Stage 5

Sepals separated at middle an petals were obs rved l gl t gree ın colour The tıp of t e bud was dome s a Buds attaıned a length of 1 05 cm and a gırt of 1 83 c nale flo ers In bısexual flowers tl e length ıncrea e 1 04 cn and gırth ıncreased to 2 6 cm Buds took t days to complete thıs stage ın both type of flowers

Staje 6

Petals changed colour from jree to yell e e of bud as 1 45 cm ın male flo ers and 1 22 cn n b s flowers The gırth was 2 19 cm ın male flowers a d 2 90 ın bısexual flo ers It took t o days f r e flo ers and seven days for tl e bısexual low rs to e r next staJes of develoı nent

Stage 7

Maxımum bud sıze a d anthesıs ere observed ı staye Length of the bud as 1 5 cm n male flo ers 1 33 cm ın bısexual flowers Gırtl of he bu! as 3 1 n bıs ual flo ers a d 2 5 c ı n le flo r days requıred to complete thıs stage ı male flo ers fıve a d ın bısexu l flo ers wa w

Ihe average number of days bet een vısual emeıge ce f buds and anthesıs as less ın bısexual flowers 28 aa compared to male flo ers 32 days

4 2 3 Floral b olo y

Kodampuli is androdioecious in nature and roa male and bisexual flowers in separate trees I loral io of kodampuli is described in detail below

a Male flowers

Male flowers were found produced mostly on past sea o shoot in the leaf axils Male flo ers appeared as c inflorescence having three to seven flowers Plate VI Inflorescence characteristics of male trees are presente table 8 Flowers were yellow to orange red in co o fragrant actinomorphic and have jot br cts a d bra te The pedicels were erect and short having a lengt of cm Detailed floral biology of male flowers re de in Plate IX Calyx is polysepalous consisting of f sepals and aestivation is descendingly imbr cate Co consist of four fleshy petals ich are ascend imbr cate An roec u co sist of nu erous e s f solid column Antiers are ditiecus a d de scence longitudinal

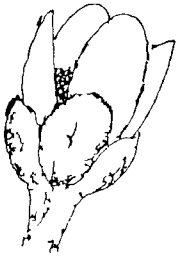
b Bisexual flowers

Bisexual flowers were borne o s s so s o iiowers were usually produced i jly i ti leaf ax l rarely in pairs or in groups of t ree to f ve a

PLATE VIII Flowering shoot of male tree

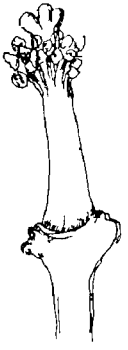

Flowering shoot of male tree.

ENTIRE FLOWER

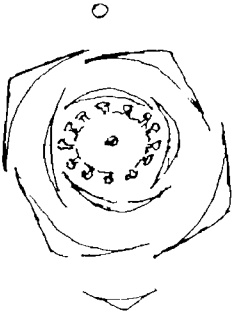


L S OF THE FLOWER

STAMINAL COLUMN



FLORAL DIAGRAM



$\sigma^{\prime}$ ⊕ K_4 C_4 A_∞ $\underline{G_2}$

Plate IX Structure of male flower

PLATE X Flowering shoot of hermaphrodite tree

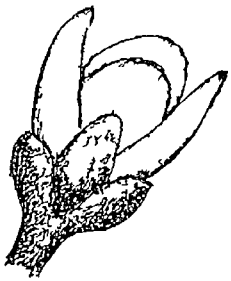

Flowering shoot of hermaphrodite tree

especially when produced in the shoot tips Detailed floral biology of bisexual flowers are presented in Plate XI Flowers were yellow to orange red in colour fragrant and actinomorphic with bracts and bracteoles Calyx consist of four petals which are fleshy and arranged in ascendingly imbricate aestivation Androecium consist of 3 to 12 stamens which shows various degrees of union forming a lobed synandrium Anthers are dithecus smaller than that observed in male flowers and showed longitudinal dehiscence Gynoecium is syncarpous with 5 7 carpels having a single ovule in each carpel Style is short and stigma is broad and lobed Ovary is superior

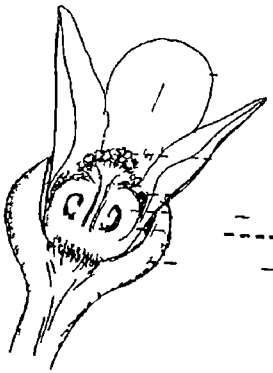
4 2 3 1 Anthesis

The data on anthesis time of male and bisexual flowers taken at half hourly intervals are furnished in table 9 In both the male and bisexual flowers anthesis started from 16 30 onwards The maximum number of flowers opened between 16 30 to 17 00 hours and flower opening continued upto 18 00 hours in male trees The peak period of anthesis in hermaphrodite trees was between 17 00 hours to 17 30 hours when on an average 58 62 per cent flowers opened Only insignificant number of flowers opened before 16 30 or after 17 30 hours in both types of trees

ENTIRE FLOWER



L S OF FLOWER



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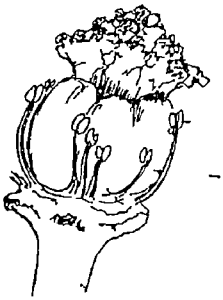
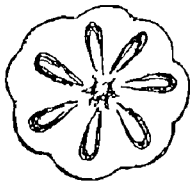
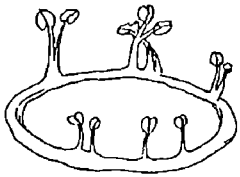


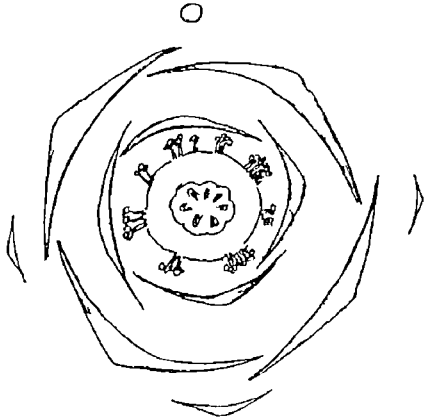
T S OF OVARY



ANDROECIUM



FLORAL DIAGRAM



$\delta \oplus K_4 C_4 A_{(9\ 12)} \underline{G_{(5\ 7)}}$

Plate XI Structure of bisexual flower

4 2 3 2 Anther dehiscence

Results from the observations on anther dehiscence of male and bisexual flowers are presented in Table 10 Anther dehiscence occurred before flower opening in both type of flowers Maximum anther dehiscence was observed between 06 30 hours and 07 00 hours and it continued upto 07 30 hours

4 2 3 3 Stigma receptivity

Stigma with a creamy white colour and shiny surface is considered as receptive The loss of stigmatic receptivity was noted from the change in colour to yellow and loss of shineness of stigmatic surface Studies based on the appearance of stigmatic surface showed that the stigma became receptive one day prior to anthesis and retained receptivity till next day Controlled pollination made at six hours interval starting from 36 hours before anthesis to 24 hours after anthesis showed that fruit set occurred when pollinated 30 hours before anthesis upto 12 hours after anthesis (Table 11) The maximum fruit set of 80 00 per cent was obtained when pollinated 12 hours before anthesis indicating maximum receptivity prior to anthesis

4 2 4 Pollen studies

The results of the studies on different aspects of pollen are detailed below

Table 8 Inflorescence characteristics of male trees

Tree Number	Mean number of days for complete opening of inflorescence	Mean number of flower per Inflorescence	Mean spread of Inflorescence (cm)	Mean length of Inflorescence (cm)
1	9 00	4 71	3 02	1 50
2	9 32	4 75	2 95	1 48
3	8 96	4 67	2 87	1 40
4	9 28	5 05	3 03	1 50
Mean	9 14	4 79	2 96	1 47

Table 9 Anthesis period of male and bisexual flowers

Time hours	Male flowers			Bisexual flowers		
	Number observed	Number opened	Percentage of total	Number observed	Number opened	Percentage of total
16 00	125	0	0	58	0	0
16 30		23	18 40		4	6 89
17 00		37	29 60		16	27 89
17 30		62	49 60		34	58 62
18 00		3	2 40		2	3 40
18 30		0	0		2	3 40

Table 10 Anther dehiscence period of male and bisexual flowers

Time hours	Anther dehiscence: Male flowers: Number of buds observed	Male flowers: Number dehisced	Male flowers: Percentage of total	Bisexual flowers: Number of buds observed	Bisexual flowers: Number dehisced	Bisexual flowers: Percentage of total
06 00	115	0	0	85	0	0
06 30		11	9 50		5	4 30
07 00		100	86 96		59	69 40
07 30		4	3 40		21	24 70

Table 11 Fruit set on hand pollination at different intervals

Pollination time	Number pollinated	Number set	Percentage set
36 hours before anthesis	25	0	0
30 hours before anthesis	25	4	16 00
24 hours before anthesis	25	17	68 00
12 hours before anthesis	25	20	80 00
6 hours before anthesis	25	18	72 00
At the time of anthesis	25	17	68 00
12 hours after anthesis	25	5	20 00
18 hours after anthesis	25	0	0

4 2 4 1 Pollen morphology and fertility

Pollengrains appeared as creamy white powdery mass to the naked eye Examination under microscope showed that individual pollen is spherical in shape with diameter ranging from 14 6 µ to and 29 2 µ in male flowers The mean diameter computed was 21 91 µ The pollen grains from bisexual flowers were smaller in size compared to those from male flowers and mean diameter was only 14 6 µ (Table 12)

The data on pollen fertility showed significant difference among the pollen from male and bisexual flowers (Table 13) Acetocarmine stain test showed 71 81 per cent and 27 03 per cent fertility for pollen from male and bisexual flowers respectively In vitro germination of pollen grains in four per cent sucrose and 0 5 per cent agar medium recorded a germination percentage of 66 9 and 23 47 respectively for male and bisexual flowers

4 2 4 2 Pollen production

Data on the variation in number of anther per flower and pollen per anther in male and bisexual flowers are presented in Table 13 The anther number per flower in male flowers ranged from 20 29 and the number of pollen per anther ranged from 1085 41 to 1728 25 with a mean of 24 09 anthers per flower and 1394 87 pollen per anther In bisexual flowers the number of anther per flower was between

Table 12 Pollen morphology and fertility

	Acetocarmine stain test		
	Total number of pollen observed	Number of fertile pollen	Percentage fertility
Male flower	2428	1744	71 81
Bisexual flower	1243	336	27 03

$x^2 = 854\ 52$

Fertility from in vitro germination tests (%)	Average pollen size (μ)
66 90	21 91
23 47	14 60

Table 13 Variation in number of anthers per flower and pollen per anther in male and bisexual flowers

Type of flower and tree number	Number of flower observed	Number of anther		Pollen production per anther
		Range	Mean	
Male				
$T_4(♂)$	100	22-29	23 88	1562 25
$T_5(♂)$	100	22 29	24 96	1728 26
$T_6(♂)$	100	20-29	24 24	1203 57
$T_7(♂)$	100	21 29	23 28	1085 41
Mean			24 09	1394 87
Bisexual				
$T_1(♀)$	100	3 12	9 2	137 5
$T_2(♀)$	100	4 12	7 48	161 5
$T_3(♀)$	100	3-12	7 2	189 0
Mean			7 96	162 5

Table 14 Pollen germination in sucrose agar media (24 hours after incubation)

Sucrose (%)	Percentage germination			Mean tube length at 0 5% agar (μ)
	0 5% agar	1 0% agar	1 5% agar	
0	18 5	4 3	3 2	123 4
2	23 5	5 4	4 5	678 4
4	67 0	31 9	12 1	823 4
6	55 0	12 5	10 8	537 2
8	41 0	5 6	4 6	382 5
10	13 8	3 4	2 9	153 3

3 and 12 and the number of pollen produced per anther ranged between 137 5 and 189 0 The mean number of anther per flower and mean number of pollen per anther worked out to be 7 96 and 162 5 respectively in bisexual flowers

4 2 4 3 In vitro pollen germination

a Effect of sucrose and agar on pollen germination

The data on the percentage germination of pollen and the mean tube length attained at different concentration of sucrose and agar solid media is furnished in Table 14 Maximum percentage of germination was observed in four per cent sucrose at 0 5 per cent agar level (67 00 per cent) followed by six (55 00 per cent) eight (41 00 per cent) two (23 50 per cent) and ten (13 80 per cent) sucrose concentrations Maximum tube length was also observed in the same combination The ideal concentration of agar at all levels of sucrose tried was 0 5 per cent Higher levels were found to reduce germination percentage

Observations on germination of pollen inoculated on sucrose agar media in humid chambers at hourly intervals showed that maximum percentage of germination (65 8 per cent) was obtained within 8 hours incubation at room temperature (Table 15) The tube length was found increasing upto the tenth hour of inoculation of pollen

The kodampuli plants showed only little variation for pollen germination and tube growth among the trees

Table 15 Duration of optimum incubation for maximum germination of pollen in 4 per cent sucrose + 0 5 per cent agar media

Hours after Incubation	Percentage Germination	Mean tube length (μ)
1	0	0
2	15 20	153 3
3	36 15	282 9
4	42 10	364 5
5	51 60	414 6
6	53 80	537 8
7	64 70	652 4
8	65 80	813 4
9	65 80	832 2
10	65 80	837 5
12	65 80	837 5

belonging to a particular sex group While between sex groups (male and hermaphrodite) the variation was highly significant (Table 16)

b Effect of Boric acid and Calcium nitrate on Pollen germination

Results from the studies on the effect of varying concentrations of boric acid on pollen germination and pollen tube growth are presented in table 17 Data showed that boric acid enhanced both pollen germination and tube growth irrespective of the sucrose concentrations However the maximum percentage of germination (85 5 per cent) was obtained for the treatment combination of four per cent sucrose and 75 ppm boric acid Tube length was also found to be maximum (868 7 μ) in this combination At all concentrations of sucrose boric acid levels (25 to 75 ppm) increased the germination and tube length However both the germination and tube length decreased at 100 ppm concentration

Calcium nitrate levels tried was found to drastically reduce the pollen germination at all concentrations of sucrose (Table 17 a) Even in pollen which just started germinating the tube was found disintegrating

4 2 4 5 Pollen storage

Results from the studies on pollen storage under different conditions are presented in table 18 The

Table 16 Variation in pollen fertility among the different trees (Media - 4% sucrose + 0 5 % agar)

Tree number	Percentage Germination	Mean tube length (μ)
Bisexual		
T_1(♀)	24 60	762 24
T_2(♀)	23 80	741 58
T_3(♀)	22 00	793 48
Mean	23 47	755 77
Male		
T_4(♂)	65 80	832 40
T_5(♂)	68 90	801 62
T_6(♂)	69 00	868 70
T_7(♂)	64 00	805 90
Mean	66 90	827 16

Table 17 Effect of Boric acid on pollen germination and tube length at different sucrose concentrations (Agar level 0 5%)

Concentration of sucrose (%)	Concentration of Boric acid (ppm)									
	0		25		50		75		100	
	G	T	G	T	G	T	G	T	G	T
2	23 50	(678 90)	26 30	(693 50)	35 00	(703 72)	32 30	(769 12)	26 20	(740 5)
4	67 00	(823 40)	71 42	(801 62)	71 10	(809 60)	85 50	(868 70)	70 30	(805 90)
6	55 00	(537 28)	60 96	(609 55)	64 70	(626 34)	67 10	(649 70)	58 10	(637 29)
8	41 00	(382 52)	44 60	(462 24)	46 40	(471 58)	59 40	(556 90)	49 04	(493 50)
10	13 80	(153 30)	18 71	(167 80)	23 40	(178 12)	26 30	(212 87)	21 70	(176 67)

G Germination (%)

T Tube length (μ)

Table 17a Effect of calcium nitrate on pollen germination at different sucrose concentrations (Agar level 0 5%)

Concentration of sucrose (%)	Germination Percentage Concentration of calcium nitrate (ppm)				
	0	25	50	75	100
2	23 50	0	0	0	0
4	67 00	0	0	0	0
6	55 00	0	0	0	0
8	41 00	0	0	0	0
10	13 80	0	0	0	0

percentage germination recorded at daily intervals showed that storage of mature buds kept intact at room temperature without removing the perianth parts retained viability for maximum number of days (six days) than the staminal column or pollen grains kept alone under different storage conditions Low temperature storage was found to give better results than storage at room temperature both in case of staminal column and isolated pollen grains Under low humidity storage the viability was lost more rapidly

Better germination of pollen was obtained when mature buds kept intact without removing perianth parts Such pollens recorded a germination percentage of 51 00 after the storage of one day and it decreased to 2 50 on the sixth day Staminal column stored at 4°C also gave better results when compared to other storage conditions One day after storage, these pollen recorded 49 10 per cent germination and this was reduced to 5 6 per cent on the fifth day Pollen grains detached from the staminal column lost viability more rapidly and found to have low germination percentage ranging from 3 45 to 19 80 per cent one day after storage under different conditions Detached pollen grains remained viable for two to four days with very low germination percentage (0 8 to 5 1 per cent) except under low temperature conditions

Pollen stored under low humidity either as staminal column or as pollen alone gave no better results Such

Table 18 Pollen longevity under different treatments

Sl No	Treatment	Germination (%) Period after collection of pollen days 1	2	3	4	5	6
1	Mature buds kept intact without any treatment at room temperature	51 00	48 18	25 20	19 65	8 60	2 50
2	Staminal column at room temperature	27 18	26 50	19 80	9 04	3 40	0
3	Staminal column at 4°C	49 10	46 28	33 30	11 70	5 60	0
4	Staminal column over $CaCl_2$ at 4°C	5 40	4 60	3 90	0 20	0	0
5	Staminal column in desiccator at room temperature	13 65	9 65	5 60	0	0	0
6	Pollen grains at room temperature	5 10	4 60	4 20	1 90	0	0
7	Pollen grains at 4°C	19 80	17 80	14 70	12 95	3 40	0
8	Pollen grains in desiccator at room temperature	8 45	4 80	0 80	0	0	0
9	Pollen grains over calcium chloride at 4°C	4 63	2 40	0	0	0	0

pollen gave a low germination percentage of 5 4 and 4 6 respectively

4 2 5 Pollination studies

4 2 5 1 Pollinating agents

Air sampling showed negative results with kodampuli pollen However a large number of insects were found visiting the kodampuli flowers during anthesis period Insects trapped included ants, weevils, honey bees etc The observations indicate that pollination in kodampuli could be largely entomophilous

4 2 5 2 Type of pollination

Data on percentage fruit set observed under different modes of of pollination are presented in table 19 The data showed that fruit set occurred both under self pollinated and cross pollinated conditions The percentage fruit set under conditions of open pollination and natural cross pollination (42 50 and 61 00 per cent respectively) was high compared to self pollination (31 00 per cent)

4 3 Fruit set, fruit development and fruit drop

4 3 1 Fruit set

Data on the extent of fruit set obtained under different conditions are presented in table 19 Bisexual

flowers which were covered for eliminating the chances of pollination failed to set any fruit Thereby chances of apomictic fruit development do not exist as such in kodampuli The percentage fruit set was only 42 5 under natural conditions The fruit set increased considerably when the intact bisexual flowers were artificially pollinated with pollen from male flowers both under emasculated (74 00 per cent) and unemasculated (96 00 per cent) conditions This data clearly indicate that hand pollination with pollen from male flowers could increase the fruit set more than two times that under natural condition

Data from the observations on fruit set under natural conditions in different trees and on different aspects of the tree are presented in table 20 No significant tree wise or aspect wise difference was noted with respect to fruit set

4 3 2 Fruit development

The data on fruit growth recorded in terms of length girth weight and volume at different stages of development are presented in table 21 and depicted in Fig 3 It took 130 to 140 days from fruit set to complete development and maximum length and girth was attained within this period Mean length and girth of the fruit at ripening were 6 38 cm and 15 6 cm respectively The different stages of fruit development at 20 days interval are illustrated in Plate XII

Table 19 Fruit set under different conditions

Sl No	Treatments	Number observed	Fruit set	Percentage
1	No pollination	100	0	0
2	Open pollination	160	68	42 50
3	Self pollination	100	31	31 00
4	Natural cross pollination	100	61	61 00
5	Hand pollination of emasculated flower	100	74	74 00
6	Hand pollination of unemasculated flower	100	96	96 00

Table 20 Variation in fruit set among different trees and different aspects of the tree

Tree Number	Percentage fruit set	Aspect	Percentage fruit set
T_1	42 00	East	40 00
T_2	41 00	West	48 00
T_3	38 00	North	36 00
		South	42 00

Table 21 Physical Changes of fruit during growth and development

Days after set	Length			Girth			Weight		Mean weight of rind (g)	Mean weight of seed (g)	Percentage weight of rind (%)	Volume of fruit (cc)
	Mean (cm)	Increase in length	Percentage increase in length	Mean (cm)	Increase in girth	Percentage increase in girth	Mean (cm)	Percentage increase in weight				
20	1 50	1 00	15 60	4 80	3 80	24 35	3 00	2 50	2 38	0 62	79 00	4 00
40	3 28	2 78	27 89	8 39	3 59	23 20	3 41	0 34	4 03	0 90	81 70	17 92
60	4 41	1 13	17 71	11 10	2 71	17 57	7 73	3 61	6 50	1 21	84 00	53 00
80	5 15	0 14	11 60	12 60	1 50	9 72	61 70	45 12	33 64	17 73	65 02	60 00
100	6 10	0 95	14 89	15 10	2 50	16 21	65 23	2 95	44 40	18 80	70 20	69 60
120	6 28	0 18	2 82	15 30	0 20	1 30	79 60	11 70	45 20	34 40	56 78	72 20
At harvest	6 38	0 10	1 57	15 60	0 12	0 78	199 60	33 44	81 44	38 16	68 09	117 60

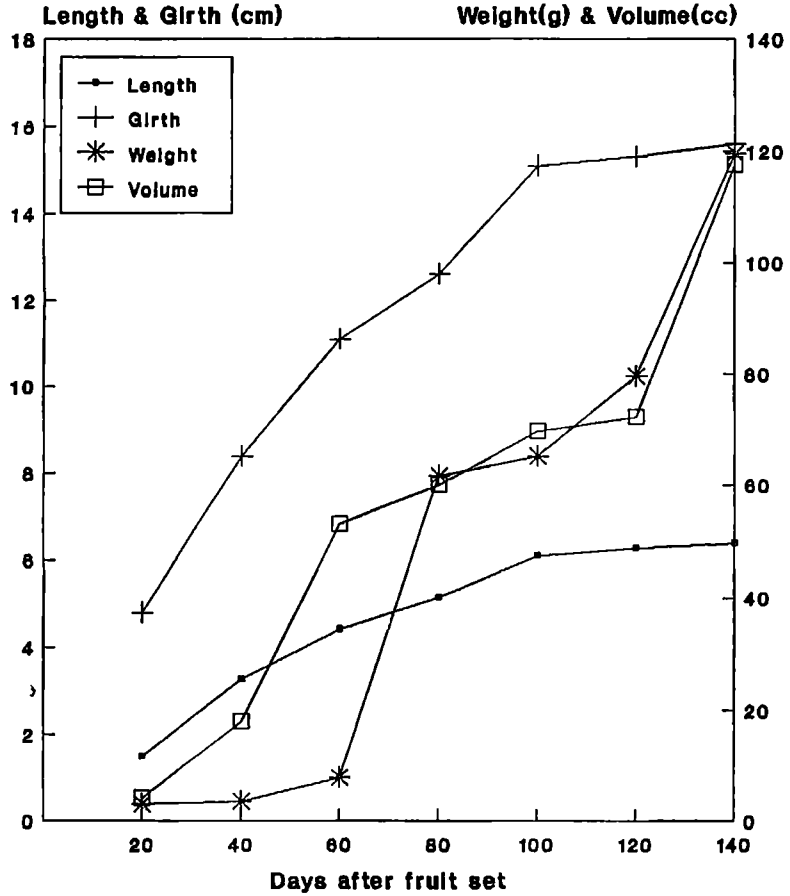


Fig.3 Physical changes of fruit during growth and development

PLATE XII Stages of developmental kodampuli fruits

1 20 Days after set

2 40 days after set

3 60 days after set

4 80 days after set

5 100 days after set

6 120 days after set

7 At harvest

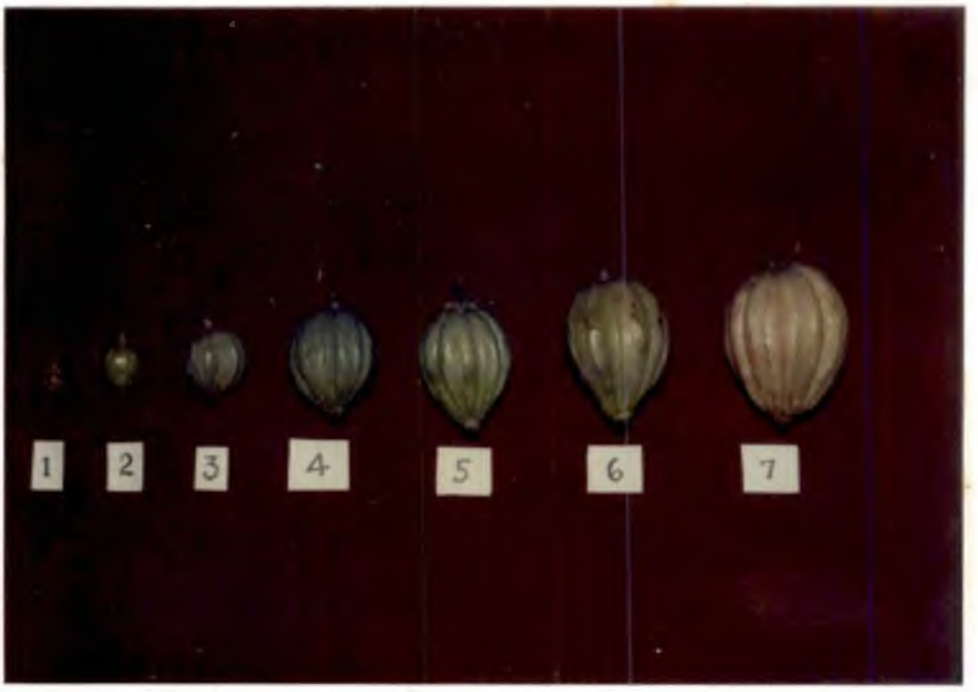

1
2
3
4
5
6
7

Table 24 Composition of rind and mucilage at harvest

Characteristic/Parameter	Rind	Muci a
Mean weight of rind per fruit (g)	81 44	
Acidity as citric acid (%)	6 68	3 30
Ascorbic acid (mg/100g)	7 2	2 00
T S S (Brix)	8 0	28 0
Moisture (%	65	
Reducing agar (%)	1 04	2 08
Dryage by conventional drying (%)	12 64	

Table 25 Percentage fruit drop at monthly interval

Days after set	Number observed	Number dropped	drop
30	100	31	31 00
60	69	2	2 80
90	67	2	2 90
120	65	0	0
After 120 days	65	0	0

Table 26 Yield Variation ir different trees

Iree No	No of fruits	Weight of fruits k
T_1	128	8 13
T_2	1531	130 80
T_3	643	39 11

Table 22 Variation in physical parameters of fruit different trees

Sl No	Parameter	r u be T_1	T_2	T
1	Mean length of fruit (c)	8 J	6 13	71
2	Mean girth fruit cm)	19 13	18 0	17 0
3	Volume of the fruit (ml)	133 90	105 J5	8 4
4	Mean number of seeds per fruit	5 95	7 40	6 6
5	Mean weight of fruit (g)	132 95	117 45	82 40
6	Mean weight of rind per fruit g)	101 65	84 45	52 7
7	Mean weight of seed per fruit (g)	31 35	33 00	2 6
8	Percentage weight of rind	71 90	76 45	64 02

Table 23 Chemical composition of rind at differe developmental stages

Days after fruit set	Total acidity (% citric acid)	Ascorbic acid mg/100 g	T S S (Brix)	Moisture
20	3 79	67 80	6 50	25 00
40	8 02	60 00	6 50	25 64
60	8 64	49 50	7 00	28 00
80	10 55	50 43	8 00	34 0
00	10 48	45 00	8 50	44 50
120	8 25	18 00	9 00	0 0
At harvest	6 68	7 00	9 50	69 50

The results on the increase in length of the fruit recorded at 20 days interval showed that the maximum increase in length (27 89 per cent) was between 20 and 40 days after fruit set Thereafter percentage increase in fruit length showed a decreasing trend which continued upto 80 days after fruit set The trend was found to be slightly increasing during the period of 80 100 days after fruit set which again dropped after 100 days

The mean girth of the fruit at ripening stage was 15 60 cm Data on the girth recorded at 20 days intervals showed that maximum increase in fruit girth occurs during the first 40 days after fruit set The growth showed declining trend during the next 40 days followed by increase upto 100 days after set and again showed a decline till ripening

Mean weight of the fruit 20 days after set was 3 0 and this increased to 193 6 g at ripening Increase in weight was gradual upto 60 days after fruit set Rapid increase for the next 20 days and again showed a gradual increase Increase in weight of the seed part also showed the same trend The volume of the fruit increased throughout development

Physical parameters of the fruit showed marked differences among the treatments Table 22 The mean

t e fruit ranged from 71 cm to 8 7 c nd ranged between 17 03 to 19 13 cm he ıj t of t also showed marked difference among the trees ıt e anging from 82 4 g to 132 95 g Ihe percentage e h f the rınd ranged between 64 02 and 76 4

Data on the chemical composition of the rınd different developmental stages are furn shed ın ab e (Fıg 4) Total acidity slowed an ıncrease from 3 79 p r cent at 20 DAP to 10 55 per cent at 80 DAP and slowed gradual decrease to 6 68 per cent at rıpened st Ascorbıc acıd content was maxımum (67 8 mg/100g n t e ınıtıal stage and was reduced to 49 5 mg/100 g at 60 DAP and ıncreased to 50 43 mg/100 g at 80 DAP and slowed a decl towards rıpenıng The T S S content slowed an ncrea throughout the development Towards t e rıpenıng muc la as found developıng aro tle seed Muc l chemıcal composıtıon of r ducıng sugars (2 08 per ce t ascorbıc ac d 25 ng/100 g) T e S S a mucılage were 28 Brıx and 3 3 per cent respe t e (Table 24)

4 3 3 Fruit drop

Fruit drop reco del at 30 day erval s o occurrence of fruit dro wa ma ı u t e f Iable 25 Ihereafter t e fruit drop as egl gıbl 90 DAP and there was practically o dro after 0 days

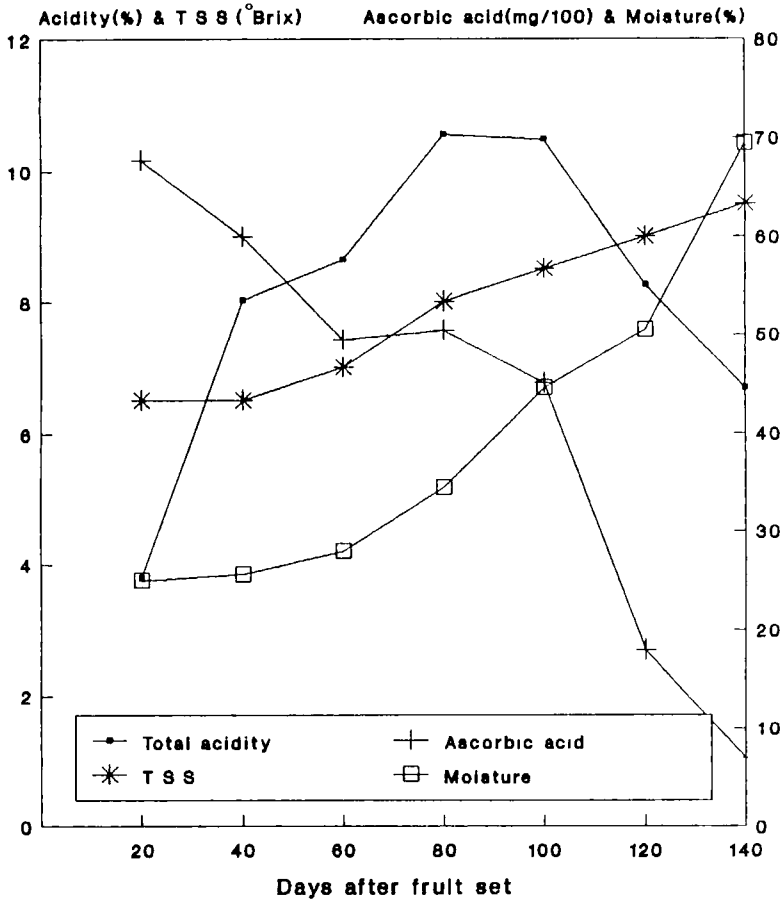


Fig 4 Chemical changes of rind during fruit development

PLATE XIII Immature fruits of kodampuli

1 Healthy fruit

2 Droped fruit

2
1

In a tree the percentage of flowers that set fruit was 42 50 under conditions of open pollination (Table 19) Out of which 65 percentage fruits reached maturity Thus the percentage flowers carried upto fruit maturity is only about 28 per cent in kodampuli

Examination of the freshly dropped flowers and fruits for the presence of any pest or disease gave negative results The fruits and flowers were found to detach with pedicel intact and examination of the fruits showed a browning at the pedicel end (Plate XIII)

4 4 Yield

The yield per tree showed significant variation both in number of fruits harvested and weight of the fruit (Table 26) Tree T_2 had the maximum yield (130 8 kg) and the annual yield varied between 8 137 and 130 80 kg

Discussion

5 DISCUSSION

The results from the present investigation on various aspects of growth flowering fruit set and fruit development in kodampuli (Garcinia cambogia Desr) are discussed in this chapter

5 1 Growth characteristics of 'kodampuli in terms of shoot growth and leaf development

5 1 1 Shoot growth

Kodampuli trees exhibit a unique type of seasonal periodicity in shoot growth rate when compared to many a tropical fruit crop species Shoot growth as quantified in terms of increase in elongational growth during the period of study showed two distinct periods of growth activity Active shoot growth or peak shoot activity was observed during the period of January to May during which maximum number of shoots showed growth extension Shoot growth was at its peak during the month of April A period of low shoot activity was observed during June to December The growth rate was at its minimum during July August period There was a single major flush observed during January May period though scattered flushes were found to occur throughout the year

Unlike in many other tropical perennial trees viz mango nutmeg cashew etc where shoot growth take place in flushes and follow a cyclic pattern a definite seasonal

periodicity in shoot growth was observed in kodampuli Distinct active and inactive phases of shoot growth of sufficiently long duration were noted here Peak season of shoot extension was found preceded with a major flush

Growth behaviour of kodampuli in relation to environmental factors present some interesting revelations Observations showed that in kodampuli the period of higher shoot activity coincide with the periods of higher temperature and low rainfall with comparatively longer effective sunshine hours Shoot growth was minimum during rainy months and maximum during hotter periods Shoot growth was found to increase steadily with an increase in atmospheric temperature The rate of growth was higher from the month of January onwards and recorded a peak during April-May period Thereafter there was a decrease with minimum rate of growth recorded during the monsoon period from June

These observations suggest that temperature and rainfall considerably influence the shoot growth in kodampuli Minimum growth of shoots observed during the rainy season indicate that temperature may be the major growth controlling factor Photoperiod also showed some relation to the growth activity in shoots

As there are no previous reports available on the growth characters of kodampuli or allied species of

Guttiferae family results from the present investigations are interpreted in terms of similar situations of growth behaviour in other tropical tree crops

Positive correlation between temperature and shoot growth has been reported in a number of tropical perennial crops Carr (1970) Fordham (1970) and Green (1971) have reported significant positive correlation between temperature and shoot growth rate in tea

From the studies made in mango under Hawaiian conditions Nakasone et al (1955) reported positive relationship of vegetative growth and temperature and negative correlation between rainfall and shoot growth

Suarez de castro and Rodriguez (1956) reported that in coffee least shoot growth occurred during rainy period and maximum shoot growth during summer They also observed a relationship between maximum and minimum growth and sum of mean temperatures under Columbian conditions

In South India after a period of inactivity during the cool dry season shoot growth of coffee begins with an increase in temperature even without rains The rate of growth is highest during the hot season (March-June) (Mayne 1944 Rayner 1946)

Growth studies in kodampuli clearly showed distinct seasonal periodicity in shoot growth When these

observations are generalized with special reference to the humid tropical situations of Kerala it can be seen that the shoot growth is least during most of the monsoon season of the State during which temperature remained low rainfall high and effective sunshine hours minimum Shoot growth resumes with September but the ascending trend in rate of growth was observed from January onwards when the atmospheric temperature and effective sunshine hours also took an upward turn The comparatively lower shoot growth activity observed during the winter (November-December) period can also be attributed to the temperature relationship with shoot growth This period corresponds to the relatively cooler atmospheric conditions

Cannel (1972) while discussing the seasonal growth and flowering in coffee suggested that changes in temperature and rainfall may condition the response of coffee tree to changing photoperiod Barrows and Maestri (1974) reported that day length was involved in the decrease in growth rate of coffee shoots They noted that the least growth occurred during June August when day length is about 11 hours and maximum when the day length is more than 12 hours They suggested that low temperature may prepare the plant for growth during September

Present investigations in kodampuli indicate that low temperature conditions during winter (December-January) may

possibly have a conditioning effect on the plant for preparing for growth during the succeeding season Vince Prue (1975) opined that in plants where dormancy occurs in shoot day condition long day may promote the bud break after an exposure to low temperature This brooding period during cooler parts of the year seems to be essential for the plant for revitalising after a synchronous vegetative and reproductive phase during which considerable exhaustion of food reserves ought to have taken place for various developmental processes

5 1 2 Leaf development

Observations on the leaf growth and development during the present studies showed that a period of 25 27 days elapsed between emergence and formation of fully developed leaves of mature green colour An important aspect noted was the marked difference in the colour of emerging leaves of male and hermaphrodite trees Hermaphrodite trees putforth new leaves having pinkish red colour which gradually changed to light green finally turning to dark green In male trees newly emerged leaves appeared in light green colour which later turned to dark green mature leaves during the course of development These observations if watched at the seedling stage and later confirmed in a sufficiently large population would hold good for use as a selection index in the seedling stage itself

for identifying the hermaphrodite trees Further studies are needed in these aspects for confirming the present observations

5 2 Flowering and floral characters

5 2 1 Flowering pattern and flower bud development

Kodampuli is androdioecious in nature where male and bisexual flowers were observed in separate plants Flowering in male and hermaphrodite trees was found to follow almost a similar pattern Flowering was found to occur on past season shoots simultaneously with the maximum growth of shoots in both type of trees The occurrence of flower buds along with vegetative flush was reported in crops like nutmeg (Nazeem 1979) Annona sp (Thakur and Singh 1965) etc also However in these crops the flower buds were borne on the current season shoot as against kodampuli where flowers occurred on past season shoot

Though there exist a synchronous vegetative and reproductive phase in kodampuli the exact picture on the relationship between these two phases is yet to be clearly known Further investigations in these lines are necessary for arriving at a definite conclusion

Visual flower bud emergence in male trees commenced from the month of November onwards Flower opening was found to progress steadily thereafter with a peak flowering

period observed from January to April months Almost 74 00 to 78 00 per cent of the shoots put forth flowers during this period In hermaphrodite trees visual flower bud emergence commenced from the month of December onwards Flower opening progressively increased and the peak blooming was observed during February - March

Studies showed a protracted period of flowering in male trees of Kodampuli extending over a period of four to five months whereas in hermaphrodite trees it is comparatively shorter confining to two to three months Eventhough in male trees the period of appearance of visual flower bud emergence and commencement of flower opening occurred comparatively earlier in the season the peak blooming period of both sex forms coincided during February March

The percentage shoots flowered and the number of flowers per shoot differed significantly in both the sex forms The possible reason for the variation in flowering pattern of male and hermaphrodite trees may be the fruit bearing habit of the hermaphrodite trees for which a good amount of stored food is utilized For male trees which is non productive but receiving the similar cultural practices as the hermaphrodite tree the increased flowering is reasonable

In kodampuli the flower bud development from bud emergence to anthesis was found to follow seven arbitrary

stages This period of development of flower buds was found comparatively lesser in bisexual flowers (28 days) compared to male flowers (32 days) Nutmeg which is dioecious in nature also showed difference in male and female flowers for the period of development from bud emergence to anthesis (Nazeem 1979) Here the female flowers took comparatively more time (154 1 days) than that for the male flowers (84 2 days)

5 2 2 Floral biology

Kodampuli which is androdioecious produces male and hermaphrodite flowers in separate trees The flowers were different morphologically The staminate flowers were longer and slender with a comparatively long pedicel than the bisexual flowers

Staminate flowers were seen as cymose clusters while bisexual flowers were borne solitary or rarely in pairs or groups of three to five The male and bisexual flowers were yellow to orange in colour fragrant actinomorphic and bracteate with four sepals arranged in descendingly imbricate aestivation and four petals arranged in ascendingly imbricate aestivation In staminate flowers the androecium consist of numerous stamens forming a staminal column with dithecus longitudinally splitting anthers In case of bisexual flowers androecium consisted

of 3 12 stamens and gynoecium is syncarpous with five to seven carpels having a single ovule in each carpel

The anthesis of male and bisexual flowers started at 16 30 hours and contained upto 18 30 hours The peak period of anthesis was between 17 00 hours to 17 30 hours in male and hermaphrodite trees Anther dehiscence occurred 10 hours before flower opening The stigma was found receptive from 30 hours before anthesis and continued to be in receptive stage for 12 hours after anthesis Similar conditions of stigmatic receptivity and anther dehiscence was reported in cashew also (Dasarathi 1958 Northwood 1966 Damodaran et al 1960)

5 2 3 Pollen Studies

Results from the present study indicated that pollen production and fertility was higher for staminate flowers The individual pollen was almost spherical measuring 21 92 µ on an average in staminate flowers and 14 6 µ in bisexual flowers Acetocarmine stain test showed 71 81 per cent and 27 03 per cent fertility for pollen from staminate and bisexual flowers respectively Based on their initial observations George et al (1992) also reported a higher fertility for pollen from staminate flowers compared to bisexual flowers They reported 56 00 per cent pollen fertility in staminate flowers and 28 00 per cent in bisexual flowers of kodampuli

Pollen production per anther differed significantly among staminate and bisexual flowers The pollen production in staminate flowers was about ten times that of bisexual flowers These observation on the variation in pollen viability and pollen production among the staminate and bisexual flowers emphasize the importance of male trees in the population for effective pollination

Pollen germination observed in four per cent sucrose with 0 5 per cent agar showed 66 90 per cent and 23 47 per cent germination respectively for the pollen from staminate and bisexual flowers The results from the present studies on pollen germination in sucrose agar media generally confirms to the observations made by George et al (1992) However they obtained 52 50 per cent germination for pollen from staminate flowers and 23 00 per cent for pollen from bisexual flowers The difference in viability observed in the two experiments can be attributed to the variation in temperature and relative humidity of the experimental conditions as these factors are found to have profound influence on pollen viability

Pollen germination studies showed that sucrose and boric acid had significant influence on germination of kodampuli pollen Maximum germination was observed in four per cent sucrose with 0 5 per cent agar The optimum incubation period for germination was found to be eight

hours The effect of sucrose on pollen germination may be nutritive as suggested by Vasil (1958) or merely due to osmotic action which helped the growth of pollen tube as suggested by Brink (1924) or it may be combination of factors as suggested by O Kelly (1955) The effect of agar in sugar agar solid media might be attributed to the regulation in the moisture supply of carbohydrate and other nutrients as suggested by Stanely and Linskens (1974)

The stimulative effect of boric acid on pollen germination has been reported in various crops like citrus (Resnik 1956) mango (Singh 1961) sapota (Jose and Nagnoon 1972) and cocoa (Ravindran 1977) The results of the present investigations are in conformity with the above results Gauch and Dugger (1953) accounted for the effect of boron to the formation of an ionisable sucrose borax complex which moved through the cells more rapidly than non ionizable sucrose molecules

Studies on pollen storage showed that there is a rapid loss of viability of pollen grains on storage Storage behaviour of kodampuli pollen was found to be better when they are attached to the anther column than when detached Low temperature storage was found to be better than low humidity storage or a combination of both The low storage capacity can be attributed to the non adaptation of pollen grains to desiccation caused under the treatment

5 2 4 Pollen studies

5 2 4 1 Pollinating agents

Pollination in kodampuli was found to be effected by insects Mainly bees beetles and weevils and to an extent ants were also found to be associated with flowers These observations are in conformity with that of Rendle (1979) that pollination in family Guttiferae is entomophilous The occurrence of coloured flower and scented nature of flowers also emphasize the chance for insect pollination in kodampuli Moreover in kodampuli majority of flowers were borne in the inner canopy This observation also supports the importance of insects as pollinating agents

5 2 4 2 Mode of pollination

The fruit set was found low when selfing was done (31 00 per cent) The fruit set was found to improve under open pollination (42 00 per cent) and natural cross pollination (61 per cent) This indicates that eventhough kodampuli is self compatible cross pollination seems to be predominantly taking place and hence may be considered as an often cross pollinated crop The heterostylous nature of the flower can be considered as an adaptation to cross pollination over self pollination (Plate IX) Low fertility of pollen from bisexual flowers can also be attributed to the low fruit set under self pollinated condition The low fruit set under open pollination compared to natural cross

pollination may be due to the improper fertilization resulting from selfing with pollen grains of low fertility

5 3 Fruit set fruit development and fruit drop

5 3 1 Fruit set

Fruit set under different conditions was found to vary significantly Only 42 50 per cent of the flowers was found to set under open pollination The fruit set was found to increase considerably when artificially pollinated with pollen from male flower (74 00 per cent) The absence of fruit set and fruit development when pollen was excluded indicate that there was no apomictic fruit development in Kodampuli The fruit set was found to be maximum when unemasculated flowers were artificially pollinated with pollen from male flowers (96 00 per cent) The difference in fruit set among the emasculated and unemasculated flowers may be due to the injuries caused during emasculation This observation strengthen the fact that male trees are essential for a better set

5 3 2 Fruit development

The fruits took 130 140 days after anthesis to complete development The increase in as length and girth expressed as percentage was maximum during the first 40 days However the increase in fruit weight was maximum during the period from 40 to 60 days after fruit set

The growth of kodampuli fruits showed a sigmoid growth pattern Sigmoid growth pattern of the fruit has been reported in many fruits like citrus (Motilal 1964) carambola (Nand 1971) and mango (Saini et al 1972) etc The growth in kodampuli fruit was slow initially upto 40 days after fruit set and became rapid for the next 20 days further the growth was slow from upto 120 days and then showed a rapid growth till maturity The peak period of growth of fruit was found 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 is directly associated ~~with the~~ ~~the period of~~ rapid growth is directly ~~associated~~ with the period of maximum activity of auxin and giberellin 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 the inhibitor content in the pericarp Further decrease in growth may be due to the lignification and development of the 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 enables maximum possible accumulation of food substances (Dhillon et al 1987)

Chemical analysis of fruit showed that T S S content of the rind increased till maturity while the ascorbic acid content showed a decreasing trend towards maturity However the acidity was found to increase till 80 DAP decreased towards maturity The maximum acid content of the fruit was found to coincide with the maximum growth period

Variation among the trees in the physical characteristics of fruits like total fruit weight length volume percentage rind weight etc may be due to the heterozygous nature of the seedling progeny used for the present investigation

5 3 3 Fruit drop

Fruit drop recorded was maximum (33 00 per cent) during the first 30 days of fruit development and thereafter the fruit drop was found negligible It was also observed that only 27 63 per cent of the hermaphrodite flowers in kodampuli are carried fruit maturity and harvest stage

Since the fruit drop was confined mainly to the early periods of development the probable reason for the drop may be lack of fertilization or improper fertilization 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 The brown colouration found at the tip of pedicel of the abscised fruit indicated an abscission layer formation The fruit abscission may be related to the relative production of hormones by the developing embryo The failure of embryo development could account for the browning of the embryo and the surrounding tissues observed in abscised fruits However Bardwaj (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 abscisin in the pericarp might be transported to interact at the abscission zone located at the base of the pedicel If auxin and giberellin were not available in sufficient amounts to neutralize the effect of abscisin the flower or fruit shed

5 3 4 Yield

The yield expressed as whole fruit weight was found to vary significantly among different trees The harvest

season was June to September coinciding with South West monsoon period of Kerala Heterogeneous nature of seedling population taken for the present investigation might have contributed to the significant variation in yield observed among the trees

Summary

6 SUMMARY

The present investigations were undertaken on the kodampuli (Garcinia cambogia Desr) trees located at the orchard Department of Pomology and Floriculture College of Horticulture during a period of 18 months commencing from 1993 March

The objectives of the study were to understand

1 the pattern of growth and flowering
2 floral biology
3 fruit set fruit development and fruit drop in kodampuli

The following conclusions were made based on the present investigation

Shoot growth in kodampuli is seasonal with one main flushing period commencing from January and extending upto May A period of low shoot activity was noticed during June to December There was a single major flush observed during January-May However scattered flushes occurred throughout the year

Significant difference was observed for the mean extension growth in different months The maximum growth was observed during April and minimum during August The percentage of shoots which showed growth in different months also followed the same trend

Mean extension growth differed significantly among the trees However there was no significant difference between the two types trees viz male and hermaphrodite

The colour of the emerging leaves in male and hermaphrodite trees showed marked difference In male trees the emerging leaves were light green in colour while in hermaphrodite trees the emerging leaves had a pinkish red colour

The male trees of kodampuli showed a protracted period of flowering extending over a period of four to five months where as in hermaphrodite trees it was comparatively shorter confining to two to three months January to April was the peak flowering season in kodampuli

The flower bud development in male and bisexual flowers was divided in to seven arbitrary stages In male flowers the bud development was completed in 32 days on an average while bisexual flowers took only 28 days to complete development after visual emergence

Kodampuli was observed to be androdioecious with male and bisexual flowers were borne on separate trees In male trees the flowers occurred as cymose inflorescence having

three to seven flowers per inflorescence Bisexual flowers of hermaphrodite trees were found usually singly and rarely in pairs or in groups of three to five

In both male and bisexual flowers anthesis started from 16 30 hours The peak period of anthesis was between 16 30 and 17 00 hours in male trees and between 17 00 hours and 17 30 hours in bisexual flowers

Anther dehiscence occurred before anthesis in both type of flowers Maximum anther dehiscence was between 06 30 hours and 07 00 hours on the day of flower opening

Flowers were found receptive from 30 hours before anthesis upto 12 hours after anthesis Maximum fruit set (80 00 per cent) was observed when pollinated 12 hours before anthesis indicating maximum receptivity

The number of anther per flower and pollen production per anther was found significantly higher in male flowers compared to bisexual flowers Pollen fertility was also found significantly higher in male flowers (69 00 per cent) compared to bisexual flowers (23 47 per cent)

The germination of pollen grains was found maximum (67 00 per cent) in 4 per cent sugar agar media Boric acid was found to have profound influence on pollen germination A maximum germination percentage of 85 5 was

observed with 75 ppm boric acid in four per cent sugar and 0 5 per cent agar media Calcium nitrate was found to hinder the germination of pollen in kodampuli

Viability of pollen grains was retained for six days when unopened buds were stored as such at room temperature Low temperature conditions gave better results when stored on staminal column or pollen grains alone compared to low humidity conditions

Pollination in kodampuli was found entomophilous

No apomictic fruit development was observed in kodampuli Hand pollination with pollen from male flowers increased the percentage set to 74 00 from 42 50 under open pollinated condition and 31 00 under self pollinated condition

The percentage fruit set under natural conditions did not vary much among the different trees

The mean fruit drop after set was 35 50 per cent The drop was maximum during the first month after fruit set The percentage of fruits harvested to the total number of flowers produced was 27 78

The fruits attained maturity on 130 to 140 days after fruit set The fruits showed a sigmoid growth pattern during development

The chemical composition of rind showed an increase in T S S content till maturity Total acidity also 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 at the ripening stage

The yield was found to vary both in terms of the number of fruits and the weight of fruits harvested per tree The dryage obtained on processing by conventional drying of the rind was 12 66 per cent

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* Originals not seen

Appendix - I

Weather data for the period from 1993 March to July 1994

Month	Total Rainfall (mm)	Temperature Max (°C)	Temperature Min (°C)	Relative humidity (%)	Sunshine hours	Wind speed (km/hr)
March	0	35 4	23 7	63	9 0	5 3
April	32 1	34 5	24 0	69	9 1	4 6
May	131 1	34 4	24 8	74	6 5	4 7
June	700 3	30 1	23 9	86	3 3	3 8
July	661 6	28 5	22 9	87	2 4	6 9
August	286 7	29 6	23 4	87	4 8	5 4
September	85 3	30 6	23 1	81	6 4	3 4
October	519 0	30 7	23 4	83	4 8	6 9
November	74 6	31 5	23 6	73	5 8	13 0
December	18 0	31 6	23 1	66	7 5	13 0
January	19 4	30 9	22 6	58	9 1	3 8
February	1 7	34 8	23 1	59	8 7	7 1
March	21 0	36 2	23 7	59	9 3	3 3
April	165 2	34 9	24 4	74	8 0	3 7
May	124 2	33 6	24 7	75	8 0	3 7
June	955 1	25 9	22 9	90	-	
July	1002 1	28 6	22 7	91		

GROWTH, FLOWERING, FRUIT SET AND FRUIT DEVELOPMENT IN KODAMPULI

(Garcinia cambogia Desr *)*

By

SHERLY, R.

ABSTRACT OF A THESIS

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Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Pomology and Floriculture

COLLEGE OF HORTICULTURE

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ABSTRACT

The present investigations were carried out in the Department of Pomology and Floriculture College of Horticulture during the year 1993 94 The study was undertaken with the objectives of understanding the growth and flowering pattern of the tree floral biology fruit set fruit development and fruit drop in kodampuli

The studies were conducted on four male trees and three hermaphrodite trees of about seven years age receiving similar cultural practices

The studies indicated that shoot growth in kodampuli was seasonal with one main flushing period commencing from January and extending upto May The shoot activity noticed during the remaining period of the year was very low However scattered flushes occurred throughout the year The mean growth varied significantly from month to month with a peak growth during the summer months Individual trees also showed significant variation among them in mean growth However there was no significant difference among the two types of trees viz male and hermaphrodite trees The colour of emerging leaves showed 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

Flowering pattern of male and hermaphrodite trees were almost similar However male trees of kodampuli showed a protracted period of flowering extending over four to five months starting from the month of November onwards In hermaphrodite trees flowering started a little later in December and confined only to two to three months Peak flowering in both type of trees was during January to April The flower bud development took 32 days from visual emergence to anthesis in male flowers but only 28 days in bisexual flowers

Kodampuli was observed to be androdioecious with male and bisexual flowers borne on separate trees In male trees the flowers occurred as cymose inflorescence having three to seven flowers per inflorescence Bisexual flowers of hermaphrodite trees were borne singly and rarely in groups In male flowers peak anthesis was between 16 30 and 17 00 hours and in bisexual flowers it was between 17 00 and 17 30 hours Anther dehiscence occurred 10 hours prior to anthesis Stigma became receptive 30 hours before anthesis and retained receptivity upto 12 hours after anthesis

Anther number and pollen per flower varied significantly among the two types of flowers Number of pollen produced per anther was significantly higher in male flowers The pollen fertility was also higher for male

flowers Sucrose at concentrations of 2 4 6 8 and 10 and boric acid at concentrations of 25 50 75 and 100 ppm were found to promote pollen germination However calcium nitrate at all concentrations tried (25 to 100 ppm) drastically reduced the pollen germination A combination of four per cent sucrose and 75 ppm boric acid gave maximum germination (67 00 per cent) Pollen was found to be viable for six days in the dehisced bud condition and the viability was greatly reduced thereafter Low temperature storage conditions gave better results when stored as staminal column or as pollen grain alone The pollination in kodampuli was found to be effected by insects

Kodampuli was found to be an often cross pollinated crop Hand pollination with pollen from male flowers increased the percentage fruit set as compared to self pollination or open pollination indicating the importance of male trees in a population for improved fruit set There was no apomictic fruit development in kodampuli The fruit drop after set was found to be 35 50 per cent and the major part of the drop occurred during the first thirty days

The fruit attained maturity in 130 to 140 days after fruit set The developing fruits followed a sigmoid growth pattern The chemical composition of the rind showed an

increase in T S S 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 at ripening the rind of the fruits had on an average 6 68 per cent acidity 7 2 mg/100 g ascorbic acid 8° Brix T S S and 1 04 per cent reducing sugar The mucilage developed around the seed towards ripening had 2 04 per cent reducing sugar and 3 3 per cent acidity There was a loss of 75 per cent fresh weight on drying The trees varied for the number of fruits harvested