GROWTH, FLOWERING, FRUITSET AND FRUIT DEVELOPMENT IN LOVI-LOVI

(*Flacourtia inermis* Roxb. and *F. cataphracta* Roxb.)

By

S. ARUMUGA PRASAD

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Pomology and Floriculture

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 654

KERALA, INDIA

1998

DECLARATION

I hereby declare that the thesis entitled '**Growth, flowering, fruitset and fruit development in lovi-lovi (*Flacourtia inermis* Roxb. and *F. cataphracta* Roxb.)**' 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, fellowship or other similar title, of any other University or Society.

Vellanikkara

19-9-1998

S. ARUMUGA PRASAD

DR. LILA MATHEW
Associate Professor
Dept. of Pomology and Floriculture
College of Horticulture

Vellanikkara

CERTIFICATE

Certified that the thesis entitled '**Growth, flowering, fruitset and fruit development in lovi-lovi (*Flacourtia inermis* Roxb. and *F. cataphracta* Roxb.)**' is a record of research work done independently by **Sri.S.Arumuga Prasad**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him

Dr.Lila Mathew
Chairperson, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Sri.S.Arumuga Prasad,** a candidate for the degree of **Master of Science in Horticulture** with major in **Pomology and Floriculture**, agree that the thesis entitled '**Growth, flowering, fruitset and fruit development in lovi-lovi (*Flacourtia inermis* Roxb. and *F. cataphracta* Roxb.**' may be submitted by Sri S Arumuga Prasad in partial fulfilment of the requirement for the degree.

Dr.Lila Mathew
Associate Professor
Department of Pomology and Floriculture
College of Horticulture, Vellanikkara
(Chairperson)

Dr.P.K.Rajeevan
Professor and Head i/c
Dept. of Pomology & Floriculture
College of Horticulture
Vellanikkara
(Member)

Dr.Sarah T. George
Assistant Professor
Dept. of Pomology & Floriculture
College of Horticulture
Vellanikkara
(Member)

Dr.Achamma Oommen
Associate Professor
Department of Plant Breeding & Genetics
College of Horticulture
Vellanikkara
(Member)

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

I deem it my profound privilege to express my deep sense of gratitude and indebtedness to ***Dr.K.Lila Mathew****, Associate Professor of Department of Pomology and Floriculture and Chairperson of my advisory committee, for the valuable guidance, constant inspiration, constructive criticism and valuable time she spared during the preparation of the manuscript.*

I offer my esteemed thanks to ***Dr.P.K.Rajeevan****, Professor and Head, Department of Pomology and Floriculture and member of advisory committee for the help and co-operation received from him during the entire programme.*

I sincerely acknowledge the relevant suggestions which I have received from ***Dr.Sarah T. George****, Assistant Professor, Department of Pomology and Floriculture. Her critical apraisal and expert guidance enabled me to prepare this piece of research work in time.*

The expert and timely help received from ***Dr.Acchama Oomen****, Associate Professor, Department of Plant Breeding and Genetics, is thankfully acknowledged.*

My hearty thanks are expressed to Dr.Luckins C. Babu, Associate Dean, College of Forestry for his whole hearted co-operation and enchanting encouragement throughout the period of investigation.

I am also thankful to all the staffs and members of the Department of Pomology and Floriculture for their whole hearted co-operation during the investigation.

I extend my profound thanks to my friends, Messrs. Ajaykumar, Ajay Alex, K.K.Jidesh, Ajith, Dhanesh Salvi Sir, Binu John and Mrs.Rajani and Ms.Samitha who were co-operative and supportive during the course of my study.

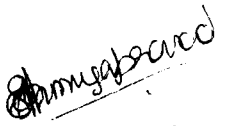
I further express my thanks to Mr.Joy for his commendable care and labour put in, to do this mundane typing work elegantly.

I can't forget the encouragement and help given by Sri.M.Mukundan Unny, Assistant Director of Agriculture, Chittur and M. Vanajathalakshan, Agricultural Officer, Krishi Bhavan, Pattencherry, to undertake this endeavour successfully.

With gratitude and affection, I recall the boundless affection, warm blessings and incessant encouragement and support given to me by my beloved parents and sisters for helping me to complete this study.

I gratefully acknowledge the award of ICAR, Junior fellowship during the period of my study.

Last but not the least, I bow my head before God Almighty for all the blessing showered on me.



S.Arumuga Prasad

CONTENTS

LIST OF TABLES

17 Pollen morphology and fertility - acetacarmine test

18 *In vitro* pollen germination - sour lovi-lovi

19 *In vitro* pollen germination - sweet lovi-lovi

20 Pollen logevity under different storage treatments in sweet lovi-lovi

21 Fruit set under different conditions in sour lovi-lovi

22 Fruit set under different conditions in sweet lovi-lovi

23 Physical changes of fruit during growth and development - sour lovi-lovi

24 Physical changes of fruit during growth and development - sweet lovi-lovi

25 Quality analysis of sour lovi-lovi fruits

26 Quality analysis of sweet lovi-lovi fruits

27 Fruit drop in in sour lovi-lovi (at 30 days interval)

28 Fruit drop in sweet lovi-lovi (at 20 days interval)

29 Tree wise variation in yield and seed characters in sour lovi-lovi

30 Tree wise-variation in yield and seed characters in sweet lovi-lovei

31 Pigment analysis

32 Percentage loss of fruits kept under different storage condition in sour lovi-lovi

33 Percentage loss of fruits kept under different storage condition in sweet lovi-lovi

34 Physiological loss in weight of fruits kept under different storage conditions in sour lovi-lovi

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Lovi-lovi, a minor fruit member of Kerala homesteads, with very attractive berries belongs to the family Flacourtiaceae. There are commonly two species commonly found in Kerala; *Flacourtia inermis* Roxb. (Sour type) and *Flacourtia cataphracta* Roxb. (Sweet type). *F. inermis*, a Malayan species, are small trees with shrub like stature and light green coloured leaves. The tree is monoecious in nature. The fruits are sour and astringent. They are rich in pectin and acid and are suitable for jams, jellies, syrups and preserves.

The sweet lovi-lovi (*F. cataphracta*) is a small dioecious shrub or spreading tree, with sharp decomposed spines on the trunk. The leaves are dark green in colour, fruits are ellipsoid in shape and are dark red or purple when ripe. The fruit has a rather, pleasant tart flavour. The flesh is firm, brownish green and fairly juicy. The fruits are used for making marmalades, jams or preserves. The leaves and young shoots, which taste like rhubarb (*Rheum rhaponticum* Linn.) are astringent and stomachic. Leaves and bark are useful for bleeding gums and toothache. An infusion of the bark is used as a gargle. The wood of this tree is red or orange red, close grained, hard and brittle. It takes a good polish and is used for agricultural implements and for block sheaves.

Many of the homesteads had a single tree of sour lovi-lovi while the occurrence of sweet type trees was very rare owing to its dioecious nature. These fruit trees were mainly propagated through seeds. It can also be grown by inarching, or budding on seedlings of the same species. After planting not much attention was given to them. Physicochemical studies conducted in the fruits indicated that in sweet as well as sour lovi-lovi only narrow variability exists except in sweetness.

General awareness on the properties of these fruit trees is meagre and scientific studies on the various aspects of these crops are scanty. More basic information on the growth, floral and fruit characters is to be gathered for commencing any improvement work in these crops. The present investigations have therefore been undertaken with a view to understand the growth habit, flowering season, pattern of flowering, floral biology and fruiting habits of sour as well as sweet lovi-lovi types under humid tropical conditions. It also envisages to study the physicochemical properties of the fruit during developmental phase and storage feasibility of both sour and sweet lovi-lovi fruits.

Review of Literature

2. REVIEW OF LITERATURE

Sour lovi-lovi (*Flacourtia inermis* Roxb.) and sweet lovi-lovi (*Flacourtia cataphracta* Roxb.) are the minor tropical fruits where the basic studies on growth, flowering and fruit development aspects were not done in an elaborative way. Since the research studies are meagre in this crop, work done on similar and other related crops were reviewed in this chapter. Major headings under research work clustered were vegetative growth studies, flowering and the related characters, fruit set and development and storage studies.

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), Bernard (1932) and McMunn (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 on the variety and environmental conditios under which they were grown. Naik and Rao (1942) and Krishnamurthi *et al.* (1961) had discribed 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 season shoot and early cessation of growth was found to be nexus 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 fruitful 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 growth and producing flowers and shoots purely vegetative.

The investigations carried out in bael (*Aegle marmelos*) showed only one flush of growth in 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 Moreuit, 1970).

2.2 Sex forms

The *F. cataphracta* trees flower generally at the beginning of rains and fruits ripen from October to November (CSIR, 1956).

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.

Garcinia cambogia was reported to be dioecious in nature (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 both sour and sweet lovi-lovi. However, detailed investigations in these aspects

were carried out in fruit trees like mango (Singh, 1958), 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 Sadhu *et al.*, 1987), nutmeg (Nazeem *et al.*, 1981; Amstrong and Drommond, 1986), tamarind (Thimmaraju *et al.*, 1977) and cashew (Shivanandam *et al.*, 1986). Literature pertaining to the investigation undertaken in lovi-lovi was almost nil and the literature of some flowering trees is given below.

2.3.1 Flowering pattern and floral biology

Flacourtia cataphracta was reported to be a dioecious shrub or spreading tree, 20.30 ft. high, with sharp decomposed spines on the trunk (CSIR, 1956).

Two main seasons of flowering were reported in *Garcinia livingstonei* (Devivedi and Bajpai, 1974) and *Garcinia mangostana* (Krishnamurthi *et al.*, 1964). The seasons were April to May and October to November in mangosteen and March and November in *G. livingstonei*. *Garcinia morella*, another important species of *Garcinia*, flowers in May (Chandrarathna, 1948). The flowering season of 'Kodampuli' (*G. cambogia*) was reported to be February by Thomas (1965). Other reports showed the flowering period of both male and bisexual trees 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 (Krishnamoorthi *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, sessile or pedicellate and solitary or in groups (CSIR, 1956).

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 broad 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 tuberiles. 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 observation. George *et al.* (1992) reported that 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 bisexual flowers, 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

The anthesis time of both male and female flowers of *Garcinia indica* was reported to be between 06.00 hrs and 08.00 hrs (Karnik and Gunjate, 1984) Anther dehiscence in *Garcinia indica* occured 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.

No work has been reported on stigmatic receptivity either in sour or in sweet lovi-lovi type.

2.3.2 Pollen studies

The science of pollen and spores has attracted the attention of research workers due to its great significance in palenological studies to taxonomists and paleontologists. It also helps in identifying the disputed varieties or species (Nair, 1960, Nair and Mehra, 1961) and provides evidence for distinguishing the amphidiploid and amphihaploid interspecific hybrids (Hossain *et al.*, 1990). The storage and germination of pollen grains play an important role in assisted pollination and hybridization programme.

2.3.2.1 Pollen morphology

Morphological characters of pollen have 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 investigations on pollen morphology of six fruit plants namely, papaya, jack, guava, sapota, pomegranate and grapes. Singh and Misra (1979) studied the characteristics of the pollen of three spcies of *Zyzyphus*. Studies on the pollen morphology of jack were carried out by Prasad and Trivedi (1978) and Joseph (1983).

2.3.2.2 Pollen fertility

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

a) Stain test

Stains which gave colour to viable pollen is often used as indices of fertility. 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 for indicating viability.

Balasubramanyam (1959) in Guava, Nirmalendunath and Randhawa (1959) in pomegranate, Singh (1961) in mango, Singh (1962b) 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 andTrivedi, 1978, Joseph, 1983, Gopinathan *et al.*, 1983), four percent sucrose for nutmeg (Nazeem, 1979) and five per cent sucrose for nutmeg (Bavappa and Banda, 1981).

2.3.2.3 Pollen storage

Storage of pollen has got 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, ber, plum, peach and apricot for 2 to 5½ years in dessiccator over sulphuric acid with 50 per cent RH 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 mangoe and litchi by Singh (1962a, b), in grapes by Nagarajan *et al.* (1965), in jack by Sinha (1975) 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, 1962b), 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 Linskens, 1974, Nair, 1977).

2.4 Pollination studies

Riabove (1930) had given a most comprehensive survey of literature about the pollination of tree 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, jack (Krishnamoorthi and Rao, 1965) and in apple (Teskey and Shoemaker, 1972). A male and female ratio of 1:10 was 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.

Detailed study on the fruit set and fruit development is lacking in both sour and sweet lovi-lovi.

2.6 Fruit drop

Several reports of fruit drop are available in a variety of other fruit crops, viz., citrus (Navriyal, 1955; Pollard and Biggs, 1969), mango (Chadha and Singh, 1963, 1964; Singh, 1964).

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 three 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 preharvest 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 gibberellins and abscissin was suggested as the cause of premature drop.

2.7 Harvest index

Maturity standard for Kinnow, Srinagar and Emperior mandarins having TSS : acid ratios of 13:0, 12:7 and 13:0, respectively were suggested when the external rind colour become orange in Kinnow and Srinagar and red in Emperior (Bhullar, 1982). In mangosteen sugar content, acidity, sugar acid ratio and vitamin C content were 14.3 per cent, 0.46 per cent, 31.3 and 42.3 mg/100 g, respectively at harvest (Daryono and Sosrodihcoyo, 1986). Pal (1987) suggested that harvest maturity in mango was attained 120 days after fruit set. In *Garcinia cambogia* fruits attained maturity 130 to 140 days after fruit set. The fruits showed a sigmoid growth pattern during development (Sherly, 1994). In mangosteen (*Garcinia mangostana* L.) fruits attained maturity 90 days after fruit set (Alex, 1996). TSS, titratable acidity, total sugars, reducing sugars, non-reducing sugars, sugar:acid ratio and ascorbic acid at harvest stage were found to be 25.30, 0.40, 15.67, 3.05, 12.62 per cent, 39.17 and 10 mg/100 g respectively.

2.8 Chemical composition of fruits

The fruits of *Flacourtia inermis* are sour and astringent. They are rich in pectin and acid and are suitable for jams, jellies, syrups and preserves. Analysis of the edible part of the fruit gave the following values: Moisture 86.6, protein 0.36, ether extract. 0.15, carbohydrates 11.39, fibre 1.11 and mineral matter 0.41 per cent (CSIR, 1956).

2.9 Yield

The yield of *Flacourtia inermis* trees was reported to be 44-270 kg of fruits per tree per annum (CSIR, 1956).

2.10 Storage of fruits

Storage studies of pear showed that fruits can be stored for several months at 5°C. Fruits when stored at 18 to 20°C, quality deterioration was rapid with marked softening occuring in 2-6 days. Ascorbic acid content of the fruit during storage decrease by 30-50 per cent from its original level (Millin *et al.*, 1982). Pota *et al.* (1987) observed that storage life of pomegranates in sealed polyethylene bags at 10°C was extended upto 12 weeks with slight changes in quality such as weight loss, total soluble solids (TSS), titratable acidity (TA) and TSS:TA ratio. Mukherjee (1953) reported that the best storage temperature of storing mango fruits was 5.5 to 9.0°C.

Materials and Methods

3. MATERIALS AND METHODS

Sour lovi-lovi (*Flacourtia inermis*) and sweet lovi-lovi (*F. cataphracta*) are two minor tropical fruits belonging to the family Flacourtiaceae. Research works with respect to the growth and flowering pattern and the generative characters are very meagre in these crops. Hence the present work was taken up to study the growth, flowering, fruitset and fruit development in sour and sweet lovi-lovi types.

The investigations were carried out on the trees maintained as a germplasm collection in the orchard, Department of Pomology and Floriculture, College of Horticulture, as well as on the trees maintained by the nurseries of the nearby locality, during the period from March 1995 to March 1996.

Six trees, each, in both sour and sweet lovi-lovi types, were selected for the present study. On each tree, the canopy was arbitrarily divided for convenience into four quadrants, viz., East, West, North and South for recording observations. From each such quadrant, 100 shoots were selected randomly for taking up the following observations.

1. The growth of shoots for a period of one year
2. Flowering and floral characters
3. Fruit set, fruit development, fruit drop and yield

3.1 Plant characteristics of sour and sweet lovi-lovi

3.1.1 Height of the tree

Height of the tree was measured by using the instrument Altimeter.This instrument gave direct reading of the height.

3.1.2 Girth of the tree

The girth at breast height over bark (1.37 m from the base in sour lovi-lovi and 50 cm from base in sweet lovi-lovi) was measured using the DBH tape. The measurement was quantified in standard S.I. system.

$$\text{Average diameter at breast height (DBH)} = \frac{\text{Girth at breast height}}{\pi} \text{ cm}$$

3.1.3 Number of primary branches

The number of primary branches was determined by counting the number of these branches in a tree.

3.1.4 Canopy spread

The distance from the main trunk to the leaves at the peripheral area of the crown was measured in two directions and the average value was computed as canopy spread.

3.1.5 Shoot extension

One hundred lateral shoots on each quadrant were selected at random in sour and sweet plants. The shoots were tagged and numbered serially during March 1995. The extension growth was measured in centimeter at monthly interval for a period of one year.

3.2 Occurrence of pests and diseases

Occurrence of any serious pest and diseases was watched in both sour and sweet lovi-lovi types, during the period of study.

3.3 Flowering and floral characters

3.3.1 Season and pattern of flowering

Time of flowering in sour and sweet trees was studied by observing 100 shoots selected at random on each tree. Observations on the time of anthesis, number of shoots flowered, number of inflorescence per shoot and number of flowers per inflorescence were recorded.

3.3.2 Flower bud development

The shoots in both sour and sweet lovi-lovi plants tagged for extension growth studies were periodically observed 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 flower buds randomly

selected on each tree. Tagging of buds was done soon after the emergence of buds as a greenish white protuberance. Observations were made on the time taken from the emergence of flower bud to flower opening, developmental stages of buds, namely, the number of inflorescence per shoot, number of flowers per inflorescence, length and spread of inflorescence, and days for flower opening.

3.3.3 Floral biology

Observations on various aspects of floral biology, viz., anthesis, stigma receptivity and pollen studies were done separately in sour (bisexual flowers) and sweet (male and female flowers) types. The flowers were described and drawings were made.

3.3.3.1 Anthesis

Preliminary observations showed that flower opening takes place in the early morning hours. In order to know the exact time of anthesis, 70 mature buds were tagged on sour and sweet lovi-lovi types separately and observations were made at half hourly intervals from 5.30 hours. The maturity of the buds was determined from the size of the buds. The experiment was repeated over a period of one week.

3.3.3.2 Anther dehiscence

The period of anther dehiscence was studied by tagging 60 mature buds of uniform size in both types of lovi-lovi. Observations were made in the morning at

half hourly interval, examining the anther for dehiscence using a hand lens as well as by observing it under a powerful microscope in the laboratory.

3.3.3.3 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 fruitset. 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 used at each time for these studies at different stages.

3.3.4 Pollen studies

Pollen studies with respect to pollen morphology, viability and storage were conducted. For the study, anthers were collected from mature buds. The maturity of the buds was judged initially by the creamy white 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.

3.3.4.1 Morphology and fertility

Twenty five well shaped mature buds were selected from bisexual flowers of sour lovi-lovi and male flowers of sweet lovi-lovi types for the study. Pollen from each bud was collected in acetocarmine (1%) 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. The fertility of the pollen grains was acertained accurately by doing the germination of pollen grains in different concentrations of sucrose and agar media. 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 diameter of the pollen grains was measured using an occular 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.

3.3.4.2 *In vitro* pollen germination

Different concentrations of sucrose, ranging from 5 to 25 per cent, with 0.5 per cent agar was tried initially. Germination was observed upto 10 per cent sugar concentration. In order to find out the optimum concentration of sucrose, the experiment was repeated with different levels of sucrose, such as, 0, 2, 4, 6, 8 and 10 per cent.

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, 0.25, 0.50 and 0.75 per cent with 0, 2, 4, 6, 8 and 10 per cent of sucrose concentration.

3.3.4.3 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 separated pollen grains were put in a clean petridish and stored under various storage conditions. The different storage conditions included in the study were

1. Keeping at room temperature without any treatment
2. Keeping over calcium chloride in a dessicator at room temperature
3. Keeping in refrigerator at 4°C
4. Keeping over calcium chloride in dessicator under refrigerated condition at 4°C

The viability was recorded for each treatment at daily interval in six per cent sucrose + 0.25 per cent agar medium after five hours incubation in moist chamber.

3.3.5 Pollination studies - mode of pollination

To ascertain the precise mode of pollination, fruitset was observed under four modes of pollination. Seventy five flowers were utilized in each experiment. Observations on fruitset was recorded 10 days after pollination.

3.3.5.1 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.

3.3.5.2 Self pollination

For knowing the extent of self pollination in sour lovi-lovi trees, individual flowers were selected and covered one day prior to anthesis to prevent

pollen contamination from outside. The covers were removed two days after flower opening and fruit set was recorded

3.3.5.3 Natural cross pollination

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

3.3.5.4 Hand pollination

Flowers were emasculated and covered one day prior to opening. These flowers were hand pollinated on the next day by rubbing the anthers collected from mature buds, on the stigmatic surface of the emasculated flower. Flowers were tagged and observed for fruit set.

3.3.5.5 Parthenocarpic fruit set

To ascertain whether any parthenocarpic fruit development was there on female trees of sweet lovi-lovi and bisexual flowers of sour trees, 50 flowers from each quadrant of the tree were emasculated one day before flower opening. These emasculated flowers were covered and left unpollinated.

3.4 Fruit development

3.4.1 Physical changes during fruit development

Fruits of 10 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 by using a scale and non-elastic twine. These observations were taken at 20 days interval for sour lovi-lovi and 14 days interval for sweet lovi-lovi fruits and continued upto harvest stage.

In order to study the changes with respect to physical parameters such as total weight, volume, shape, colour, total number and weight of seeds etc. fruit samples were picked at 20 days interval commencing from fruit set for sour lovi-lovi and 14 days interval for sweet lovi-lovi and observations were recorded.

3.4.2 Biochemical changes during fruit development

Fruit samples were drawn at 20 days interval after 60 days of fruit set in sour lovi-lovi and 20 days after fruit set in sweet lovi-lovi and was subjected to analysis in order to know the chemical composition of fruits during different stages of fruit development. The fruits were analysed to determine the TSS, acidity, ascorbic acid, total sugars, reducing and non-reducing sugar and sugar acid ratio. The methodology followed for analysing the above biochemical parameters are given below.

3.4.2.1 Total soluble solids (TSS)

TSS was determined by using a hand refractometer and expressed as degree Brix (AOAC, 1980).

3.4.2.2 Total sugars, reducing sugars and non-reducing sugars

Total sugars, reducing sugars and non-reducing sugars were estimated by the Lane and Eynon method as outlined by Ranganna (1977).

3.4.2.3 Titratable acidity

Acidity was determined by titration with standard NaOH solution and expressed as percentage of citric acid following, Ranganna (1977).

3.4.2.4 Ascorbic acid

Ascorbic acid was determined as described by Ranganna (1977).

3.4.2.5 Sugar acid ratio

Sugar acid ratio was worked out from estimated values of total sugars and acidity estimated.

3.4.3 Fruit drop

To know the extend of fruit drop in sour lovi-lovi, fruits immediately after set were tagged and observed at monthly interval. In sweet lovi-lovi the fruit drop was observed at 20 days interval. Extend of drop during difterent stages of development was recorded.

3.4.4 Harvest index

Harvest index was determined taking into consideration of the physical and chemical changes associated with the fruit development.

3.5 Yield

The yield of the tree was recorded during each harvest from individual trees.

3.5.1 Fruit weight

From a random sample, weight of the individual fruit was determined at the time of harvest.

3.5.2 Number of fruits

The number of fruits obtained from each tree was estimated from the total yield and average individual fruit weight.

3.5.3 Seed character

Fruits were observed to determine the seed characters like number of seeds in a fruit and 100 seed weight.

3.5.4 Hundred seed weight

Seeds from fruits of a particular tree was pooled and dried and hundred seed weight was determined.

3.6 Pigment analysis

Fully ripened fruits were used for the pigment analysis. The fresh fruit was ground to paste using a mortar and pestle. From each sample 2 g of the ground material was taken in a small conical flask, 25 ml of 9 per cent methonolic HCl added and kept overnight. This was then decanted using cotton wool in the funnel. The material was treated again with 10 ml of 1 per cent methanolic HCl and kept for one hour. Decantation was repeated. In each case the volume was made up to 50 ml in volumetric flask and 10 ml sample from this was used to determine the percentage transmission and absorbance of the samples. This was done at 540 nm using a Bausch and Lomb spectronic 20. The total pigment content was calculated in absolute quantities with the aid of extinction coefficient established for cranberry anthocyanin dissolved in alcoholic solvent system (Ranganna, 1977).

3.7 Storage studies

In order to understand the optimum storage conditions required for the fruits, fresh ripened fruits were harvested and subjected to different storage treatments. The various treatments included in the study were

T_1 - Storage under room condition

T_2 - Storage in polythene cover under room condition

T_3 - Storage under refrigerated condition

T_4 - Storage of fruits in polythene cover in refrigerated condition

The percentage loss of fruits and percentage loss in weight of fruits for each treatment were determined at daily interval. The fruits were also subjected to

4. RESULT

Results of the studies on sour lovi-lovi (*F. inermis*) and sweet lovi-lovi (*F. cataphracta*) are presented in this chapter. Results are under the major heads plant characteristics, flowering and floral character, fruit set, fruit development, fruit drop and storage studies.

4.1 Plant characteristics

The data on the plant characters of sour lovi-lovi, like tree height, diameter at breast height (DBH), number of primary branches and canopy spread are presented in Table 1.

Trees T_1 and T_2 recorded the maximum height of 9.0 m each, the diameter (DBH) was also found to be maximum in T_1 and T_2 (20.38 cm and 18.75 cm, respectively). Tree one (T_1) had more number of primary branches (16) followed by T_2 and T_3 (15, each) whereas canopy spread was maximum in T_2 (6.2 m^2). All the plant characters, viz., height, DBH, number of primary branches and canopy spread were lowest in T_3.

The data on the plant characters of male and female trees of sweet lovi-lovi are presented in Table 2 and 3, respectively. In male trees, T_1 recorded maximum height of 11.0 m with 44 primary branches. The DBH and canopy spread were also maximum in this tree with values 49.36 cm and 15.2 m, respectively. T_3 and T_5 were equal in height (9.5 m) with 40 and 41 primary branches, respectively. T_2 recorded the lowest value in all the plant characters, viz., height, DBH, number of primary branches and canopy spread.

Table 1. Plant characters of sour lovi-lovi

Sl.No.	Treatment No.	Height (m)	Diameter at breast height (cm) DBH	Number of primary branches	Canopy spread (m^2)
1	T_1	9.0	20.38	16	6.2
2	T_2	9.0	18.78	15	5.2
3	T_3	7.5	14.33	13	4.5
4	T_4	8.5	17.51	15	5.6
5	T_5	8.0	16.50	14	5.5
6	T_6	8.5	17.00	14	5.7

Table 2. Plant characters of sweet lovi-lovi - male tree

Sl.No.	Treatment No.	Height (m)	Diameter at breast height (cm) DBH	Number of primary branches	Canopy spread (m^2)
1	T_1	11.0	49.36	44	15.2
2	T_2	8.5	42.99	32	9.0
3	T_3	9.5	46.17	40	10.4
4	T_4	10.0	47.77	43	11.5
5	T_5	9.5	45.32	41	10.0

Table 3. Plant character of sweet lovi-lovi - female tree

Sl.No.	Treatment No.	Height (m)	Diameter at breast height (cm) DBH	Number of primary branches	Canopy spread (m^2)
1	T_1	13.0	55.73	38	16.0
2	T_2	11.5	52.54	31	14.5
3	T_3	13.5	54.14	36	15.0
4	T_4	12.5	55.73	38	14.3
5	T_5	11.0	50.32	30	13.5

In female trees T_3 recorded maximum height of 13.5 m, but the number of primary branches was maximum (38, each) in T_1 and T_4. Maximum canopy spread (16 m) was also seen in T_1. All the plant characters, viz., height, DBH, number of primary branches and canopy spread were the lowest in T_5.

4.2 Shoot growth

The shoot growth, measured as the extension of the shoot, was recorded for a period of one year from April 1995 to March 1996, both in case of sour and sweet lovi-lovi. Shoot extension studies in sour lovi-lovi indicated that there was growth in all months although the extent of growth varied from month to month (Table 4). Maximum mean growth was recorded during the month of September (3.25 cm) which accounted 28.99 per cent of the total growth for the year. This was closely followed by the growth in June. Mean extension growth in May and August also showed some significant values while in case of rest of the months there was very little growth. The growth was minimum during April (0.07 cm) which accounted 0.62 per cent of the total growth.

The percentage of shoots that showed growth in different months also followed the same trend (Table 4). Highest growth was recorded in June (59.65%) and lowest in April (5.76%).

The data of shoot extension in sweet lovi-lovi (male tree) are presented in Table 5. Extension of shoot was noticed in all months although the extend of growth varied from month to month. The maximum mean growth was recorded during September (4.78 cm) which accounted for 28.48 per cent of the total growth for the year. This was closely followed by that during June (2.9 cm) and August

Table 4. Mean monthly shoot extension of sour lovi-lovi

Months	Mean extension (cm)	Growth expressed as percentage of the total	Percentage of shoots showing growth value
1995			
April	0.07	0.62	5.76
May	1.79	15.96	47.89
June	2.80	24.97	59.65
July	0.56	4.99	25.46
August	1.67	14.89	38.64
September	3.25	28.99	56.92
October	0.15	1.33	13.65
November	0.13	1.16	8.79
December	0.28	2.49	15.64
1996			
January	0.15	1.33	12.56
February	0.28	2.49	18.64
March	0.08	0.71	7.81

Table 5. Mean monthly shoot extension of sweet lovi-lovi - male tree

Months	Mean extension (cm)	Growth expressed as percentage of the total	Percentage of shoots showing growth value
1995			
April	1.10	6.55	13.90
May	1.50	8.93	42.65
June	2.90	17.28	59.66
July	0.75	4.46	32.61
August	2.89	17.22	42.52
September	4.78	28.48	65.67
October	0.64	3.81	16.53
November	0.49	2.92	10.42
December	0.54	3.22	25.67
1996			
January	0.47	2.80	24.96
February	0.65	3.87	43.16
March	0.07	0.41	10.16

(2.89 cm) which accounted for 17.28 and 17.22 per cent of the total growth for the year, respectively. Mean extension growth was notable during the months April and May while in the rest of the months there was not much significant growth. Minimum growth was accounted during March (0.07 cm) which accounted for 0.41 per cent of the total growth.

The data pertaining to shoot extension are presented in Table 6. There was growth in all months although the extent of growth varied from month to month. Here also the maximum mean growth was recorded during September (3.54 cm) which accounted for 18.51 per cent of the total growth for one year. This was followed by that in June (2.5 cm) and August (2.57 cm) which accounted for 13.07 and 13.44 per cent of the total growth of the year, respectively. Mean extension growth in February, March, April, May and October showed a fair value while in rest of the months, there was not much significant growth. The growth was minimum during December (0.49 cm) which accounted for 2.56 per cent of the total growth.

The percentage of shoots that showed growth in different months also followed the same trend as for the mean growth both in case of male and female trees. Maximum percentage of shoots that showed growth was during September both in male trees (65.67%) as well as in female trees (62.16%).

4.3 Incidence of pests and diseases

No serious pests and diseases were noticed in both sour and sweet lovi-lovi trees.

Table 6. Mean monthly shoot extension of sweet lovi-lovi - female tree

Months	Mean extension (cm)	Growth expressed as percentage of the total	Percentage of shoots showing growth value
1995			
April	1.40	7.30	7.60
May	1.60	8.36	35.65
June	2.50	13.07	53.46
July	0.90	4.70	20.56
August	2.57	13.44	28.76
September	3.54	18.51	62.16
October	1.56	8.15	13.12
November	0.95	4.96	10.62
December	0.49	2.56	19.66
1996			
January	0.86	4.44	22.56
February	1.34	7.00	39.15
March	1.42	7.43	9.65

4.4 Flowering and floral characters

4.4.1 Pattern of flowering

Results obtained from the studies on flowering in individual sour (*Flacourtia inermis*) and sweet, (*F. cataphracta)* lovi-lovi trees are presented in Table 7.

In *F. inermis* there were two seasons of flowering, viz., June-July and October-November and also some scattered flowering throughout the year. Flowers appeared both on current and past season shoots. Percentage of flowering was more during June-July when compared to October-November. In sour lovi-lovi the percentage of shoots that flowered ranged from 49.00 to 69.00 (Table 8).

Visual emergence of flower buds in *F. inermis* commenced by the middle of June and progressed steadily thereafter. Peak flowering period was observed by the end of July. Almost 59.5 per cent of the shoots put forth flowers during this period. The average number of flower clusters per flowering shoot was 30.5 and the average number of flowers per inflorescence was 5.1 (Table 8).

F. cataphracta is dioecious in flowering habit and there was only one flowering season. The male trees flowered much earlier with the flower buds appearing in the month of October, whereas in female trees it was by the middle of November. The peak flowering period in male tree was by the middle of November while in female tree it was by the first week of December (Table 7). Flowering was noticed mainly in the past season shoots. Almost 80 per cent of shoots put forth flowers during this period. The average number of inflorescence per shoot was 17.4, and the average number of flowers per inflorescence was 13.39 in male trees

Table 7. Season and pattern of flowering in sour and sweet lovi-lovi

Tree type	Month of visual flower bud emergence	Period of maximum flowering	Flowering intensity (%)
Sour lovi-lovi	June	July	59
	October	November	41
Sweet lovi-lovi			
Male tree	October	November	80
Female tree	November	December	80

Table 8. Extent of flowering in individual trees

Tree No.	Percentage of shoots flowered	Mean number of inflorescence per fowering shoot	Mean number of flowers per inflorescence
Flacourtia inermis			
T1	56	31	2
T2	58	32	4
T3	49	29	3
T4	61	27	5
T5	64	34	8
T6	69	30	9
Mean	59.5	30.5	5.1
Flacourtia cataphracta			
Male tree			
T1	78	18	12.75
T2	77	18	12.40
T3	80	19	13.20
T4	76	16	13.20
T5	84	16	13.40
Mean	79	17.4	13.39
Female tree			
T6	81	8.2	13.8
T7	79	8.0	11.0
T8	80	8.6	11.0
T9	79	8.4	9.6
Mean	79.75	8.55	11.35

(Table 9). In female trees the average number of inflorescence per shoot was 8.56 and the average number of flowers per inflorescence was 11.35 (Table 9).

4.4.2 Flower bud development

After the visual emergence, flower bud passed through a series of morphological changes to reach the anthesis stage. The whole period of flower bud development was divided into four arbitrary stages in sour lovi-lovi. In sweet lovi-lovi four arbitrary stages were identified in the development of male flowers and three in the case of female flowers.

The chronological order of these developmental stages and the mean size and nature of the bud in these stages were studied and the data were summarised in Table 10.

Stages of development of flower bud in sour lovi-lovi (*F. inermis*) (Plate 1).

Stage I

The buds were light greenish in colour and were covered with sepals and remained in this stage for four to five days. The mean length of inflorescence was 0.5 cm and the breadth was 0.8 cm.

Stage II

This stage lasted for two to three days in which the calyx split opened at the centre and stigma could be seen protruding out through this opening. The

Table 9. Flowering and floral characters in sour and sweet lovi-lovi

Tree type	Season and habit of flowering	Number of inflorescence per shoot	Number of flowers per inflorescence	Flower type
Sour lovi-lovi	Current as well as in past season shoot	30.50	5.10	Bisexual
Sweet lovi-lovi	Past season shoot	17.40	13.39	Male
	Past season shoot	8.55	11.35	Female

Table 10. Duration of different stages and size of inflorescence during development in sour lovi-lovi

Stage	Duration of each stage (days)	Mean size of inflorescence		Nature of bud at each stage
		Length (cm)	Breadth (cm)	
I	4-5	0.5	0.8	Buds covered with sepals
II	2-3	0.6	0.9	Calyx split open stigma protrudes
III	4	1.1	1.7	Calyx fully opened anthers seen
IV	2	1.5	2.1	Anthesis starts

Plate 1. Flower buds in an inflorescence of sour lovi-lovi (*Flacourtia inermis*)

Plate 2. Fully opened flowers in an inflorescence of sour lovi-lovi (*F. inermis*)

anthers still remained covered inside the calyx. The mean inflorescence length was 0.6 cm and breadth, 0.9 cm.

Stage III

In this stage the tip of intact anthers could be seen as the calyx was fully opened. The filaments increased in length and this stage lasted for four days. The inflorescence was 1.1 cm in length and 1.7 cm in breadth (mean values).

Stage IV

The anthers were free, filaments attained maximum length. The ovary was creamy white coloured and the anthers were yellow. By this time the flowers were fully developed and retained in this stage for two days. The inflorescence was 1.5 cm in length and 2.1 cm in breadth. The anthers turned brown and shed off. The stigmatic end too turned reddish brown from glossy cream yellow, the ovary became enlarged, the nectary also became brownish yellow. The anthesis was at this stage (Plate 2).

The stages of development of flower bud in sweet lovi-lovi (*H. cataphracta*) was as follows.

In male tree four arbitrary stages were identified. For complete development of flower buds it took about 22-26 days from the flower bud appearance (Table 11).

Stage I

In early stages buds were green and dome shaped and this stage lasted for 10-14 days. The inflorescence was 0.7 cm in length and 0.9 cm in breadth.

Table 11. Duration of different stages and size of inflorescence in sweet lovi-lovi

Stage	Duration of each stage (days)	Mean size of inflorescence		Nature of bud at each stage
		Length (cm)	Breadth (cm)	
Male flowers				
I	10-14	0.7	0.9	Buds intact and domeshaped
II	5-6	0.9	1.5	Calyx just opens
III	2-3	1.5	1.9	The filaments attain maximum length
IV	2-3	1.7	2.3	Anther dehisces
Female flowers				
I	4-5	0.9	1.6	Buds green and domeshape
II	2-3	1.7	2.0	Calyx splits open and gynoecium becomes visible
III	2-3	1.9	2.3	Stigma becomes receptive

Stage II

This stage lasted for 5-6 days. In this stage, the calyx just opened and anthers seen but the filaments were concealed. Anthers were intact and green in this stage. The green colour of the anthers turn to yellow and spreading of anthers started after one day. The filaments could be seen as the calyx is fully opened. The mean inflorescence length and breadth were 0.9 and 1.5 cm respectively.

Stage III

The colour of the anthers turned creamy yellow and filaments which were creamy coloured attained maximum length in two to three days. This was the fully developed stage of male flower. This stage lasted for 2-3 days. The mean length and breadth of inflorescence was 1.5 and 1.9 cm respectively.

Stage IV

In this stage the anther dehiscence occurred and it was in the early morning hours (5-6 am). The flowers remained in this stage for 2-3 days. The length at this stage of inflorescence was 1.7 cm and breadth 2.3 cm. Then the anthers turned brown and flowers shed (Plate 3).

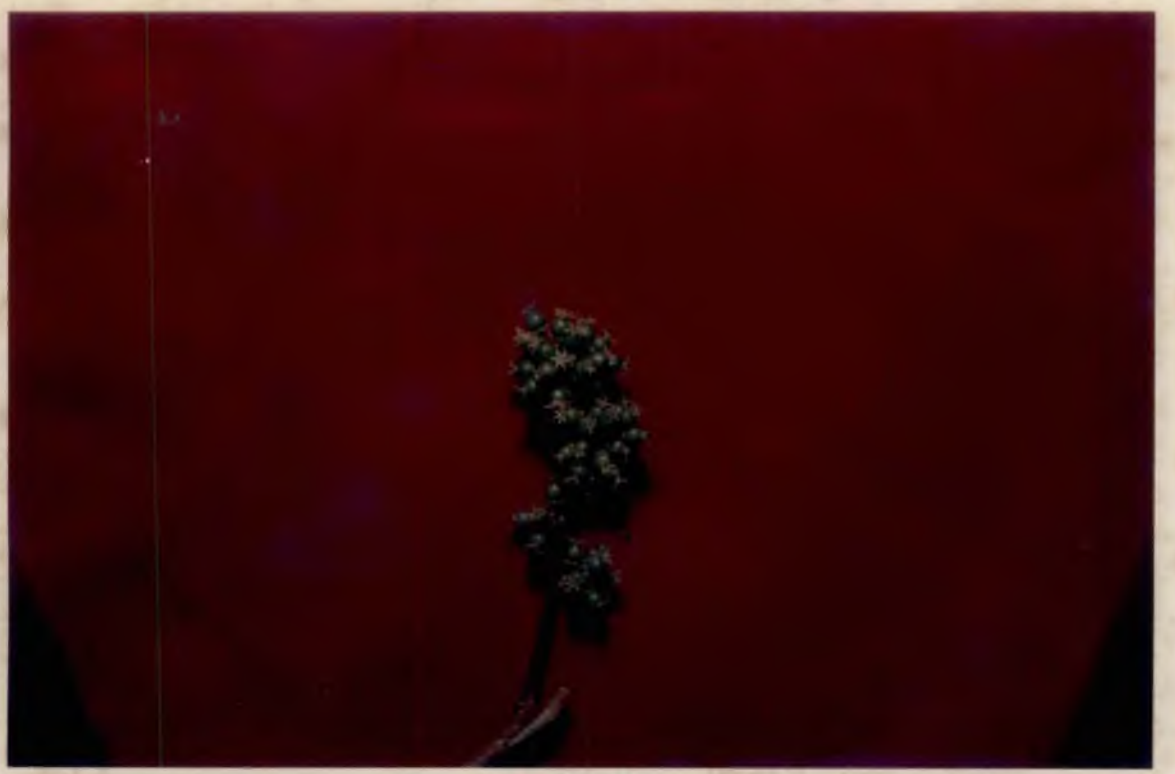
In the case of female flowers the number of stages during development fall into three arbitrary stages (Table 11)

Stage I

In the early stage the buds appeared as green and were dome shaped. The calyx was closed in this stage. This stage lasted for 4-5 days. The mean length and breadth of inflorescence were 0.9 cm and 1.6 cm, respectively.

Plate 3. Fully opened male flowers in an inflorescence of sweet lovi-lovi (*Flacourtia cataphracta*)

Plate 4. Female flowers in an inflorescence of sweet lovi-lovi (*F. cataphracta*)



Stage II

In this stage the calyx split opened and gynoecium became visible. This stage was completed with in 2-3 days. The inflorescence was 1.7 cm in length and 2.0 cm in breadth.

Stage III

In this stage the colour of stigma changed from green to yellow and stigma became receptive. This stage was completed in 2-3 days. The mean length and breadth of inflorescence at this stage was 1.9 cm and 2.3 cm respectively (Plate 4).

In sour lovi-lovi the average number of days between visual emergence of buds and anthesis was 10-14 days.

In sweet lovi-lovi, male flowers took about 19-26 days from flower bud appearance to the complete development of flower. While female flowers required only 9-11 days from the flower bud appearence to the stigma receptivity stage.

4.4.3 Floral biology

In *F. inermis* (sour lovi-lovi) the flowers are bisexual and were produced in both past as well as current season shoots.

Flowers of sour lovi-lovi were actinomorphic with five perianth lobes, arranged in imbricate aestivation, ovary was superior and an yellow coloured nectariferous disc was present just below the ovary. Anthers were 16-20 in number, seen around the nectary ring. Style 5 in number with capitate stigma, ovule 8-12 in number and were arranged in axile placentation. The anthers were two celled and the dehiscence was longitudinal. Anther dehiscence occurred around 6.00 am to 7.00 am. Stigma was receptive only for the opening day and the colour was glossy cream, afterwards it changed to reddish brown (Fig.1).

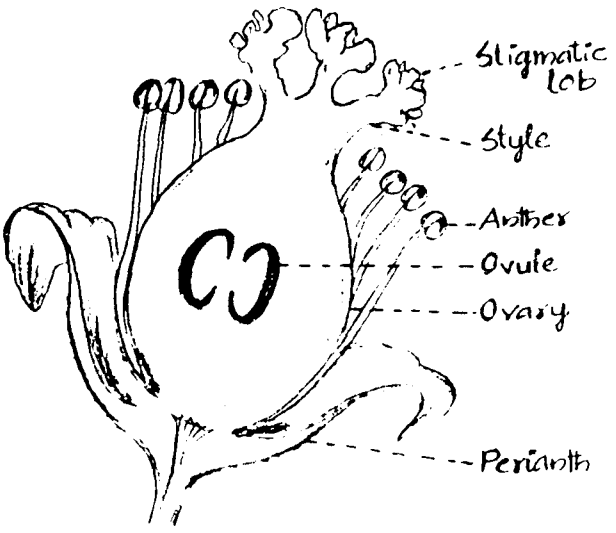
The *F. cataphracta* plant is dioecious in nature with male and female flowers on separate trees. Both male and female flowers were small in size and appeared as terminal/lateral cymose clusters on past season wood.

Male flowers appeared as axillary or terminal cymose clusters. They have five perianth lobes which are green in colour and arranged in imbricate aestivation. Androecium consists of numerous of stamens with slender dorsified filaments. The anthers are two celled and the dehiscence is longitudinal. Floral diagram of male flower is given in Fig.2.

Female flowers appeared in fascicles, perianth consist of two to five lobes and arranged in imbricate aestivation. Gynoecium is syncarpous with 5-7 carpels having a single ovule in each carpel and the ovules are arranged in axile placentation. Style 5-8 each ending with capitate stigma. Diagramatic description of female flowers is given in Fig.3.

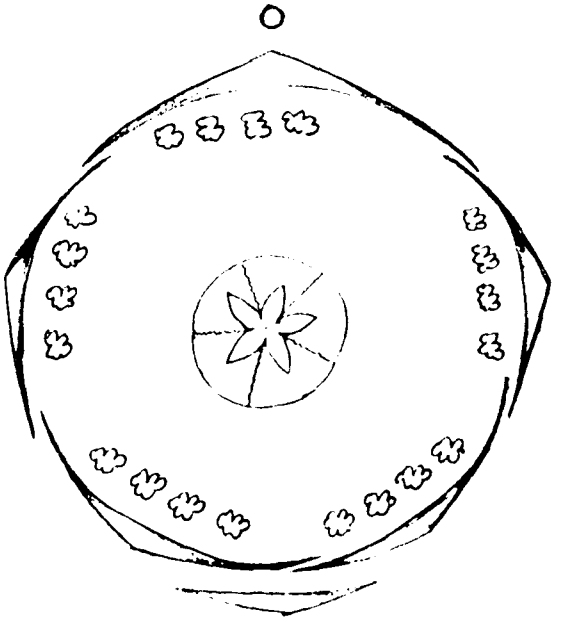
Fig.1. Structure of bisexual flower - Sour lovi-lovi

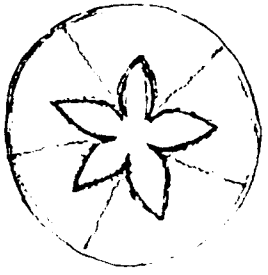
Entire flower



L.S. of the flower

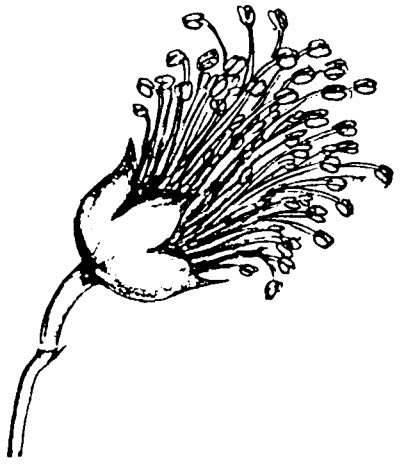
Floral diagram





T.S. of ovary

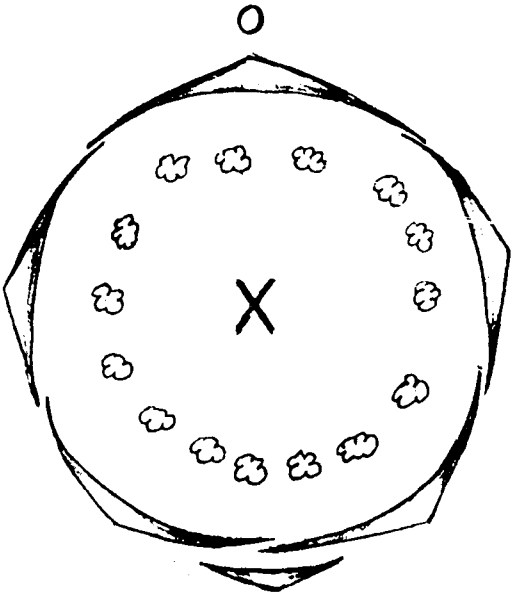
Fig. 2. Structure of male flower - Sweet lovi-lovi



Entire flower

Anther

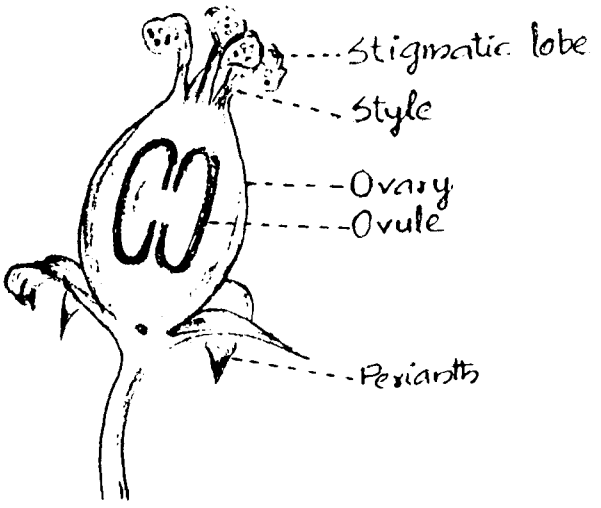
Floral diagram



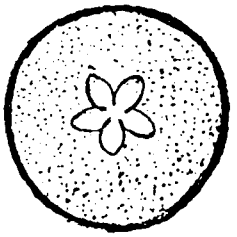
♂ P5 A∝ G0

Fig.3. Structure of female flower - Sweet lovi-lovi

Entire flower

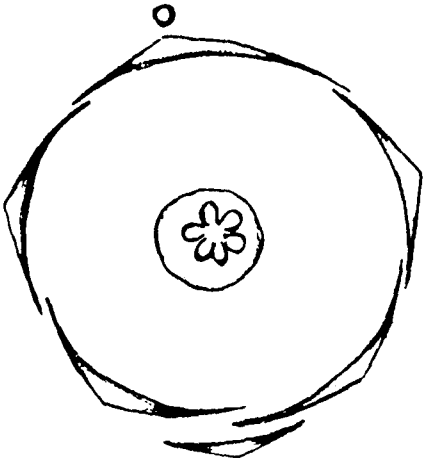


L.S. of flower



T.S. of ovary

Floral diagram



♀ P5 A0 G1(5-7)

4.4.3.1 Anthesis

The data on anthesis time of sour lovi-lovi are shown in Table 12. Flowers were observed at half hourly interval. In the case of sour lovi-lovi the anthesis started from 6.00 am onwards. Maximum number of flowers opened between 6.00 and 7.00 hours and flower opening continued upto 7.30 hours.

In the case of sweet lovi-lovi the male and female flowers showed almost same pattern in anthesis time. In both the cases the anthesis started from 6.00 hours and the maximum number of flowers opened between 6.30 and 7.00 hours as shown in Table 13.

4.4.3.2 Anther dehiscence

In sour lovi-lovi, anther dehiscence started from 6.00 hours and continued upto 8.00 hours. Maximum percentage of anther dehiscence was observed between 7.00 and 7.30 hours (Table 14).

In sweet lovi-lovi also anther dehiscence started from 6.00 hours and continued upto 8.00 hours. Maximum anther dehiscence of 47.14 per cent was observed at 7.00 hours (Table 15).

The anther dehiscence was longitudinal in both cases.

4.4.3.3 Stigma receptivity

In the flowers of sour lovi-lovi, stigma with a glossy creamy white colour was considered as receptive. The loss of stigmatic receptivity was noted from the

Table 12. Anthesis period in sour lovi-lovi - Bisexual flowers

Time hours	Number observed	Number opened	Percentage total
5.30	70	0	0.00
6.00		12	17.14
6.30		25	35.71
7.00		29	41.42
7.30		4	5.71
8.00		0	0.00

Table 13. Anthesis period in sweet lovi-lovi*

Time hours	Male flowers		Female flowers	
	Number opened	Percentage total	Number opened	Percentage total
5.30	0	0.00	0	0.00
6.00	4	5.71	9	12.85
6.30	13	18.57	12	17.14
7.00	29	41.41	25	35.71
7.30	18	25.71	19	27.14
8.00	6	8.57	5	7.14
8.30	0	0.00	0	0.00

* Average of 70 observations

Table 14. Anther dehiscence period in bisexual flowers of sour lovi-lovi

Time hours	Number of buds observed	Number dehisced	Percentage total
5.30	60	0	0.00
6.00		5	8.33
6.30		12	20.00
7.00		24	40.00
7.30		11	18.33
8.00		8	13.33

Table 15. Anther dehiscence period in male flowers of sweet lovi-lovi

Time hours	Number of buds observed	Number dehisced	Percentage total
5.30	60	0	0.00
6.00		4	5.71
6.30		25	35.71
7.00		33	47.14
7.30		7	10.00
8.00		8	1.44

change of colour from glossy cream to reddish brown. Stigma was receptive only for the opening day. Controlled pollination made at six hours interval starting from 12 hours before anthesis upto 30 hours after anthesis showed that the fruit set occurred when pollinated between 6 hours before anthesis and 24 hours after anthesis (Table 16). The maximum fruitset of 84 per cent was obtained when pollinated 12 hours after anthesis, indicating maximum receptivity at that period.

In sweet lovi-lovi also the same procedure was adopted. Controlled pollination was made at six hours interval starting from 18 hours before anthesis upto 30 hours after anthesis showed that maximum fruitset of 88 per cent was obtained when pollinated 12 hours after anthesis (Table 16).

In both cases the stigmatic lobes were persistent and remained attached to the distal end of fruits throughout its development. Stigmatic head turned black in colour during the development of fruits.

4.4.4 Pollen studies

The results of the studies on various aspects of pollen are detailed below.

4.4.4.1 Pollen morphology and fertility

Pollen grains appeared as creamy white with yellowish tinge to the naked eye. Examination under microscope showed that individual pollen is spherical in shape with diameter ranging from 10.3 to 20.5 μ in sour lovi-lovi. The pollen size is much larger in size in male flowers of sweet lovi-lovi and it ranged from 15.6 μ to 32.3 μ (Table 17).

Table 16a. Stigma receptivity of sour lovi-lovi
Fruit set on hand pollination at different intervals

Pollination time	Number pollinated	Number set	Percentage set
12 hours before anthesis	25	0	0
6 hours before anthesis	25	7	28
At the time of anthesis	25	12	48
6 hours after anthesis	25	18	72
12 hours after anthesis	25	21	84
18 hours after anthesis	25	17	68
24 hours after anthesis	25	4	16
30 hours after anthesis	25	0	0

Table 16b. Stigma receptivity of sweet lovi-lovi
Fruit set on hand pollination at different intervals

Pollination time	Number pollinated	Number set	Percentage set
18 hours before anthesis	25	0	0
12 hours before anthesis	25	3	12
6 hours before anthesis	25	7	28
At the time of anthesis	25	13	52
6 hours after anthesis	25	19	76
12 hours after anthesis	25	22	88
18 hours after anthesis	25	18	72
24 hours after anthesis	25	2	8
30 hours after anthesis	25	0	0

Table 17. Pollen morphology and fertility - acetocarmine stain test

Tree type	Total number of pollen observed	Size (μ)	Number of fertile pollen	Percentage fertility	Fertility from *in vitro* germination
Sour lovi-lovi	1490	10.3 to 20.5	596	40	48
Sweet lovi-lovi male flowers	1320	15.6 to 32.3	1100	83	85

Pollen fertility of sour lovi-lovi and sweet lovi-lovi (male) was tested by using the acetocarmine stain test and by the *in vitro* germination of pollen grains in sucrose and agar medium. Acetocarmine stain test showed 40 per cent fertility for sour lovi-lovi bisexual flowers while in male flowers of sweet lovi-lovi it was 83 per cent.

4.4.4.2 *In vitro* pollen germination

Effect of sucrose and agar on pollen germination

The data on the percentage germination of pollen grains of sour lovi-lovi at different concentrations of sucrose and agar solid media are furnished in Table 18. Maximum percentage of germination was observed in 6 per cent sucrose and 0.25 per cent agar medium (58), followed by 4 per cent (42) and 2 per cent (31) sucrose + 0.25 per cent agar. Higher levels of sucrose and agar were found to reduce the germination percentage of pollen grains (Plate 5).

In sweet lovi-lovi, the maximum percentage of pollen germination was observed in 4 per cent sucrose and 0.25 per cent agar medium (93.4), followed by 6 per cent (84.6) and 8 per cent (70.4) sucrose (Table 19). The optimum concentration of agar was found to be 0.25 per cent.

4.4.4.3 Pollen storage

Results from the studies on pollen storage (in sweet lovi-lovi) under different storage conditions are presented in Table 20. The medium used for pollen germination studies was sucrose 6 per cent and agar 0.25 per cent. The percentage germination recorded at daily interval showed that storage of pollen grains at 4°C,

Table 18. *In vitro* pollen germination - sour lovi-lovi
Pollen germination in sucrose agar media 24 hours after incubation

Sucorse (%)	Percentage germination		
	0.25	0.5 (Agar %)	0.75
0	20.5	15.0	9.0
2	31.0	20.3	16.5
4	42.0	25.4	18.6
6	58.0	31.5	23.5
8	30.0	19.4	11.4
10	11.0	5.3	2.3

Table 19. *In vitro* pollen germination - sweet lovi-lovi
Pollen germination in sucrose agar media 24 hours after incubation

Sucorse (%)	Percentage germination		
	0.25	0.5 (Agar %)	0.75
0	50.5	40.7	25.6
2	59.6	51.8	40.5
4	93.4	79.5	50.6
6	84.6	70.5	40.7
8	70.4	59.4	29.5
10	40.6	25.6	10.3

Plate 5. Germinated pollen of sweet lovi-lovi male flowers

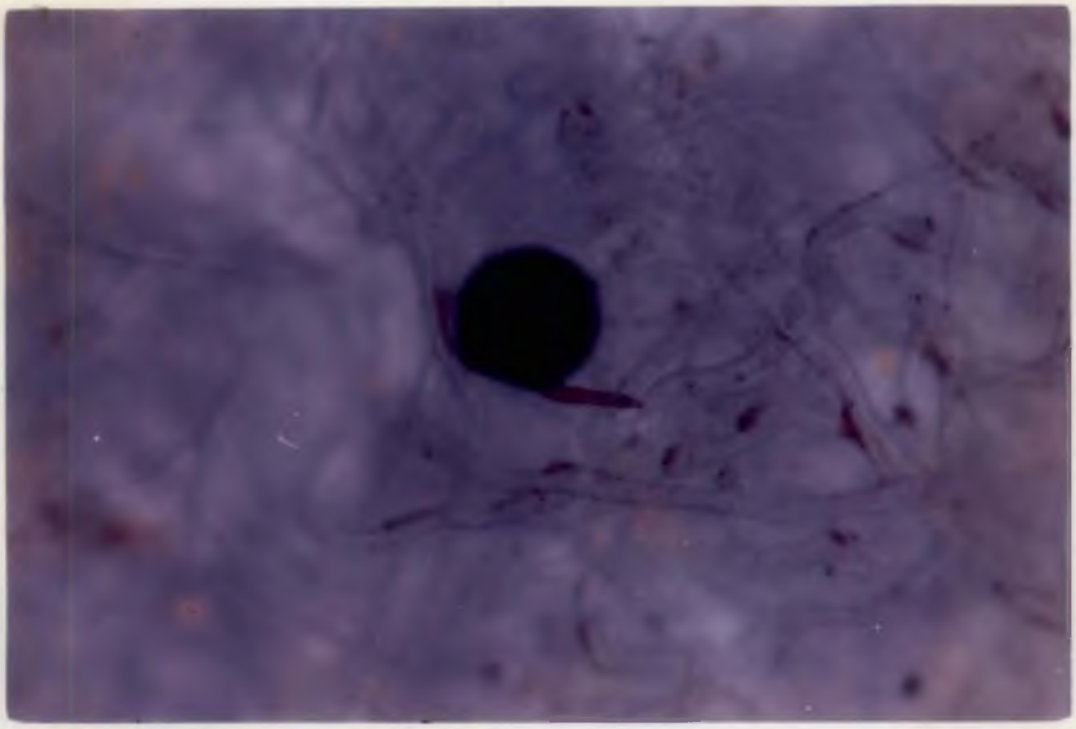


Table 20. Pollen longevity under different storage treatments in sweet lovi-lovi male types

Storage treatment	Germination percentage						
	Period after collection of pollen in days						
	1	2	3	4	5	6	7
1) Pollen grains at room temperature	6.80	3.20	1.20	0.50	0.00	0.00	-
2) Pollen grain in dessicator at room temperature over $CaCl_2$	10.80	3.88	0.80	0.20	0.00	0.00	-
3) Pollen grains at 4°C	37.30	27.66	18.31	7.80	5.20	1.60	-
4) Pollen grains in dessicator at 4°C over $CaCl_2$	4.16	1.56	0.20	0.00	0.00	0.00	-

retained viability for maximum number of days (six days) when compared to other treatments. Storage of pollen grains at low temperature gave better results than storage at room temperature. In the case of room temperature storage, pollen recorded 6.8 per cent germination, one day after storage and this was reduced to 0.5 per cent on the fourth day. When pollen grains were stored in dessicator at room temperature, there was drastic reduction in viability of pollen grains from 10.8 per cent on the first day of storage to 0.2 per cent on the fourth day. The pollen grains stored at 4°C in dessicator also showed viability only upto third day of storage.

4.4.5 Pollination studies

4.4.5.1 Mode of pollination

The percentage of fruitset observed under different mode of pollination in sour lovi-lovi showed that fruitset occurred both under self pollinated and cross pollinated conditions (Table 21). Maximum percentage of fruitset was obtained by hand pollination of either unemasculated flowers (89.33%) or emasculated flowers (85.33%). The fruitset in sour lovi-lovi under open pollinated condition was 83.65 per cent. The fruitset obtained by natural cross pollination was less (68%), while set obtained by self pollination of flowers was 74.66 per cent which was in between the percentage of fruitset in open pollinated and natural cross pollinated condition.

In sweet lovi-lovi, the data showed that there was significant difference in fruitset between the hand pollination and natural pollination. Percentage of fruit set without pollination was nil, thereby ruling out the chances of apomictic fruit development. The percentage of fruitset was 89.33 in open pollinated condition, while in hand pollinated condition it was 96 per cent (Table 22).

Table 21. Fruit set under different conditions in sour lovi-lovi

Sl.No.	Treatments	Number of flowers observed	Fruit set	Percentage
1	Open pollination	75	63	83.65
2	Self pollination	75	56	74.66
3	Natural cross pollination	75	51	68.00
4	Hand pollination of emasculated flower	75	64	85.33
5	Hand pollination of unemasculated flower	75	67	89.33

Table 22. Fruit set under different conditions in sweet lovi-lovi

Sl.No.	Treatments	Number of flowers observed	Fruit set	Percentage
1	No pollination	75	0	0
2	Open pollination	75	67	89.33
3	Hand pollination	75	72	96.00

4.4.5.2 Pollinating agents

A large number of insects were found visiting the lovi-lovi flowers during the anthesis period. These included ants, honeybees, weevils etc. The observations indicated that pollination in lovi-lovi flowers (both sour and sweet) could largely be entomophilous.

4.5 Fruit development

4.5.1 Physical changes during fruit development

The data on fruit growth recorded in terms of length, girth, weight and volume in sour lovi-lovi are presented in Table 23. Studies showed that it took about 110-120 days from fruitset to complete the development of fruit and maximum fruit size was attained during 100-120 days after fruit set. At the early stages of fruit development the length of the fruit was 0.8 cm and it was 2.2 cm at 120 days after set. Maximum increase in length was noticed in between 100 and 120 days (28.57%). Girth of the fruit was 3.1 cm (20 days after fruitset) and it increased upto 8.2 cm (120 days after fruitset). Maximum increase in the girth of the fruit was noted in between 60 to 80 days of development. A similar trend of increase was noticed in the weight of the fruit, i.e., the maximum increase in weight (26.8%) was in between 60 and 80 days of development. Thereafter the increment showed a decreasing trend as in the case of girth. Maximum increase in volume (27.45%) was attained when the fruit was between 20 and 40 days of development (Fig.4) (Plate 6a and b).

In sweet lovi-lovi the fruit developmental parameters were recorded at fortnightly interval. The results on the increase in weight, volume, length and girth

Table 23. Physical changes of fruit during growth and development - sour lovi-lovi

Days after fruit set	Mean weight (gm)	Percentage increase in weight	Mean volume (ml)	Percentage increase in volume	Mean length (cm)	Percentage increase in length	Mean girth (cm)	Percentage increase in girth
20	0.85	0.00	0.90	0.00	0.80	0.00	3.10	0.00
40	1.90	19.30	2.30	27.45	1.10	21.40	3.90	15.68
60	3.20	21.80	3.50	23.52	1.40	21.40	5.00	21.56
80	4.80	26.80	4.40	17.60	1.50	7.10	6.32	25.82
100	6.00	20.16	5.60	23.52	1.80	21.40	7.50	23.10
120	6.70	11.76	6.00	7.80	2.20	28.57	8.20	13.72

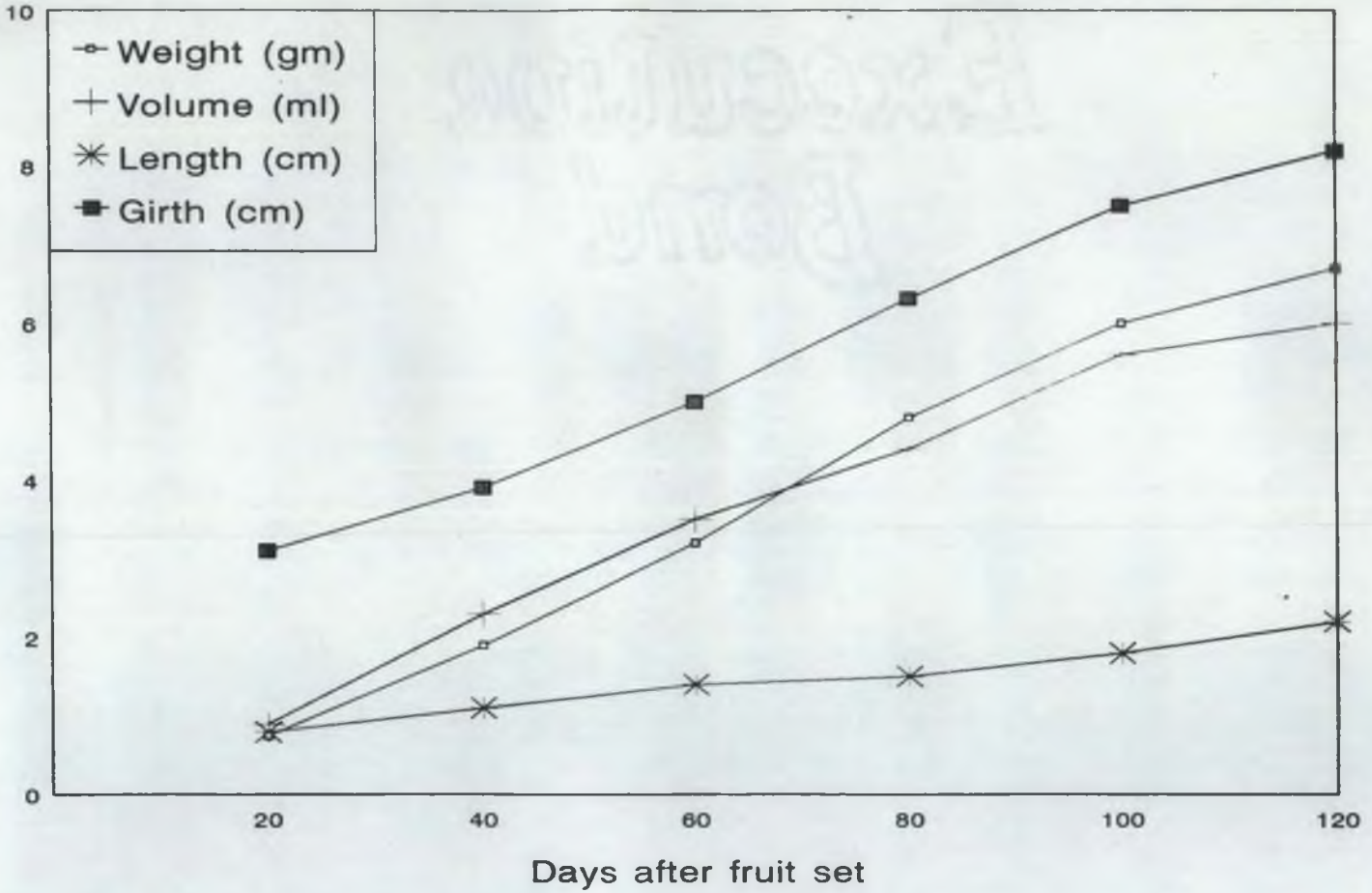
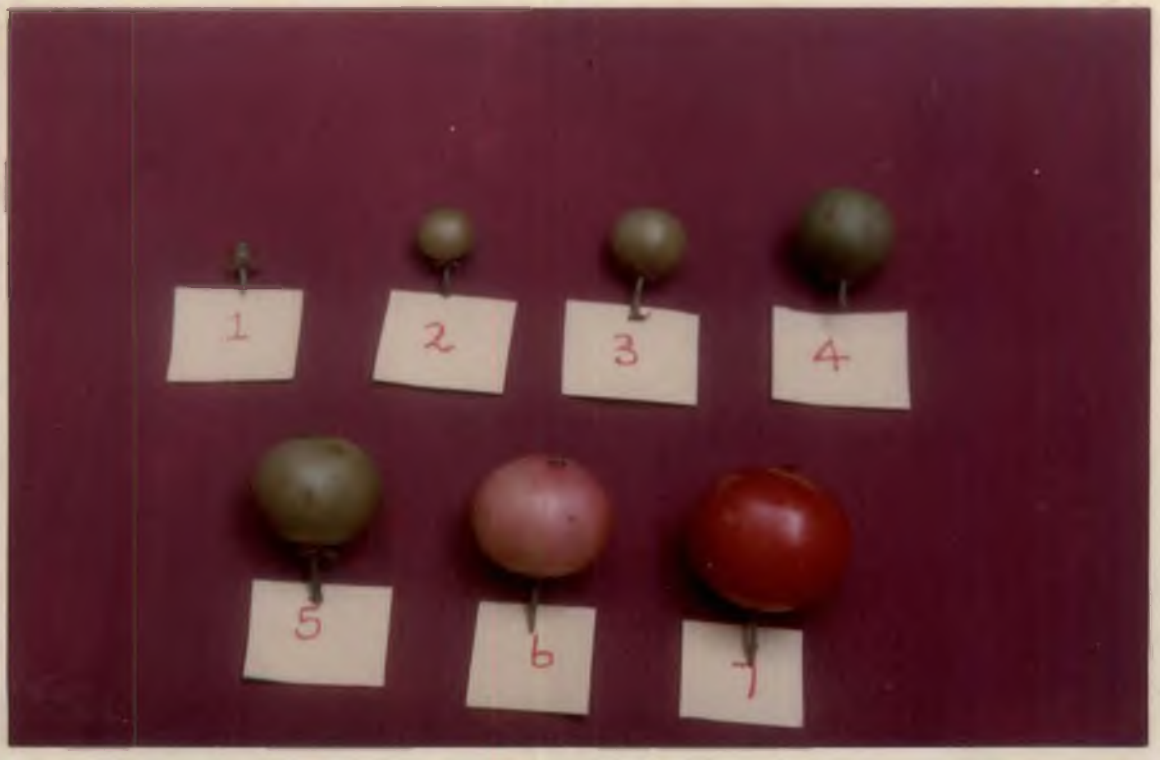


Fig.4. Changes in mean weight, volume, length and girth during growth and development of fruits in sour lovi-lovi

Plate 6a. Fruiting twig of sour lovi-lovi

Plate 6b. Stages of fruit development in sour lovi-lovi


FRUITING BRANCH
Flacourtia inermis


1
2
3
4
5
6
7

showed that maximum increase in weight (52.08%), volume (54%), length (31.42%) and girth (29%) were obtained when the fruit was in between 56 and 70 days of development period (Table 24). Afterwards, only a slight percentage of increase was noticed in all the parameters like volume, weight, length and girth of the fruits. The fruits took about 80-84 days for the complete development (Fig.5) (Plate 7a and b).

4.5.2 Biochemical changes during fruit development

The chemical analysis of fruits of both sour and sweet lovi-lovi was carried out for determining TSS, titratable acidity, ascorbic acid, total sugar, reducing and non-reducing sugars and sugar acid ratio. In the case of sour lovi-lovi the chemical analysis was carried out from 60 days after fruitset upto 120 days, at 20 days interval. Total soluble solids showed an increase from 4.5 to 10.5° brix at ripening stage. Titratable acidity showed a decreasing trend. The value ranged from 3.2 per cent on the 60th day of set to 1.1 per cent at the fully ripened stage. Only trace quantity of ascorbic acid was present in all stages of development of the fruit. Total sugars along with reducing and non-reducing sugars increased during the development of fruit. At ripening stage total sugars were found to be 2.9 per cent with 1.8 and 1.1 per cent of reducing and non-reducing sugars, respectively. Sugar acid ratio ranged from 0.13 to 2.63 where a sudden increase in this value was observed during 100 days to 120 days after fruit set (0.56 to 2.63) (Table 25) (Fig.6).

Fruits of sweet lovi-lovi were chemically analysed from 20 days of fruitset to harvesting stage, i.e., 80 days after fruitset. The total soluble solids showed an increase from 12.2° brix to 20.3° brix at ripening stage. Titratable acidity

Table 24. Physical changes of fruit during growth and development - sweet lovi-lovi

Days after fruit set	Mean weight (gm)	Percentage increase in weight	Mean volume (ml)	Percentage increase in volume	Mean length (cm)	Percentage increase in length	Mean girth (cm)	Percentage increase in girth
14	0.15	0.00	0.40	0	0.40	0.00	1.20	0.00
28	0.46	5.50	0.70	6	0.80	28.57	2.90	27.00
42	1.21	13.02	1.50	16	1.20	28.57	4.20	20.96
56	2.80	27.60	2.20	14	1.30	7.10	5.50	20.96
70	5.80	52.08	4.90	54	1.74	31.42	7.30	29.00
84	5.90	1.73	5.40	10	1.80	4.20	7.40	1.60

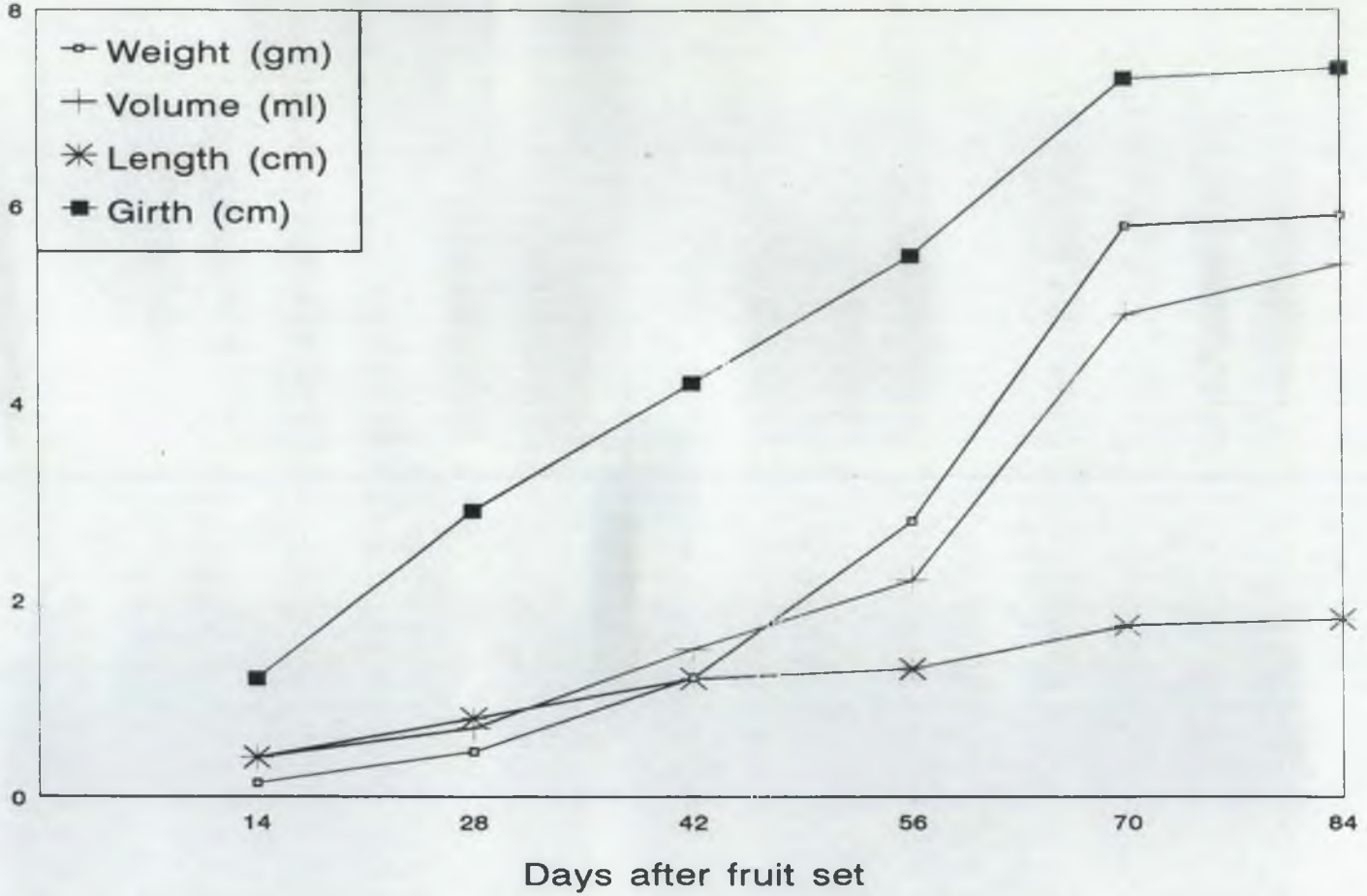


Fig.5. Changes in mean weight, volume, length and girth during growth and development of fruits in sweet lovi-lovi

Plate 7a. Fruiting twig of sweet lovi-lovi

Plate 7b. Stages of fruit development in sweet lovi-lovi


FRUITING TWIG
Hacourtia cataphracta

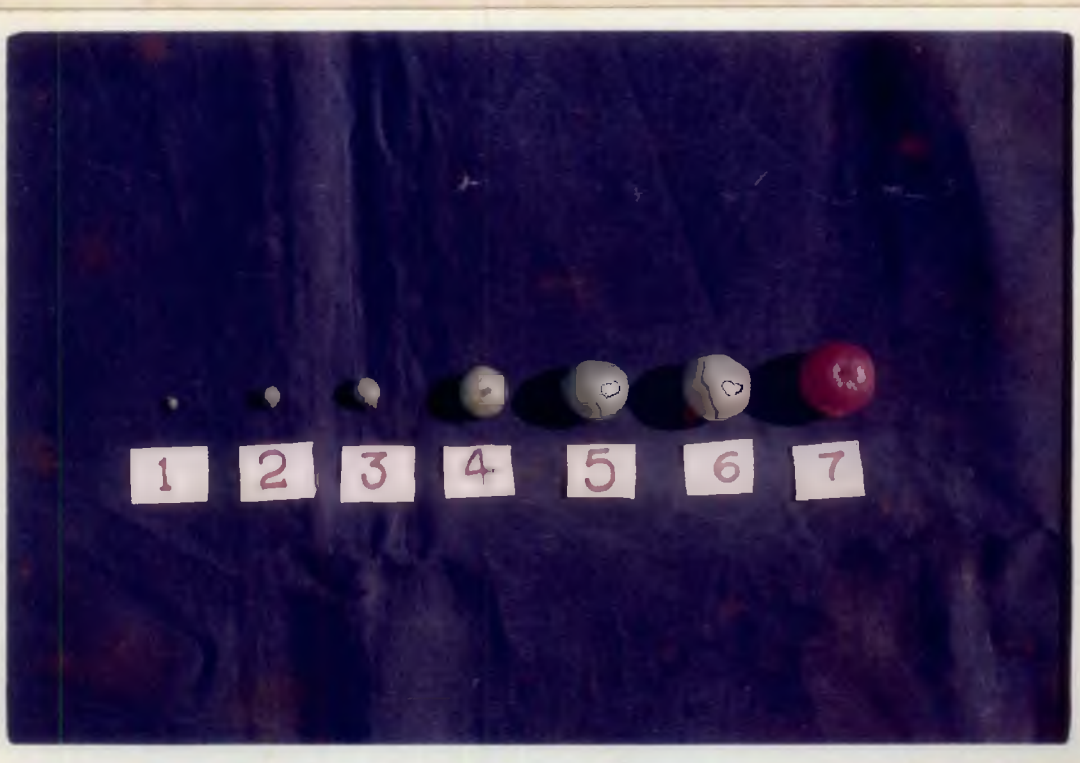

1
2
3
4
5
6
7

Table 25 Quality analysis of sour lovi-lovi fruits

Days after fruit set	TSS °Brix	Tritratable acidity (%)	Ascorbic acid mg/100	Total sugar (%)	Reducing sugar (%)	Nonreducing sugar (%)	Sugar acid ratio
60	4.5	3.2	Present in traces only	0.4	0.2	0.2	0.13
80	6.0	2.8		0.9	0.3	0.6	0.32
100	7.5	2.5		1.4	0.7	0.7	0.56
120	10.5	1.1		2.9	1.8	1.1	2.63

Table 26. Quality analysis of sweet lovi-lovi fruits

Days after fruit set	TSS °Brix	Tritratable acidity (%)	Ascorbic acid mg/100 g	Total sugar (%)	Reducing sugar (%)	Nonreducing sugar (%)	Sugar acid ratio
20	12.2	2.5	15.5	3.5	1.1	2.4	1.4
40	15.3	2.3	16.2	7.6	4.6	3.0	3.3
60	18.8	2.1	17.5	10.5	7.5	3.0	5.0
80	20.3	1.5	18.5	16.5	10.5	6.0	11.0

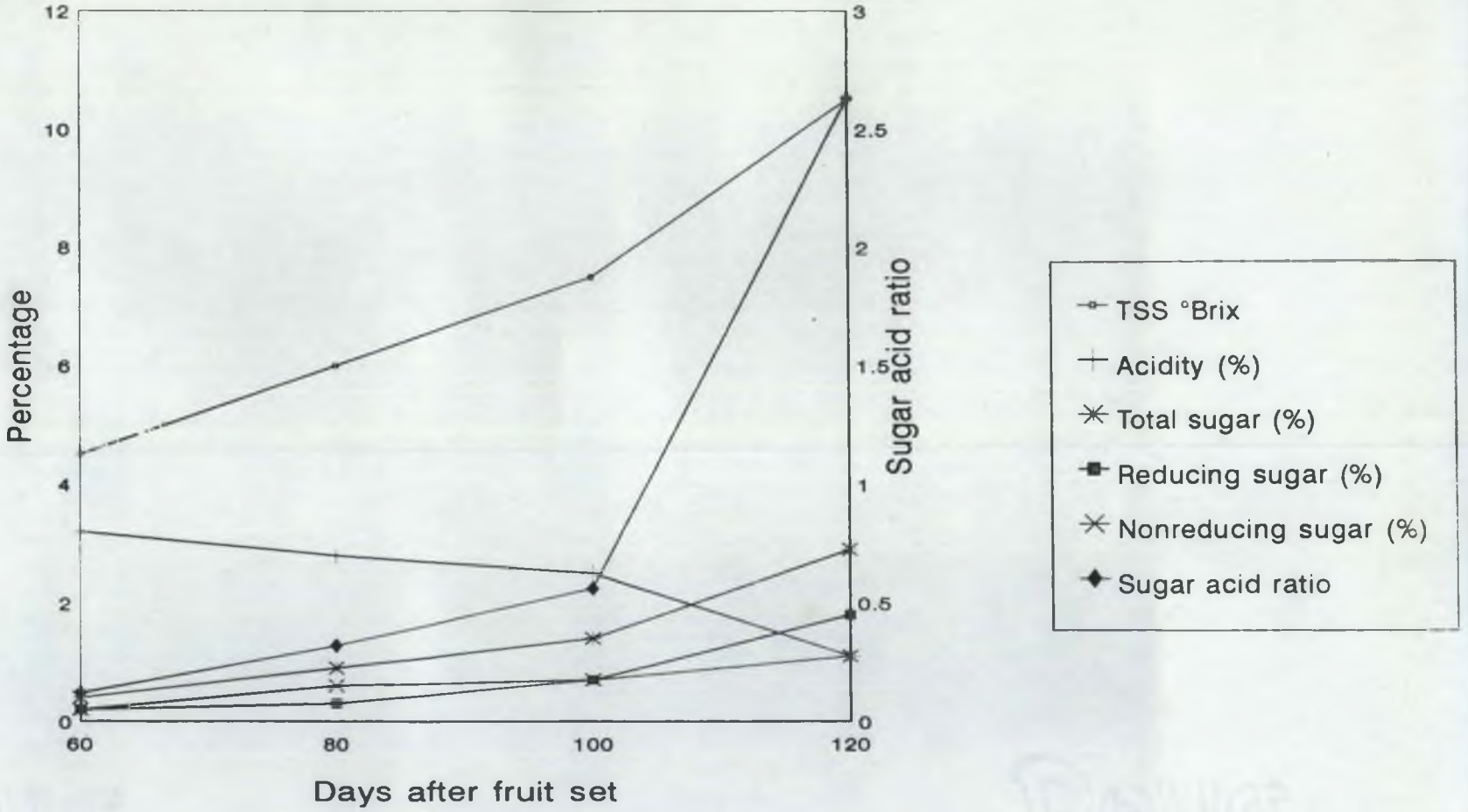


Fig.6. Chemical composition of sour lovi-lovi fruits at different stages of development

showed a decreasing trend and the value ranged from 2.5 to 1.5 per cent at the ripening stage. The ascorbic acid content also increased from 15.5 per cent to 18.5 per cent at the time of harvest. The total, reducing and non-reducing sugars increased during the development of fruit from 20th day and reached the maximum during the ripening stage. At ripening stage, total sugars was 16.5 per cent with 10.5 per cent reducing and 6.0 per cent non-reducing sugars. Sugar acid ratio was 1.4 at 20 days after fruit set and it increased gradually upto 60 days. Then it showed a double fold increase and reached the ratio of 11 at 80 days after fruit set (Table 26) (Fig.7).

4.5.3 Fruit drop

4.5.3.1 Fruit drop in sour lovi-lovi

In *F. inermis* fruit drop was recorded at monthly interval and the data showed that the fruit drop was maximum during 30 days after fruitset. This accounted for 15 per cent of the total fruitset. Another 9.41 per cent fruit drop was recorded during the second month of fruit development. Thereafter, fruit drop was negligible and practically no drop was observed during the maturation stage (Table 27).

4.5.3.2 Fruit drop in sweet lovi-lovi

Fruit drop recorded at 20 days interval showed that the drop was maximum during the first twenty days after fruitset (Table 28). This accounted for 22 per cent of total fruitset. Another 15.38 per cent fruit drop was observed during the next 20 days of development. Thereafter fruit drop was negligible and no drop was observed till the harvest time in sweet lovi-lovi.

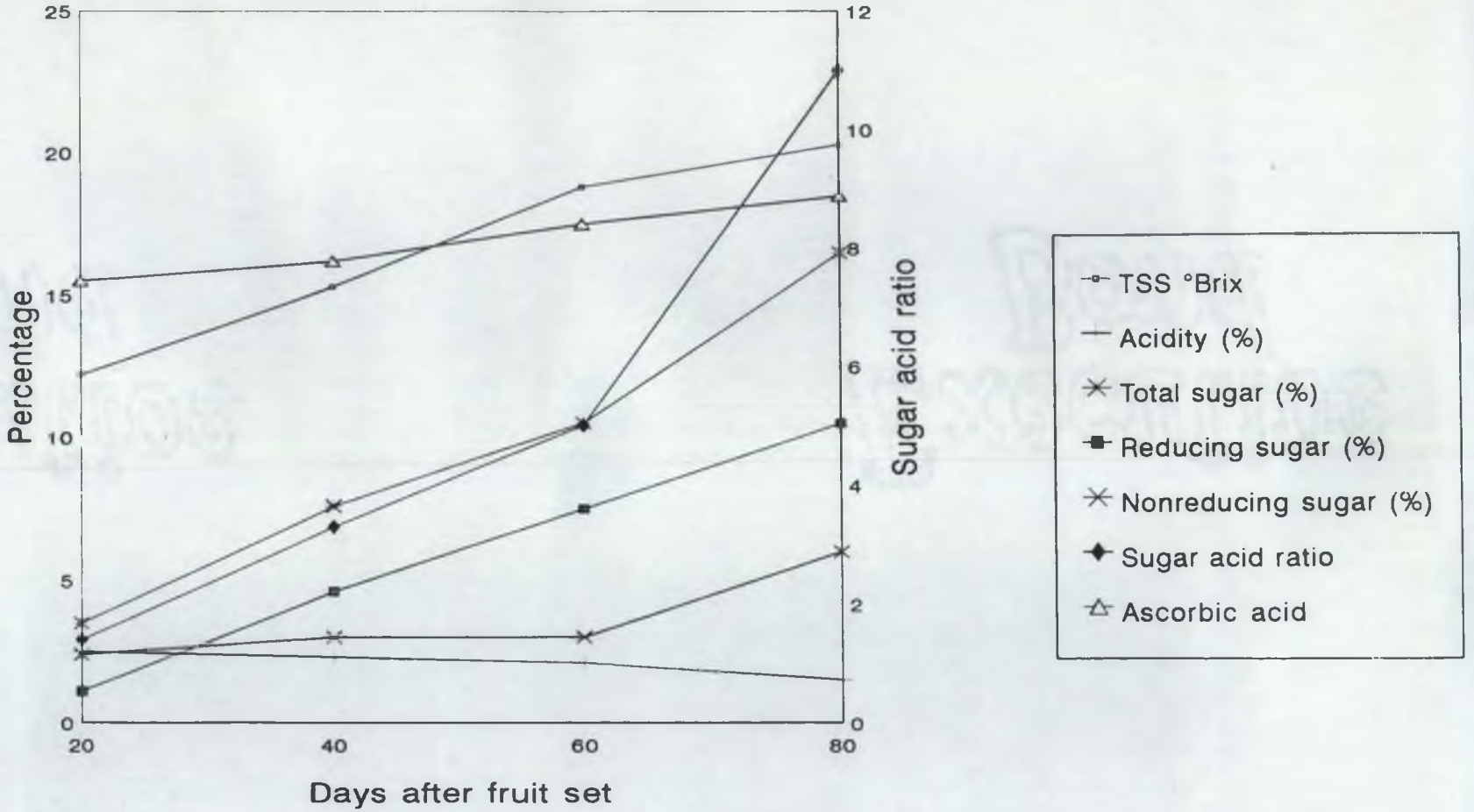


Fig.7. Chemical composition of sweet lovi-lovi fruits at different stages of development

Table 27. Fruit drop in sour lovi-lovi (at 30 days interval)

Days after fruit set	Number of fruits observed	Number dropped	Per cent dropped
At fruit set	100	0	0.00
30	100	15	15.00
60	85	8	9.41
90	77	0	0.00
120	7	0	0.00

Table 28. Fruit drop in sweet lovi-lovi (at 20 days interval)

Days after fruit set	Number of fruits observed	Number dropped	Per cent dropped
At fruit set	100	0	0.00
20	100	22	22.00
40	78	12	15.38
60	66	0	0.00
At harvest	66	0	0.00

4.5.4 Harvest index

The fruits of both sour and sweet lovi-lovi were harvested at the fully ripened stage when the colour of the fruits became dark red. In sweet lovi-lovi, browning of fruits was noticed once the fruits were detached from the tree as the fruit stalk was practically nil. The fruits were tightly attached to the bearing shoots and the pedicels were very short. The fruits should be harvested along with the pedicels as the fruits without pedicels showed browning immediately after harvest. The extent of browning in sour lovi-lovi fruits was less when compared to sweet lovi-lovi as they could be harvested along with their short pedicels. The sour lovi-lovi fruits took about 110-120 days to reach the harvest stage. At this stage the mean weight, volume, length and girth of the fruits were 6.7 g, 6 cc, 2.2 cm and 13.72 cm, respectively (Table 23) (Plate 8 and 9). The TSS, titratable acidity, total sugars, reducing sugars and sugar acid ratio were 10.5°brix, 1.1 per cent, 2.9 per cent, 1.8 per cent, 1.1 per cent and 2.63 respectively at this stage (Table 25). The sweet lovi-lovi fruits took about 80-84 days to reach the harvest stage. The mean weight, volume, length and girth of fruits at this stage were 5.9 g, 5.4 cc, 1.8 cm and 7.4 cm respectively (Table 24). The TSS, titratable acidity, total sugars, reducing sugars, non-reducing sugars, ascorbic acid and sugar acid ratio were 20.3° brix, 1.5 per cent, 16.5 per cent, 10.5 per cent, 6 per cent, 18.5 mg/100g and 11, respectively, at this stage (Table 26).

Fruits should be prevented from falling down on the ground while harvesting since it will cause mechanical injury to the fruits. So care should be taken while harvesting lovi-lovi fruits.

Plate 8 a. Fully ripened fruits in sour lovi-lovi
b. Cross section of healthy fruits

Plate 9. Fully ripened fruits in sweet lovi-lovi
a) Cross section of healthy fruits
b) Cross section of shrivelled fruits


1
2


1
2

4.6 Yield

There was wide variation in yield among individual trees both in sour and sweet lovi-lovi. The yield of individual trees was estimated by recording the weight of number of fruits obtained from each tree during each harvest. The yield in sour lovi-lovi ranged from 35-50 kg fruits per tree per annum. In sweet lovi-lovi it ranged from 70-95 kg fruits per tree per annum (Tables 29 and 30).

4.6.1 Number of fruits

Tree wise variation was noticed in total number of fruits in sour lovi-lovi (Table 29). Tree number T_1 recorded highest number of fruits (10,000) and T_3 recorded the lowest number (3500). In sweet lovi-lovi also tree wise variation was recorded in the total number of fruits (Table 30). Tree number T_2 recorded the highest number of fruits (16050) and T_6 recorded the lowest number (11990).

4.6.2 Seed characters

The fruits from individual trees were pooled separately and a random sample of 100 fruits were taken for determining the seed characters. In sour lovi-lovi the number of seeds per fruit ranged from 8 to 15 in different trees i.e., tree number T_3 had 14-15 seeds, T_1, T_2, T_4 and T_6 had 11-13 seeds and T_5 had 8-10 seeds per fruit (Table 29). Hundred seed weight differed from tree to tree. Tree number T_5 recorded the highest seed weight (7.90 g) while in T_4, T_1, T_3, T_2 and T_6 the values were 7.70 g, 7.47 g, 7.40 g, 7.30 g and 7.10 g, respectively. The percentage of edible portion ranged from 90-95 in T_6 where as it was 85-90 per cent in all other sour lovi-lovi trees studied (Table 29).

Table 29. Tree wise variation in yield and seed characters in sour lovi-lovi

Sl.No.	Tree number	Yield kg fruits/tree	Number of fruits in 000's	Number of seeds/fruit	100 seed weight (g)	Percentage of edible portion
1	T_1	50	10.0	11-13	7.47	85-90
2	T_2	49	9.8	11-13	7.30	85-90
3	T_3	35	3.5	14-15	7.40	85-90
4	T_4	40	8.0	11-13	7.70	85-90
5	T_5	37	7.4	8-10	7.90	85-90
6	T_6	42	8.4	11-13	7.10	90-95

Table 30. Tree wise variation in yield and seed characters in sweet lovi-lovi

Sl.No.	Tree number	Yield kg fruits/tree	Number of fruits in 000's	Number of seeds/fruit	100 seed weight (g)	Percentage of edible portion
1	T_1	80	13.55	10-12	3.47	89-92
2	T_2	95	16.05	10-12	3.80	89-92
3	T_3	79	13.35	10-12	3.25	89-92
4	T_4	83	14.02	10-12	3.25	89-92
5	T_5	76	12.84	9-10	3.00	93-96
6	T_6	70	11.99	12-14	3.75	93-96

The same procedure was followed in sweet lovi-lovi also for determining the seed characters.

Minimum number of seeds found in a fruit was 9 and it varied upto 14. Here also tree-wise variation was seen i.e., it ranged from 9-10, 10-12 and 12-14 in T_5, T_1 to T_4 and T_6, respectively. Hundred seed weight was highest in T_2 (3.80 g) and lowest in T_5 (3.00 g). The percentage of edible portion varied from 89 to 92 in T_1 to T_4 and 93-96 in T_5 and T_6, respectively (Table 30).

4.7 Pigment analysis

The absorbance value of fruit sample obtained at different wave lengths viz., 490, 500, 520, 525, 530 and 540 nm, showed that the maximum absorbance was observed in 490 and 500 nm (Table 31). It indicated that the fruit sample contained higher quantity of anthocyanin and anthocyanidin. It was an indication of the present of pelargonidin of pelargonidin-3-glucoside (Ranganna, 1977).

4.8 Storage studies

4.8.1 Fruit loss

There was notable difference in loss of fruit between those kept in refrigerated and room temperature conditions. In all treatments the loss of fruits started from the next day of harvest itself. Sour lovi-lovi fruits stored in room temperature (T_1) and stored in polythene cover under room temperature (T_2) showed a loss of about 42 and 40 per cent respectively on the second day of storage while treatment T_3 (fruits in refrigerated condition) and T_4 (fruits in polythene cover in refrigerated condition) showed a loss of only 23 and 22 per cent respectively

Table 31. Pigment analysis in sweet lovi-lovi fruits

Wave length (nm)	OD value (absorbance)
490	1.35
500	1.25
520	0.95
525	0.90
530	0.80
540	0.57

(Table 32). In T_1 and T_2 complete loss of fruits occurred on sixth day of storage while in T_3 and T_4 it was on tenth day of storage.

Percentage loss of sweet lovi-lovi fruits kept under different storage media were recorded at daily interval and the data were presented in Table 33. Percentage loss of fruits in T_1 and T_2 in the first day of storage was 26.56 per cent and 22.44 per cent respectively. While for treatment T_3 andT_4 it was 9.86 and 8.6 per cent. Complete loss of fruits in T_1 and T_2 occurred on fourth day of storage but in T_3 and T_4 it was on fifth day of storage.

4.8.2 Physiological loss in weight of fruits in storage

Significant difference was observed in the physiological loss in weight of in room temperature and refrigerator storage Sour lovi-lovi fruits stored in room temperature (T_1) or in polythene cover under room temperature recorded maximum loss in weight during the fourth day of storage (4.6% and 4.5%) itself, while the fruits kept in T_3 and T_4 storage condition showed the maximum loss in weight only in tenth day of storage (5.0% and 4.8%, respectively (Tablt 34).

In sweet lovi-lovi also the same trend as in sour lovi-lovi was seen for this character (Table 35). Here maximum loss in weight of fruits stored under room temperature was noted during the third day (6.4% and 6.1%) itself. Fruits stored in refrigerated atmosphere showed maximum weight loss on the fifth day of storage (4.9% and 4.5%).

Table 32. Percentage loss of fruits kept under different storage conditions at daily interval in sour lovi-lovi (2 days interval)

Sl. No.	Treatments	Fruit loss (%)				
		Interval (days)				
		2	4	6	8	10
1	T_1	42	76.5	100		
2	T_2	40	76.4	100		
3	T_3	23	38.5	63	79	100
4	T_4	22	38.0	61	78	100

Table 33. Percentage loss of fruits kept under different storage conditions at daily interval in sweet lovi-lovi (daily interval)

Sl. No.	Treatments	Fruit loss (%)					
		Interval (days)					
		1	2	3	4	5	6
1	T_1	26.56	40.30	66.54	100.0	-	-
2	T_2	22.44	40.54	65.55	100.0	-	-
3	T_3	9.86	33.56	54.05	70.4	100	-
4	T_4	8.60	32.56	54.55	70.1	100	-

Table 34. Physiological loss in weight of fruits kept under different storage conditions in sour lovi-lovi (2 days interval)

Sl. No.	Treatment	PLW (%)				
		Interval in days				
		2	4	6	8	10
1	T_1	3.7	4.6	-	-	-
2	T_2	3.5	4.5	-	-	-
3	T_3	3.4	4.2	4.7	4.8	5.1
4	T_4	3.4	4.1	4.5	4.6	4.8

Table 35. Physiological loss in weight of fruits kept under different storage condition in sweet lovi-lovi (daily interval)

Sl. No.	Treatment	PLW (%)				
		Interval in days				
		1	2	3	4	5
1	T_1	4.2	5.8	6.4	-	-
2	T_2	4 0	5.5	6.1	-	-
3	T_3	3.1	3.6	4.2	4.7	4.9
4	T_4	2.8	3.2	3.8	4.2	4.5

4.8.3 Biochemical analysis

The fruits of sour as well as sweet lovi-lovi types were analysed biochemically for determining the qualities of the fruits in various storage media at two days interval in sour lovi-lovi and at daily interval in sweet lovi-lovi. The results showed that in sour lovi-lovi fruits, the total soluble solid content (TSS) decreased in the storage, irrespective of the type of storage media. During the second day of storage the TSS content ranged from 10.4 to 10.6° brix, and it decreased to 6° brix in open storage and 5° brix in refrigerated storage condition during the sixth and tenth day, respectively (Table 36).

Sweet lovi-lovi fruits recorded a higher TSS value compared to sour lovi-lovi. Daily TSS content analysed in the fruits stored under various storage media showed a declining trend in all the treatment. During the first day the TSS content ranged from 20.4 to 20.5° brix, and it was decreased to 10.2° brix at the fourth day of storage in ambient condition (Table 37).

Total sugar content also showed a decreasing trend in sour lovi-lovi fruits in all the storage media (Table 38). It ranged from 2.75 to 2.96 at the second day of storage. The minimum values of 0.6 and 0.7 were recorded in the eighth day of storage in T_1 and T_2 while in T_3 and T_4 the minimum values were reached in the tenth day of storage (0.60 and 0.71 respectively).

In sweet lovi-lovi, among the four treatments total sugars ranged from 16.34 to 16.65 during first day of storage. Decrease in total sugars were more rapid in third and fourth day of storage in T_1 and T_2 while it was on the fourth and fifth day in T_3 and T_4 (Table 39).

Table 36. Changes in TSS of fruits kept under different storage condition in sour lovi-lovi (2 days interval)

Sl. No.	Treatment	TSS °Brix				
		Interval (days)				
		2	4	6	8	10
1	T_1	10.5	8.4	6.0	-	-
2	T_2	10.6	9.8	6.4	-	-
3	T_3	10.6	9.4	7.6	6.4	5.0
4	T_4	10.4	9.6	7.4	6.2	5.3

Table 37. Changes in TSS of fruits kept under different storage conditions in sweet lovi-lovi (daily interval)

Sl. No.	Treatment	TSS °Brix				
		Interval (days)				
		1	2	3	4	5
1	T_1	20.4	18.7	12.5	10.2	-
2	T_2	20.5	18 5	12.1	10 3	-
3	T_3	20.4	18.5	12.6	12.1	10.2
4	T_4	20.5	18.9	12.7	12.2	10.5

Table 38. Changes in total sugars of fruit kept under different storage conditions in sour lovi-lovi (2 days interval)

Sl. No.	Treatment	Total sugars (%)				
		Interval (days)				
		2	4	6	8	10
1	T_1	2.96	2.10	0.6	-	-
2	T_2	2.75	2.11	0.7	-	-
3	T_3	2.94	2.50	2.0	1.3	0.60
4	T_4	2.83	2.40	2.1	1.4	0.71

Table 39. Changes in total sugars of fruit kept under different storage conditions in sweet lovi-lovi (daily interval)

Sl. No.	Treatment	Total sugars (%)				
		Interval (days)				
		1	2	3	4	5
1	T_1	16.64	14.34	10.64	6.56	-
2	T_2	16.56	14.51	10.62	6.41	-
3	T_3	16.34	15.03	11.63	7.05	6.50
4	T_4	16.65	15.54	11.91	7.85	6.40

The reducing sugar also showed a reducing trend both in sour as well as sweet lovi-lovi fruits. In sour lovi-lovi the reducing sugar level ranged from 1.7 to 1.8 in the second day of storage. Minimum values (0.5 and 0.4) were reached by the sixth day of storage for T_1 and T_2, while in T_3 and T_4 the minimum values were attained by the tenth day of storage (Table 40).

The reducing sugar content in sweet lovi-lovi ranged from 10.32 to 10.54 in all the four treatments during the first day of storage. The minimum values of 2.45 and 2.56 were attained by fourth day of storage in T_1 and T_2 condition, respectively, while in T_3 and T_4, the minimum values of 2.15 and 2.04, respectively, were attained by fifth day of storage (Table 41).

Reduction in the non-reducing sugar content exhibited a similar pattern as that of reducing sugars. The lowest values of non-reducing sugar, 0.1 and 0.3 (T_1 and T_2, respectively) in sour lovi-lovi fruits were attained by sixth day of storage. The minimum values for treatments T_3 and T_4 (0.2 and 0.3, respectively) were showed on the tenth day of storage (Table 42).

In sweet lovi-lovi fruits, the non-reducing sugar ranged from 6.21 to 6.93 during the first day of storage among the treatments. The minimum value of 4.11 and 3.85 was shown by the fourth day of storage in T_1 and T_2 condition while in T_3 and T_4 the minimum values of 2.35 and 2.36 were recorded on the fifth day of storage (Table 43).

Titratable acidity of the fruits showed a reverse trend when compared to that of sugars, i.e., the titratable acidity was found to increase with the increase in storage life. This was applicable to both sweet and sour lovi-lovi. In sour lovi-lovi

Table 40. Changes in reducing sugars of fruit kept under different storage condition in sour lovi-lovi (2 days interval)

Sl. No.	Treatment	Reducing sugar (%)				
		Interval (days)				
		2	4	6	8	10
1	T_1	1.8	1.5	0.5	-	-
2	T_2	1.7	1.5	0.4	-	-
3	T_3	1.8	1.7	1.2	0.7	0.4
4	T_4	1.7	1.8	1.2	0.71	0.4

Table 41. Changes in reducing sugars of fruit kept under different storage condition in sweet lovi-lovi (daily interval)

Sl. No.	Treatment	Reducing sugar (%)				
		Interval (days)				
		1	2	3	4	5
1	T_1	10.43	8.34	5.21	2.45	-
2	T_2	10.54	8.12	5.34	2.56	-
3	T_3	10.32	8.73	5.92	3.74	2.15
4	T_4	10.52	8.85	6.15	3.85	2.04

Table 42. Changes in non-reducing sugars in sour lovi-lovi kept under different storage condition (2 days interval)

Sl. No.	Treatment	Non-reducing sugar (%)				
		Interval (days)				
		2	4	6	8	10
1	T_1	1.16	0.63	0.10	-	-
2	T_2	1.05	0.60	0.30	-	-
3	T_3	1.14	0.80	0.80	0.60	0.20
4	T_4	1.13	0.60	0.90	0.69	0.30

Table 43. Changes in non-reducing sugars in sweet lovi-lovi kept under different storage condition

Sl. No.	Treatment	Non-reducing sugar (%)				
		Interval (days)				
		1	2	3	4	5
1	T_1	6.21	6.00	5.43	4.11	-
2	T_2	6.92	6.39	5.28	3.85	-
3	T_3	6.82	6.30	5.71	3.91	2.35
4	T_4	6.93	6.69	5.76	3.95	2.36

the maximum acidity of 2.2 and 2.1 was reached by the sixth day of storage for T_1 and T_2, respectively, while in T_3 and T_4 the maximum values of 2.4, each, was attained by the tenth day of storage (Table 44).

In sweet lovi-lovi titratable acidity in the first day of storage was same (1.5%) in all the four treatments. Maximum value of 2.1 and 2.2 for the treatments T_1 and T_2, respectively, was observed on the fourth day of storage. In T_3 and T_4 the maximum value of acidity (2.1%) was recorded by the fifth day of storage (Table 45).

Table 44. Changes in titratable acidity of fruits kept under different storage conditions in sour lovi-lovi (2 days interval)

Sl. No.	Treatment	Titratable acidity (%)				
		Interval (days)				
		2	4	6	8	10
1	T_1	1.70	1.92	2.20	-	-
2	T_2	1.70	1.95	2.10	-	-
3	T_3	1.75	1.80	2.00	2.25	2.40
4	T_4	1.75	1.85	2.00	2.30	2.40

Table 45. Changes in tritratable acidity of fruits kept under different storage conditions in sweet lovi-lovi (daily interval)

Sl. No.	Treatment	Titratable acidity (%)				
		Interval (days)				
		1	2	3	4	5
1	T_1	1.50	1.65	1.89	2.10	-
2	T_2	1.50	1.85	2.90	2.20	-
3	T_3	1.50	1.74	1.90	2.00	2.1
4	T_4	1.50	1.73	1.85	2.00	2.1

Discussion

5. DISCUSSION

The results generated from the present studies on various aspects of growth, flowering, fruitset, fruit development, storage and biochemical studies in sour lovi-lovi (*Flacourtia incrmis)* and sweet lovi-lovi (*F. cataphracta*) are discussed in this chapter.

5.1 Growth characteristics in sour lovi-lovi and sweet lovi-lovi

Sour lovi-lovi and sweet lovi-lovi are the two important members of the family Flacourtiaceae and are considered as minor tropical fruits. They require a tropical climate with relatively high temperature and humidity, moderate rainfall and a shady environment, especially during the early stages of seedling growth. The grown up tree requires comparatively open condition for its proper growth.

5.2 Shoot growth

The shoot growth in sour lovi-lovi was found to be cyclic, a period of growth followed by the period of quiescence. Growth was not seen in all the shoots during all the flushes. However, when the entire tree was considered, continuous growth was observed in all the months, though it was negligible in summer months. The extension growth proceeds by periodic flushes. There were two main peak seasons of extension growth, viz., May-June and August-September. In September alone 28.99 per cent of the total growth was recorded. This was closely followed by June (24.97%) and then comes May and August (15.96% and 14.89%) respectively.

In sweet lovi-lovi both male and female trees showed almost same growth pattern, which was very much similiar to that observed in sour lovi-lovi trees.

Several workers (Sen and Mallik, 1941); Naik and Rao, 1942; Krishnamurthi *et al.*, 1961; Randhawa and Sinha, 1963 and Singh and Ghose, 1965) have reported cyclic or rythmic growth in perennial trees. Similiar cyclic pattern of growth was observed in lovi-lovi trees also (both in sour and sweet lovi-lovi types). The higher growth rate exhibited during September and May-June is quite reasonable considering the high soil moisture level and optimum temperature during the periods. The low moisture level in summer, coupled with comparatively low relative humidity may be the possible reasons for the absence of growth or poor growth during the summer months. The climatic factors such as temperature, rainfall and relative humidity may not be the only limiting factors for the growth of lovi-lovi trees (both sour and sweet types). The moisture level of soil and the internal physiological conditions of the tree were also be the controlling factors as the data clearly indicated that a slight increase in growth, eventhough not significant, is recorded throughout the year. Sherly (1994) reported similar type of growth in *Garcinia cambogia*, where a main flushing season was followed by scattered flushing throughout the year.

Compared to many other perennial crops, the mean extension growth of shoots in lovi-lovi trees for a period of one year was found to be in range of low to medium. In nutmeg this type of growth was reported by Crucickshank (1973) and Nazeem (1979). In many cases, rhythmic growth is determined endogenously. Internodal length and number of leaf primordia are the basic physiological units which determine the extension growth of a shoot and it can be further modified by the climatic and nutritional factors.

5.2.1 Tree architecture

The visible, morphological expression of the genetic blue print of a tree is referred as its architecture (Halle *et al.*,1978). The concept of architectural modelling is a dynamic one which requires constant watch about the growth pattern of the tree, right from the seedling stage. After computing the growth characteristics, it can be fitted to any of the established models. But in sour as well as in sweet lovi-lovi trees a limited research work has been carried out regarding the organisational pattern of the trees. An attempt in this line was made in the present study.

Studies conducted envisaged that almost similar type of growth pattern was exhibited by both lovi-lovi types. The seedlings consisted of a parent shoot on which the leaves were borne singley in a distichous manner. The newly emerging leaves were distinct from the mature leaves by its colouration. In sour lovi-lovi the emerging leaves are purplish red in colour whereas in sweet lovi-lovi, they are brownish red. Size, shape and serration in the leaves were almost similar in both the types but they can be differentiated by seeing the colour and thickness of the mature leaves. Sour lovi-lovi leaves were lighter green in shade and comparatively thin whereas sweet lovi-lovi (both male and female trees) leaves were bright green coloured and thicker in texture.

The first pair of branches produced by the trunk axis marks the end of the seedling stage. In sour lovi-lovi branching started from 0.5 m to one metre height from ground level but in sweet lovi-lovi in many cases it started from the ground level itself. Sharp decomposed spins were present in the main trunk of sweet lovi-lovi where as spines were absent in sour types.

Lovi-lovi trees have a monopodial trunk which grows rhythmically and develops branches, the branches themselves were morphogenetically identical with the trunk. This character is much relevant in case of sweet lovi-lovi compared to sour lovi-lovi trees. Branching in lovi-lovi is sylleptic initially, i.e., near the top of the main trunk, the meristem shows its orthotrophic character and produces a sub erect shoot, with fairly complete radial symmetry. However, after the production of 2nd and 3rd order laterals, the orthotropic nature of the branches get diffused. Thus the further meristems develop plagiotropically and the inflorescence is seen on later type of branches which are usually fourth or fifth order in position.

Growth in lovi-lovi is rhythmic with variation in the periodicity of growth. In sour and sweet lovi-lovi, two periods of active growth was seen, followed by a comparatively inactive stage. It is often correlated with season and also on endogenous factors which control the shoot extension.

Several tree architectural models have been proposed by Halle *et al* (1978). The architectures of both sour and sweet lovi-lovi were not described in any models. However, the observations made pointed out that these trees have close proximity to Rauh's model where many of the tropical trees and especially one member of the family Flacourtiaceae is fitted.

5.3 Flowering and floral characters

5.3.1 Flowering pattern and flower bud development

In sour lovi-lovi flowers are bisexual in nature. Flowering was seen both on current as well as past season shoots. The tree produced flowers almost through out the year with two distinct peak seasons and the peak flowering seasons were coped up immediately after the flushing or along with the end of flushing period.

Rivals (1966) discussed about the continous flowering nature of the pleonanthic shoots, which is common in many tropical trees. In certain trees such shoots showed the peak flowering just after the shoot growth. Such a coincidence of shoot expansion and flowering was seen in sour lovi-lovi also. Occurrence of flower buds along with the vegetative flush was reported in crops like nutmeg (Nazeem, 1979 and *Annona* sp. (Thakur and Singh, 1965). The visual emergence of flower bud had two seasons, i.e. June and October with maximum flowering in July and November, which accounts for 59 and 41 per cent of flowering intensity. Environmental factors as well as genetic factors have pronounced influence on flowering. In sour lovi-lovi, the peak flowering season was coincided with a low mean temperature and relatively high humid climate.

Sweet lovi-lovi trees are dioecious in nature. There was only one flowering season in both male and female trees. In male tree the visual flower bud emergence was seen during the month of October while in female trees it was on November. There was roughly one month difference between the flower bud emergence in male and female trees. The period of maximum flowering was in November for male trees and December for female trees.

In sweet lovi-lovi flowering season was coincided with relatively cooler months characterised by comparatively lower rainfall, temperature and sunshine hours (Thakur and Singh, 1965). But in sour lovi-lovi peak flowering could be noticed in high rainfall with high relative humidity periods as well.

The percentage of shoots flowered and the mean number of flowers per inflorescence were less in sour lov-lovi when compared to sweet lovi-lovi. But the number of inflorescence per flowering shoot was more in sour lovi-lovi than in sweet lovi-lovi trees. In both cases, flowers were seen from basal portion to the

distal portion of a shoot. Individually they are described as lateral cymes subtended by foliage which is one of the characteristic feature of pleonanthic shoots (Rivals, 1966).

5.3.2 Floral biology

In sour lovi-lovi trees, the flowers were bisexual and were produced in both past as well as current season shoots, while the sweet lovi-lovi trees were dioecious in nature with male and female flowers on separate trees. The flowers of both sour and sweet lovi-lovi were small in size. Flowers in cymes were emerged from each node of a lateral shoot right from the base to the terminal portion of the shoot. The flowers had five perianth lobes and they were arranged in an imbricate aestivation. In sour lovi-lovi the anthers were 16-20 in number, seen around the nectary ring. While in sweet lovi-lovi male flowers, the androecium consisted of numerous number of stamens with slender dorsified filaments. In both types, the anthers were two celled and the dehiscence was longitudinal. In sour as well as sweet lovi-lovi, the gynoecium was syncarpous with 5-7 carpels having a single ovule in each carpel and the ovules are arranged in axile placentation.

In sour lovi-lovi the flower bud development from bud emergence to anthesis was found to here four arbitrary stages. It took about 10-14 days to complete these stages. In sweet lovi-lovi, the male flower bud development from bud emergence to anthers was divided into four arbitary stages (19-26 days), while for female flowers it was divided into three arbitrary stages (9-11 days). Nutmeg, which is dioecious in nature showed such a difference among the male and female flower development period i.e., from bud emergence to anthesis (Nazeen, 1979). In nutmeg females flowers took comparatively more time (154.1 days) than that for the male flowers (84.2 days).

In 'Kodampuli' the flower bud development in male and bisexual flower was divided into seven arbitrary stages which required about 32 and 28 days, respectively for the completion (Sherly, 1994). In mangosteen the flower bud development was divided into six artibtrary stages. On an average the bud development was completed in 28 days (Alex, 1996).

The anthesis of the flowers in both sour and sweet lovi-lovi started at 6.00 hours and continued upto 7.30 hours in sour lovi-lovi and 8.00 hours in sweet lovi-lovi. Maximum number of flowers opened was in between 6.00 and 6.30 hours in sour lovi-lovi and it was between 6.30 and 7.00 hours in sweet lovi-lovi flowers. Anther dehiscence occured from 6.00 hours continued upto 8.00 hours in both types. The stigma was found receptive from 12 hours before anthesis in sour lovi-lovi and 18 hours before anthesis in sweet lovi-lovi. The receptivity of stigma continued upto 30.00 hours after anthesis in sour as well as sweet lovi-lovi flowers. Similar conditions of stigmatic receptivity and anther dehiscence was reported in cashew also (Dasarathi, 1958; Northwood, 1966; Damodaran *et al.*, 1966).

5.3.2.1 Pollen studies

Results from the present study indicated that pollen fertility was higher for male flowers of sweet lovi-lovi when compared to sour lovi-lovi. The individual pollen was almost spherical in shape, measuring 10.3 μ to 20.5 μ in sour lovi-lovi and 15.6 μ to 32.3 μ diameter in sweet lovi-lovi male flowers. Acetocarmine stain test showed 40 per cent and 83 per cent fertility for pollen from bisexual flowers of sour and male flowers of sweet lovi-lovi, respectively. The fertility of pollen grain when tested through *in vitro* germination showed a germination of 48 per cent for the bisexual flower of sour lovi-lovi and 85 per cent for sweet lovi-lovi male flowers. In jack 89 to 93 per cent pollen fertility was reported (Joseph, 1983).

George *et al.* (1992) also reported a higher fertility for pollen from staminate flowers compared to bisexual flowers in *Garcinia combogia*. Sherly (1994) reported 71.81 per cent and 27.03 per cent fertility, respectively, for pollen from staminate and bisexual flowers of kodampuli.

Pollen grain germination studies in sour lovi-lovi recorded the maximum value of 43 per cent in six per cent sucrose and 0.25 per cent agar medium while in sweet lovi-lovi highest germination percent (93) was obtained in four per cent sucrose + 0.25 per cent agar medium.

Pollen germination studies showed that sucrose and agar had significant influences on germination of lovi-lovi pollen. 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 regulataion in the moisture, supply of carbohydrate and other nutrients as suggested by Stanely and Linskens (1974).

The optimum incubation period was found to be 24 hours in both types of lovi-lovi. The period of incubation varied from crop to crop. The incubation period required was more in lovi-lovi as compared to jack (6-8 hrs) or kodampuli (8 hrs)(Joseph, 1983 and Sherly, 1994).

Studies on pollen storage showed that there is a rapid loss in viability of pollen grains on storage. Low temperature storage gave better results than storage at room temperature. The percentage germination recorded at daily interval showed that storage of pollen grains at 4°C retained viability for maximum number of days

(six days) when compared to other treatments. Low temperature storage was found to be better than the low humidity storage or a combination of both. Little is known about the changes occurring to the pollen in sour and sweet lovi-lovi during storage, both on the genetic capacity as well as on the morphology. According to Stanley and Linskens (1974) decrease in pollen viability during storage may be attributed to reduction in the intracellular rates of respiration and changes in the endogenous growth hormones. Low temperature storage can retain the viability of the pollen grains or it ensures protection against dessication.

5.3.3 Pollinating agents

A large number of insects were found visiting the lovi-lovi flowers during the anthesis period. These include ants, honeybees, weevils etc. The observations indicated that pollination in lovi-lovi flowers (both sour and sweet) could largely be entomophilous. In Flacourtiaceae no reports are there about the ways of pollination and pollinating agents but the slight scented nature of the flowers and slow dispersal of the pollen grains after dehiscence are the adaptations for entomophily. Rendle (1979) reported that in the family Guttiferae pollination is through insects.

5.3.3.1 Mode of pollination

In sour lovi-lovi among the different modes of pollination, the fruit set was found to be low under natural pollinated conditions (68.00%). Maximum fruitset of 89.33 per cent was obtained for the hand pollination of unemasculated flowers. This indicated that eventhough sour lovi-lovi flowers were self and cross compatible and could take 68 per cent fruitset under natural condition, it could be further increased by hand pollination (upto 90.00%).

In sweet lovi-lovi the female flowers which were covered at the time of flower bud emergence for preventing pollination failed to set any fruit. The fruit set under hand pollinated condition was 96.00 per cent when compared to 89.33 per cent under open pollinated condition. It gives the clear evidence that pollination is a must for getting fruit set in sweet lovi-lovi thus ruling out the parthenocarpic development of the fruits. As in sour lovi-lovi, compared to open pollination, hand pollination gave a higher per cent of fruitset in sweet lovi-lovi also.

5.4 Fruit set, fruit drop and fruit development

5.4.1 Fruit set

In sour lovi-lovi the percentage of fruit set varies under different condition. The lowest fruit set of 68.00 per cent was obtained under naturally cross pollinated condition. The fruit set under open and self pollinated conditions was 83.65 and 74.66 per cent, respectively. Hand pollination of emasculated flowers gave a fruit set of 85.33 per cent while the highest per cent of 89.33 per cent fruit set was obtained for the hand pollination of unemasculated flower. The absence of fruit set and fruit development when pollen was excluded, indicated that there was no apomictic fruit development in sour lovi-lovi. The difference in fruit set among the emasculated and unemasculated flowers may be due to injuries caused during emasculation.

In sweet lovi-lovi, the female flowers, which were covered at the time of flower bud emergence for preventing pollination, fails to set any fruit. This indicated that in this fruit also there was no apomictic fruit development. The fruit set under open pollinated condition was 89.33 per cent while a fruit set of 96.00 per cent was obtained under hand pollinated condition. The slight variation in the per cent of fruit set may be due to factors like delay in the pollen germination found in

this crop (24 hours of incubation) and due to the loss of stigmatic receptivity by that time. These possibilities were eliminated in hand pollination where a higher fruit set is possible as evident from the present study.

5.4.2 Fruit drop

In both sour and sweet lovi-lovi the fruit drop was confined mainly to the early periods of development, i.e., upto 40-60 days. The reasons for this may be due to lack of fertilization or improper fertilization. Chadha (1963) had attributed the competition between young developing fruits for nutrients 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 the 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. Davies and Addicott (1972) reported that during the early stages of fruit development the senescence promoting effect may be due to the presence of ABA. They also opined that mature fruits did not continue to produce the senescence stimulus and hence a reduction in the fruit drop was effected. Present studies also showed that after the early stages of fruit drop, it appeared to be minimum and practically nil in later stages.

5.4.3 Fruit development

The fruits of sour lovi-lovi required about 110-120 days for the complete development while sweet lovi-lovi needed 70 to 80 days from fruitset to complete development of the fruit. Studies conducted revealed that fruit growth in sour as well as sweet lovi-lovi showed a sigmoid pattern. Such a type of fruit growth pattern has been reported in many major and minor fruit crops like Mango (Saini, *et al.*, 1972), Carambola (Nand, 1971), Kodumpuli (Sherly, 1994) and mangosteen

(Alex, 1996). Sour lovi-lovi showed a slow and steady increase in the fruit characters upto 100 days after fruitset and afterwards only a slight increase was noticed in the characters like length, girth, weight and volume (Fig.1). In sweet lovi-lovi fruits, a slow and steady increase was seen in all the biometrical characters upto 50 days and then a sudden increase in all the characters, except fruit length, upto 70 days after fruit set. Afterwards only a slight increase was observed till the time of harvest, in all the biometric characters (Fig.2). This type of fruit growth was also reported in kodampuli (Sherly, 1994) and Mangosteen (Alex, 1996). One of the possible reason for the peak increase in the fruit characters was that this period may coincide with the peak growth period of seed. This was supported by Chacko *et al.* (1970) and they reported that in mango rapid fruit growth was associated with the period of maximum activity of gibberellins and auxins present in the seed.

The fruits of sour as well as sweet lovi-lovi are almost round in shape and the green fruits acquired darker shades of red colour (tree wise variation noticed) towards ripening stage. The peel of the fruit was very thin and had maximum red colour while the flesh has got yellowish brown colour. Seeds, arranged in axile placentation were seen embedded in the flesh and the number varied from 7-15 per fruit.

Chemical analysis of the fruits showed that TSS content, total sugars, reducing and non reducing sugars and sugar acid ratio showed an increasing trend till harvest stage while the titratable acidity exhibited a reducing trend. In sour lovi-lovi only, traces of ascorbic acid was present but in sweet lovi-lovi it increased upto 18.5 mg/100 g at ripened stage (Fig.3 and 4).

5.4.4 Harvest index

Correct stage of maturity is indicated by several pointers based on visual, physical and chemical indices. Present study indicated that lovi-lovi fruits are non-climateric. Hence the fruits of lovi-lovi should be harvested at the fully ripened stage, i.e., when the fruits are blood red in colour. At this stage the fruits will have maximum weight, volume, length, girth and maximum TSS and sugar content. The sour lovi-lovi fruits took about 120 days to reach the harvest stage, while the sweet lovi-lovi took about 80-84 days to reach this stage. At this stage in sour lovi-lovi the TSS should be 10.5 ± 1° Brix. Brix and sugar acid ratio 2.63 ± 0.2 and in sweet lovi-lovi. The TSS should be 20.3° ± 1° Brix, sugar acid ratio as 11. Fruits should be prevented from falling on the ground while harvesting since it will cause mechanical injury to the fruits. Another major limitation of this fruit was the occurrence of browing, once the fruits are detached from the plant. The occurrence of browning is more rapid in sweet lovi-lovi fruits when compared to sour lovi-lovi. One of the possible reason for this is, sour lovi-lovi fruits can be harvested along with its short pedicels which is absent in sweet types. This causes a small opening at the proximal end of the fruit while harvesting, which favours rapid phenolic oxidation in sweet lovi-lovi fruits. So the lovi-lovi fruits, as far as possible, should be harvested along with the pedicels.

5.5 Yield

Tree wise variation was observed in yield in sour as well as sweet lovi-lovi. In sour lovi-lovi it varied from 35 to 50 kg/tree per year while it was 71 to 95 kg/tree per year in sweet lovi-lovi. The yield of sour lovi-lovi was reported to be 44-270 kg tree/year (CSIR, 1956).

Soil characters and microclimatic elements had a strong influence in the tree yield (CSIR, 1956). Among sour and sweet lovi-lovi, eventhough there are two fruiting seasons in sour lovi-lovi, total yield recorded was low, compared to sweet types. Age of the tree may be one of the crucial factors for such a difference the yield as the sweet lovi-lovi trees selected for the study were about 18-20 years old while the sour ones aged about 12-14 years.

5.6 Pigment analysis

Fully ripened fresh fruit samples of sweet lovi-lovi were used for pigment analysis. Studies showed that lovi-lovi fruits contain the pigment anthocyanin and anthocyanidin because maximum absorbance was observed in 490 and 500 nms. According to Ranganna, 1977, it was an indication of the presence of pelargonidin or plargonidin-3-glucoside.

5.7 Storage studies

The storage life of both sour and sweet lovi-lovi fruits was found to be poor when compared to other perennial fruit plants. In sour lovi-lovi when the fruits were kept under open condition complete loss of fruits occurred on sixth day of storage while in those kept under refrigerated condition complete loss of fruit occurred on tenth day of storage. Deterioration of the fruits started from the first day of storage itself in sweet lovi-lovi but the loss was more under room conditions than those kept under refrigerated condition storage.

The percentage loss in weight of fruits kept in refrigerated conditions was low compared to room temperature storage. Maximum loss in weight of fruit in sour lovi-lovi fruits occurred on fourth day of storage in ambient condition while it

was on tenth day in refrigerated storage. In sweet lovi-lovi, maximum loss in weight of fruits was noted on the second day of open storage but it was on the fifth day at low temperature storage.

Total soluble solids, total sugars, non-reducing sugars and reducing sugars showed a declining trend in all the treatments. TSS was found to decrease from 10.6° brix to 5.0° brix in sour lovi-lovi, at varying intervals for different treatments. In sweet lovi-lovi fruits the declining range was 20.3 to 12.6° brix.

The maximum value of total sugars, which ranged from 2.75 to 2.96 per cent, decreased to a minimum value ranging between 0.21 to 0.94 per cent at the end of storage period in sour lovi-lovi, while in sweet lovi-lovi, the values ranged from 16.34 to 16.65 per cent to a minimum value ranging between 6.4 and 6.5 per cent at the end of storage period.

The reducing and non-reducing sugars also decreased during the period of storage, both in sour and sweet lovi-lovi fruits. Titratable acidity showed a reverse trend when compared to that of sugars. Titratable acidity was found to increase with storage life in both types.

The loss of fruits during storage is mainly due to dehydration as well as disease caused by fungi, particularly in the open condition. White fungal mycelia could be seen on the surface of the fruit. The fruits were shrivelled and they started turning to brownish black colour at the advanced stage of storage. All the fruits became unfit for consumption.

Storage losses of fresh produce in ambient temperature condition was very high in Kerala due to high temperature and humidity. Storage at low

temperature immediately after harvest reduces the rate of respiration resulting in reduction of building up of the respiration heat, thermal decomposition, microbial spoliage and also helps in retention of quality and freshness for a long period. This might be the reason for increased storage life under refrigerated condition. In the present study, the reduction in quality of fruits in both sour and sweet lovi-lovi fruits was gradual in refrigerated storage when compared to those in the room conditions. Daryono and Sosrodihcoyo (1986) reported that in mangosteen, after seven days of storage, weight loss and percentage of diseased fruits were 3.3 per cent and 23.9 per cent, at ambient temperature and zero and 11.0 per cent respectively, at 5°C. Safeda guava fruits could be stored for four weeks in cold storage at 8.5 to 14°C (Singh and Mathur, 1984).

The loss in quality of fruit under room condition was more drastic when compared to those in refrigerated condition. But there is three to four days difference in the storage life of fruits kept under refrigerated and room condition, especially in sour lovi-lovi fruits. Better containers and packing can extend the storage life of lovi-lovi fruits under low temperature storage. Fruits packed in polythene bags creats a modified atmosphere with more carbon-di-oxide and less oxygen than in air. This could extend the storage life (Dalal and Subramanyan, 1970). This will protect the fruit from physiological, pathological and physical deterioration in the marketing channel and retains its attractiveness.

Summary

SUMMARY

Present studies were undertaken on lovi-lovi trees both sour (*Flacourtia inermis* Roxb.) and sweet (*F. cataphracta* Roxb.) types which were grown in the orchard, Department of Pomology and Floriculture, College of Horticulture and the near by nurseries during the period 1995-96.

The objectives of the study were to understand

1) The pattern of growth and flowering
2) Floral biology
3) Fruit set, fruit development, fruit drop and quality analysis of both sour and sweet lovi-lovi types.

The following conclusions were made based on the investigations.

Almost similar type of growth pattern was seen in sour lovi-lovi and sweet lovi-lovi trees. The trees had a monopodial trunk meristem with orthotropic growth pattern. Branching was sylleptic, started from 0.5 m to one metre height in sour lovi-lovi and in sweet lovi-lovi, it was seen below 0.5 m height. After the second and third order laterals, orthotrophic nature got diffused and the rest of the meristem developed plagiotropically. Growth was rhythmic and leaf arrangement was distichous. Emerging leaves were purplish red in colour in sour lovi-lovi where as they were brownish red in sweet lovi-lovi.

Average height of sour lovi-lovi tree was about 8.4 m with 15 primary branches and that of sweet lovi-lovi was about 9.7 m with 40 primary branches. Two main flushing seasons were noticed, in both types, one during May-June and

the other from August-September. Shoot growth was seen in all the months with maximum during the month of September.

There were two main season of flowering in *E. inermis*, i.e., during June-July and October-November. Scattered flowering was seen through out the year. The flower bud development in sour lovi-lovi was divided into four arbitary stages. It took about 10-14 days from visual emergence of buds to anthesis.

There was only one flowering season in *E. cataphracta* which is dioecious in nature. For the male trees the flowering initiated from October while in female trees it was by the middle of November. In male flowers five arbitary stages were identified for the complete development of flower buds and it took about 22-26 days for the complete development of flower bud. For female flowers three arbitory stages were identified it required about 9-11 days for the complete development. Usually flowers were borne in clusters in both sour and sweet types in the fourth or fifth order branches.

In sour lovi-lovi anthesis started from 6.00 hours and continued upto 7.30 hours with peak period of anthesis between 6.00 and 7.00 hours. In sweet lovi-lovi (both male and female flowers) anthesis started from 6.00 hours and the maximum number of flowers opened between 6.30 and 7.00 hours. Highest percentage of anther dehiscence was between 6.30 and 7.00 hours in both the types.

Stigma was found receptive only for the opening day in both lovi-lovi types. Fruit set occurred when pollinated in between 6 hours before anthesis to 24 hours after anthesis in sour lovi-lovi. In sweet lovi-lovi also the maximum fruit set of 88 per cent was obtained when pollinated 12 hours after anthesis.

Number of anthers per flower and pollen fertility were found significantly higher in male flowers of sweet lovi-lovi compared to bisexual flowers of sour lovi-lovi. *In vito* germination of pollen grains of bisexual flowers of sour lovi-lovi showed the highest germination of 48 per cent in 6 per cent sucrose and 0.25 per cent agar medium, while in sweet lovi-lovi male flowers, the pollen grain germination was maximum in 4 per cent sucrose and 0.25 per cent agar medium (85%).

Viability of pollen grains was retained for six days when stored at 4°C. The storage of pollen grains at room temperature gave poor results.

Pollination in lovi-lovi (bour sour and sweet types) was found to be entomophilous.

Maximum percentage of fruit set was obtained in hand pollination both in unemasculated and emasculated flowers of sour lovi-lovi. The fruitset obtained by natural cross pollination was less (68%) while the set obtained by self pollination was in between the percentage of fruitset in open pollinated and natural cross pollinated condition.

In sweet lovi-lovi no opomictic fruit development was seen. The percentage of fruitset was 89.33 in open pollinated condition, while in hand pollinated condition it was 96 per cent.

Fruit drop in sour lovi-lovi was maximum during the first thirty days after fruit set. Another little fraction of fruit drop was recorded during the second month of fruit development. Afterwards, the drop noticed was practically nil. In sweet lovi-lovi, the drop was maximum during the first twenty days of fruit development. Also

a small percentage of drop was seen during the next twenty days. Thereafter no drop was observed.

The fruits of sour lovi-lovi ripened on the tree by 110-120 days after fruit set. The physical characters of fruits like weight, volume, length and girth were increased upto harvest. In sweet lovi-lovi the fruits required about 80-84 days for complete development. In this the maximum increase in weight, volume, length and girth were obtained when the fruit was in between 56 and 70 days of development. A sigmoid growth pattern was observed in the fruit development both in sour as well as sweet lovi-lovi types.

Chemical analysis of fruits of sour lovi-lovi and sweet lovi-lovi showed that TSS content, total sugars reducing sugars and non-reducing sugars and sugar acid ratio increased upto harvest, while the titratable acidity showed a decreasing trend towards harvest.

The fruits of both sour and sweet lovi-lovi were harvested at the fully ripened stage. For sour lovi-lovi it took about 120 days to reach this stage and sweet lovi-lovi needed about 80-84 days. The weight, volume, length and girth of the fruits were maximum at this stage. The TSS, titratable acidity, total sugar, reducing and non-reducing sugar and sugar acid ratio were 10.5, 1.1, 2.9, 1.8, 1.1 and 2.63 respectively for sour lovi-lovi and for the sweet lovi-lovi fruits it is 20.3, 1.5, 16.5, 10.5, 6 and 11.0.

Wide variation in yield among individual trees was noticed, four sour lovi-lovi it ranges from 35 to 50 kg per tree per annum and for sweet lovi-lovi it ranges from 70 to 95 kg fruits per tree per annum.

The number of seeds in sour lovi-lovi fruits ranged from 8 to 15 while in sweet lovi-lovi fruits it ranged from 9 to 14. The hundred seed weight ranged from 7.1 to 7.9 g in sour lovi-lovi while in sweet lovi-lovi it ranged from 3 to 3.8 g.

Proper harvesting and handling practices were important in lovi-lovi to avoid mechanical injury, also the fruits should be used without delay since storage life was very poor for these fruits. But compared to sweet lovi-lovi the storage life of sour lovi-lovi fruits was higher, as they can be harvested along the pedicel.

The pigment analysis of the sweet lovi-lovi fruits indicated the presence of anthocyanin and anthocyanidin.

The pigment analysis of the sweet lovi-lovi fruits indicated the presence of anthocyanin and anthocyanidins.

The storage life of both sweet and sour lovi-lovi fruits was very poor. Complete loss of fruits occurred on sixth day of storage in sour and fourth day of storage in sweet lovi-lovi types. Also the TSS, total, reducing and non-reducing sugars decreased during the storage period. The storage life was extended to ten days in sour lovi-lovi and five days in sweet lovi-lovi fruits under refrigerated condition.

References

Vasil, J.K. 1958. Storage experiment with pollen of cultivated fruit trees and vegetable. *Sci. Cult.* **24**(5):233-236

Zirkle, C. 1937. Acetocarmine mounting media. *Science* **85**:528

*Originals not seen

Appendix

APPENDIX

Weather data for the period from April, 1995 to March, 1996

Month	Total rainfall (mm)	Temperature (° C)			Relative humidity (%)	Sunshine hours
		Max.	Min.	Mean		
1995						
April	118.7	36.6	24.9	30.8	71	271.7
May	370.5	38.5	23.9	28.7	78	201.9
June	500.4	31.6	23.1	27.4	86	109.6
July	884.7	29.9	23.2	26.6	89	65.6
August	448.7	30.6	23.7	27.1	86	115.3
September	282.5	30.1	23.5	26.8	82	184.4
October	110.4	33.2	23.2	28.2	78	257.7
November	88.4	31.3	22.5	26.9	80	196.7
December	0.0	32.5	21.3	26.9	57	319.5
1996						
January	0.0	33.1	22.4	27.8	53	292.7
February	0.0	34.7	23.4	29.1	53	286.1
March	0.0	36.4	24.3	30.4	60	281.3

GROWTH, FLOWERING, FRUITSET AND FRUIT DEVELOPMENT IN LOVI-LOVI

(*Flacourtia inermis* Roxb. and *F. cataphracta* Roxb.)

By

S. ARUMUGA PRASAD

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Pomology and Floriculture
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 654
KERALA, INDIA

1998

ABSTRACT

Studies were carried out at College of Horticulture, Vellanikkara, Thrissur during 1995 to 1996 to know about the growth habit, flowering pattern, floral biology, fruit set and development and storage life of sour (*Flacourtia inermis* Roxb.) and sweet (*F. cataphracta* Roxb.) lovi-lovi types.

There were two main seasons of shoot growth both for sweet as well as sour lovi-lovi trees. One season is from May to June and the other during August-September.

Similar type of growth pattern was seen in sour and sweet lovi-lovi trees. The trees had a monopodial trunk meristem with orthotropic growth pattern. Leaf arrangement was distichous and emerging leaves were purplish red in colour in sour lovi-lovi and brownish red in sweet type.

Two main flowering seasons were noticed in sour lovi-lovi viz., June-July and October-November and the flower bud development was completed with in 10-14 days time. Sweet lovi-lovi which is dioecious in nature had only one flowering season. The male trees flower on October and the female types on November. Male flowers required about 22-26 days for the bud development where as the female flower buds took about 9-11 days only for the completion.

The peak period of anthesis in sour lovi-lovi bisexual flowers was between 6.00 and 7.00 hours, while the sweet lovi-lovi male and female flowers showed the peak period of anthesis between 6.30 and 7.00 hours. But peak period of anther dehiscence was same in sour lovi-lovi and sweet lovi-lovi which was observed between 6.30 and 7.00 hours.

The flowers of sour lovi-lovi was found to be receptive only for the opening day while in sweet lovi-lovi the maximum fruit set was obtained when pollinated 12 hours after anthesis.

Pollen grains of male flowers of sweet lovi-lovi was found to be more fertile (83 per cent) compared to the bisexual flowers of sour lovi-lovi (40 per cent). The combination of 6 per cent sucrose and 0.25 per cent agar medium showed the maximum pollen germination of 48 per cent in sour lovi-lovi where as sweet lovi-lovi it was on 4 per cent surcorse and 0.25 per cent agar medium (85%).

Among the different methods of pollination, hand pollination of unemasculated flowers gave the highest percentage of fruit set in both types.

The fruit drop was maximum during the first 30 days of fruit development in sour lovi-lovi while in case of sweet lovi-lovi it was maximum during the first 20 days of fruit development.

The fruits of sour lovi-lovi came to harvest stage by 110-120 days after fruit set where as in sweet lovi-lovi it was by 80-84 days after fruit set.

The chemical analysis of fruits of sour lovi-lovi showed that the TSS content increased upto harvest, so also the total sugars, reducing and non-reducing sugar and sugar acid ratio,while the titratable acidity showed a decreasing trend towards the harvest stage. The same trend in the biochemical parameters was observed in sweet lovi-lovi fruits also. Pigment analysis of sweet lovi-lovi fruits indicated the presence of anthocyanin and anthocyanidins.

Proper harvesting and handling practices were important in lovi-lovi to avoid mechanical injury. Yield varied from 35-50 kg fruits/tree/annum in sour

lovi-lovi and it was 70 to 95 kg fruits/tree/annum in sweet lovi-lovi. The number of fruits ranged from 3500-10000 in sour lovi-lovi and from 11990-16050 in sweet lovi-lovi. Fruit to fruit variation was noticed in number of seeds per fruit and 100 seed weight in both types.

In general, storage life of both sweet and sour lovi-lovi types was very poor in ambient condition. The storage life of sour lovi-lovi was more as they could be harvested along with the pedicel. Refrigerated storage extended the post harvest life of fruits by three to four days.