# VARIETAL EVALUATION AND COMPATIBILITY STUDIES IN SAPOTA

## (*Manilkara achras* [Mill]. Fosberg)

By

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**THESIS**

**Submitted in partial fulfilment of the requirement for the degree of**

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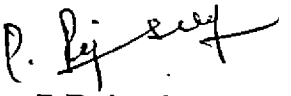
## DECLARATION

I hereby declare that the thesis entitled **"Varietal evaluation and compatibility studies in Sapota (*Manilkara achras* [Mill]. Fosberg)"** 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.



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## CERTIFICATE

Certified that this thesis entitled **"Varietal evaluation and compatibility studies in Sapota (*Manilkara achras* [Mill]. Fosberg)"** is a record of research work done independently by **Mr.P.Rajasekar,** 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.

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We, the under signed members of the Advisory Committee of Mr.P.Rajasekar, a candidate for the degree of Master of Science in Horticulture with major field in Pomology and Floriculture, agree that the thesis entitled "Varietal evaluation and compatibility studies in Sapota (*Manilkara achras* [Mill.] Forsberg)" may be submitted in partial fulfilment of the requirement for the degree.

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P. Rajasekar

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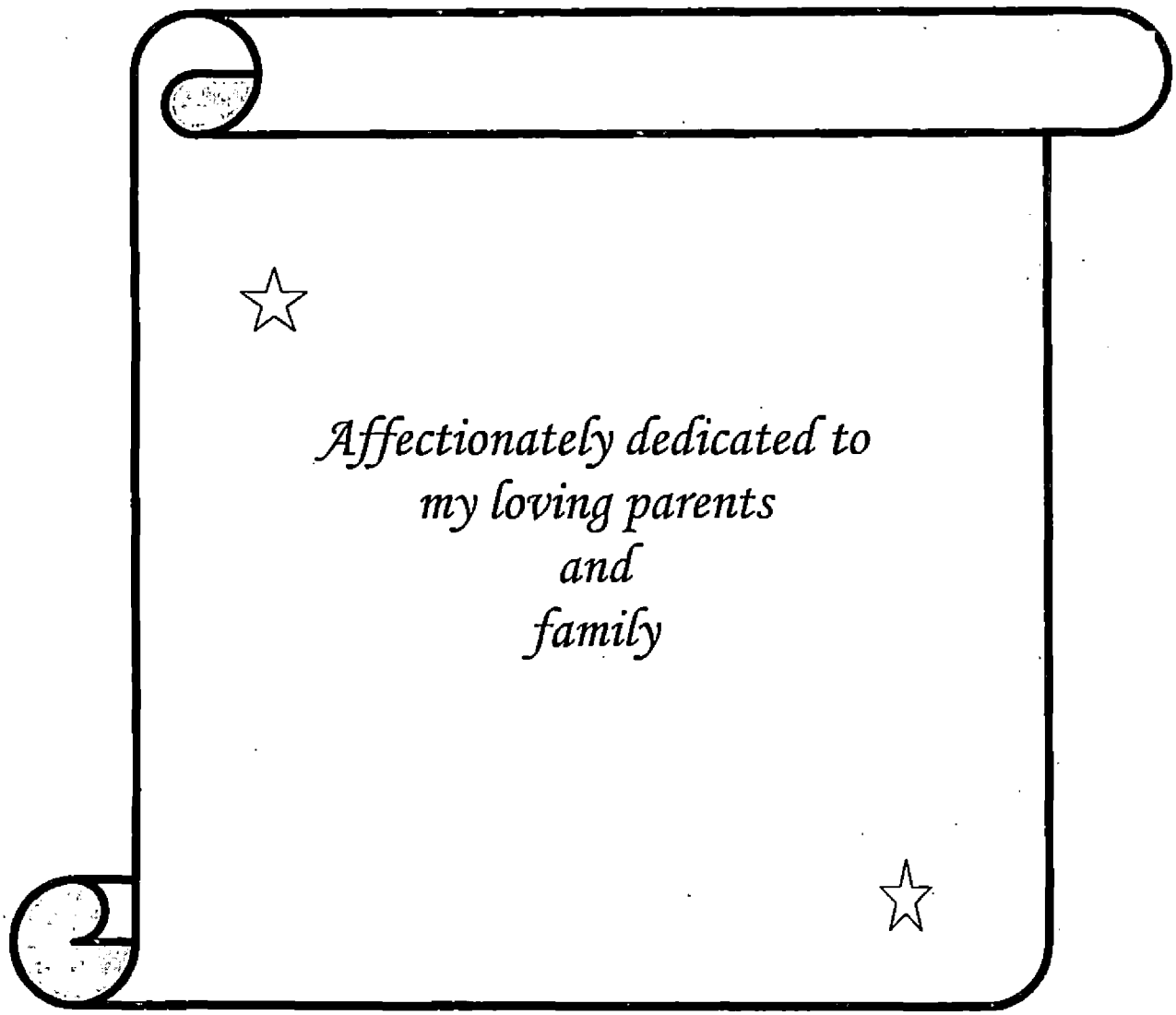


*Affectionately dedicated to*
*my loving parents*
*and*
*family*

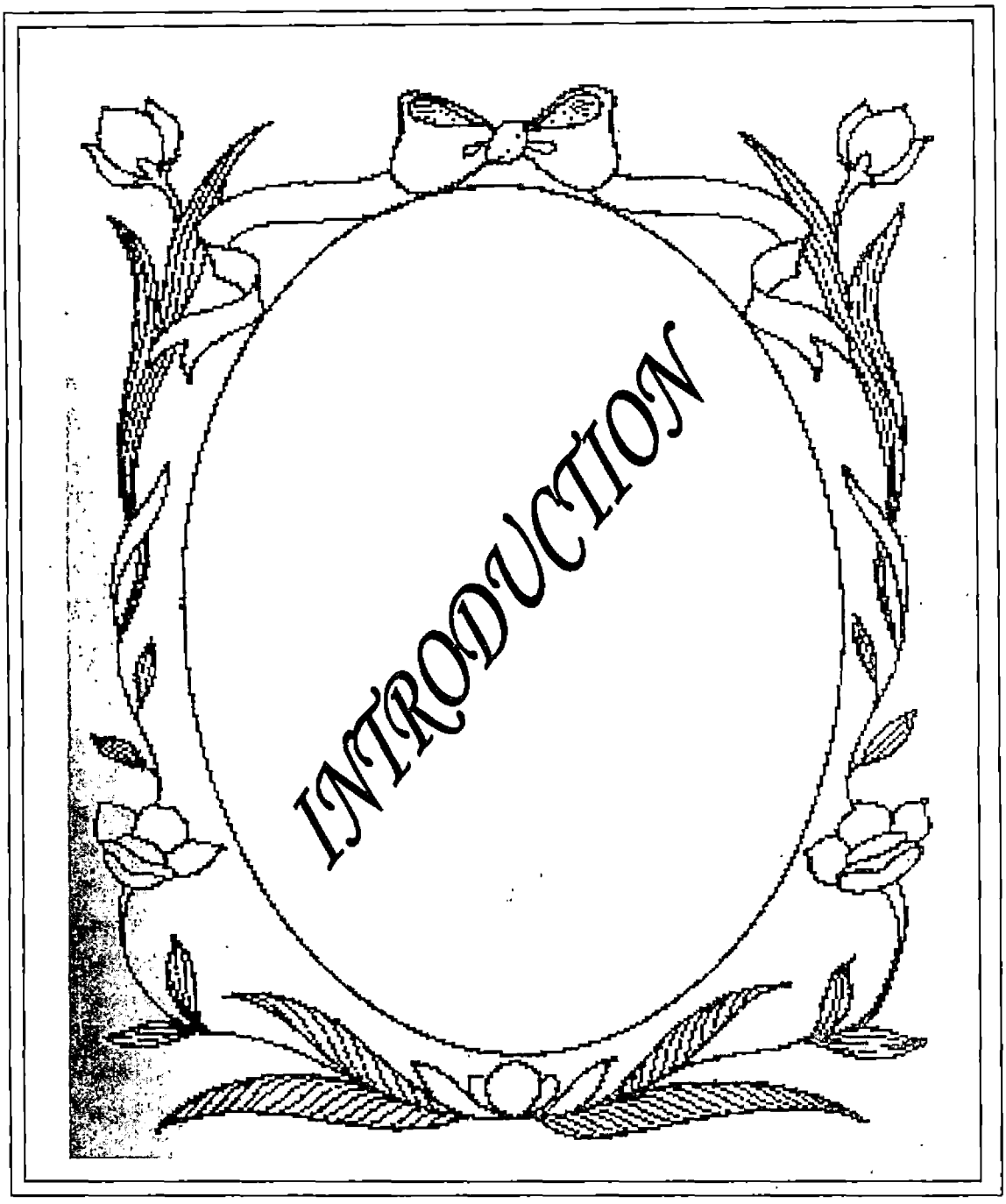
## CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF PLATES

## LIST OF APPENDIX


INTRODUCTION

# 1. INTRODUCTION

Sapota *(Manilkara achras* (Mill). Fosberg), a member of family Sapotaceae, is a fairly slow growing, long-lived tree. It is believed native to Yucatan and possibly other nearby parts of Southern Mexico, as well as North East Gautemala. The *Manilkara* species is found in forest throughout the tropical America,which was introduced long ago followed by the West Indies, the Bahamas, Bermuda and Southern part of Florida mainland. Early in colonial times, it was carried to Philippines and was later adopted everywhere in the old world tropics.

Sapota is the source of chickle, the principle ingredient in chewing gum. The chickle is extracted from the trunk of the tree as white latex exudates. Today, sapodilla is cultivated for its fruits in most areas. Although synthetic gums are primarily used, some countries such as Mexico, Venezuela and Guatemala, still grow sapodilla for chickle.

Sapota grown on a commercial basis in India (Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, and West Bengal), the Philippines, SriLanka, Malaysia, Mexico and Venezuela. India is the largest producer of sapota in the world with annual production of 0.90 million tonnes from an area of 0.07 million hectares.

The future of Sapota appears to be promising, since the attention on the crop is receiving from growers and consumers in many countries. India's production of Sapota continues to grow up and there is an active research programme in our country with specific goals towards improving storage, transport and marketing strategies. Sapodilla has been identified by the ministry of Agriculture in Malaysia to be promoted under the programme for the development of its fruit industry (Bakar and Karim, 1994).

In commercial growing, low fruit set and unfruitfulness are the two major problems, which reduce the yield of this crop in certain varieties. Quite often in homesteads, as in Kerala, where single tree is grown, though flowering is noticed, fruit set is practically nil. Crop improvement programme in this crop is also limited. Before starting any hybridization programme, the basic knowledge of floral biology of the plant is of utmost importance. The understanding of proper stage of pollination for efficient fertilization is another pre-requisite. If two varieties are non-synchronous in flower opening, the chances for using such combinations are rare in crossing

programmes. In such cases, stored pollen will be beneficial. Moreover, to overcome adversities, knowledge of proper medium for quick germination of pollen grains will be of added advantage. For planning an effective selection strategy, understanding the interrelationship between yield and its component characters is of vital importance. The information on heritability with genetic advance for different parameters will help the breeder to identify the characters to be relied upon and to decide the breeding strategies to get quality fruit and yield. In order to select suitable parents for improvement programme, compatibility between the varieties are to be understood.

Keeping in this view, the present investigation was undertaken with the following objectives,

1. To characterize and evaluate the sapota varieties for their vegetative, fruit and yield characters for exploiting the variability under humid tropical conditions of Kerala.
2. To study the floral biology of sapota varieties.
3. To study the extent of compatibility within and among different varieties along with the viability of hybrid seeds.
4. To find out an effective method to overcome the incompatibility barrier.
5. To understand the physiological barriers to successful fruit set by studying the pollen–pistil interaction.

REVIEW OF
LITERATURE

# 2. REVIEW OF LITERATURE

Sapota (*Manilkara achras* [Mill.] Fosberg) is a delicious fruit introduced from Tropical America. It is now widely cultivated throughout the tropics. It belongs to the family Sapotaceae. It is also known as Sapodilla or Chiku (India). The name Sapodilla is derived from the Spanish word Zapotilla, meaning "small sapote". It is mainly cultivated for its fruits, while in Southeast Mexico, Guatemala, British Honduras and other countries chickle is commercially produced from trunk of the tree (Avilan *et al.*1981).

The knowledge of vegetative growth, floral biology, pollen production and pollination has become indispensable in the field of breeding of fruit crops owing to its potentialities in the breeding for improving various non-synchronous cultivars. Sapota was improved for various characters like fruit size, fruit weight, less number of seeds and dwarf stature, etc. Moreover, to overcome the adversities, knowledge on proper medium for quick germination of pollen grains will be of much advantage in sapota. A few outstanding varieties are very healthy and sturdy but do not set fruit in large. To overcome such adversities, aided pollination through certain effective chemicals may result in fruit set. The exact stage of pollination for efficient fertilization should also be known. For successful breeding programme, knowledge about the presence of adequate genetic advance and genetic divergence in a population and extension of association between characters is essential. To corroborate the work, an attempt has, therefore, been made to review the literature on vegetative growth, floral biology, pollen and pollination studies, fruit set and development and extent of compatibility between the varieties in sapota and other fruit trees, which has been presented below.

## 2.1. GROWTH STUDIES

The relationship between vegetative growth and fruiting was studied in different tropical and subtropical tree crops lilapota, mango, guava, citrus, annona, nutmeg etc.

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

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).

Growth studies were undertaken in detail in many guava varieties. Aravindakshan (1960) reported two definite seasons of growth flushes and flowering in guava. Three classes of shoots were recognized in guava, viz., shoots that produced flowers and ceased growth, shoots which continued growth and producing flowers and shoots purely vegetative.

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.

In mango, a number of workers have studied the pattern of growth flushes. Singh and Khan (1939), Roy (1953), Singh (1959) and Reddy (1983) have reported different periods of primary and extension 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 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.

## 2.2. FLOWER PRODUCTION AND BLOSSOM STUDIES

In sapota, floral characters were studied by Patil and Narwadkar (1974) and Nalawadi *et al.* (1977). Detailed investigations on flower production and blossom studies were carried out in fruit trees like mango (Singh, 1958), Jack (Sinha, 1975; Joseph, 1983), guava (Seth, 1962; Sehgal and Singh, 1967; Ojha *et al.*, 1986; Kahlon *et al.*, 1987 and Sadhu *et al.*, 1987), nutmeg (Nazeem and Nair, 1981;Amstrong and Drommond, 1986), tamarind (Thimmaraju *et al.*, 1977) and cashew (Shivanandam *et*

*al.*, 1986). The literature pertaining to the investigation undertaken in sapota and other fruit trees is given below.

**2.2.1. Flowering pattern and floral biology**

Nalawadi *et al.* (1977) studied the floral biology of sapota at the Agricultural College, Dharwad, Karnataka, in Kalipatti, Cricket Ball, Calcutta round and Oval cultivars. Three seasons of flowering were recorded with maximum in June, while in October and March the flowering was less. Dhaliwal *et al.* (1990) reported that there were two main seasons in sapota, viz., June and November and the duration of full bloom ranged from 16 days to 19 days.

Lenka *et al.* (1996) reported two distinct peak flowering periods in sapota cultivars (February-April and October –November). The crop requires 55 days to 60 days from flower bud initiation to anthesis under Bhubaneshwar conditions. The per centage of flower buds, which developed into flowers, ranged from 50.00 in Cricket Ball to 72.72 in Kalipatti. The gap between flowering and fruit set was 50.0 days to 54.5 days. Gunaki *et al.* (1999) reported that in sapota the highest flowering was observed during November – January, followed by July – August, the lowest flowering was observed in March.

***2.2.1.1.Anthesis and anther dehiscence***

Nalawadi *et al.* (1977) observed peak period of anthesis in sapota by 04.00 a.m. Minhas and Sandhu (1985) in an experiment with three cultivars stated that anther dehiscence started before anthesis, suggesting protandry and maximum dehiscence occurred between 08.00 a.m. and 11.00 a.m. Lenka *et al.* (1996) reported that peak period of anthesis in sapota was at 04.00 hour and continued up to 08.00 hour.

***2.2.1.2. Stigma receptivity***

Heslop and Shivanna (1977) observed two types of stigma in angiosperms. These included those stigmas, which were dry at maturity having no free flowing secretion and those, which remained wet bearing such a fluid in the receptive stage. Sporophytic self- incompatibility was associated with dry papillae stigma. Trinucleate

pollen not readily germinating *in vitro* tend to be associated with dry stigma while wet stigma forms having binucleate pollen easily germinated in liquid or semisolid media.

Stigma receptivity was maximum from a day before anthesis to a day after anthesis in sapota (Minhas and Sadhu, 1985). Stigma receptivity was maximum on the day of anthesis in *Garcinia indica* (Karnik and Gunjate, 1984). In *G.Cambogia* stigmatic receptivity was found to be maximum 12 hours before anthesis (Sherly, 1994).

**2.2.2. Pollen studies**

The science of pollen and spores has attracted the attention of research workers due to its great significance in palynological studies to taxonomists and palynologists. It also helps in the elucidation of radiation effect, helps to identify the disputed varieties or species (Nair, 1960) and provide 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.

***2.2.2.1. Pollen production***

The exact measurement of the amount of pollen produced per anther is essential to evaluate the worth of a variety as a pollinator, more accurately. A method for determining the number of pollen grains per anther with the aid of haemocytometer, a technique adopted in clinical field was confirmed and modified by Rao and Khader (1960) in fruit crops like sapota, papaya and pomegranate. The amount of pollen produced per blossom or anther varies between variety to variety in guava (Nair *et al.*, 1964).

Pollen production studies had been reported in fruit crops like sapota, papaya and pomegranate (Rao and Khader, 1960), guava (Nair *et al.*, 1964) and in varikka and koozha types of jack (Joseph, 1983).

*2.2.2.2. 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.

Rao and Khader (1960) made investigation on pollen morphology of six fruit crops, namely, sapota, guava, papaya, jack, pomegranate and grapes. In mango, pollen grains are oblong, when dry and more spherical when hydrated (Mukherjee, 1949; Singh, 1954; Randhawa and Damodaran, 1961. Singh (1961) observed that mean length of pollen grains of 50 Indian mango cultivars ranged from 23.5-micro metre to 28.3-micro metre. Nair and Mehra (1961) had described the pollen grains of citrus species. Singh and Mishra (1979) studied the characteristic of the pollen of three species of *Zizyphus*.

*2.2.2.3. Pollen viability*

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

*a. Stain test*

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

Balasubramanyam (1959) in guava; Nirmalendunath and Randhawa (1959) in pomegranate; Singh (1961) in mango; Singh (1962b) in litchi; Nalawadi *et al.* (1975) in annona and sapota 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 collected in sugar or sugar-agar medium, the pollen tubes were as long as or even longer than those found in nature. Nebel (1939) reported good pollen germination at various concentrations of cane sugar for different crops, viz, 2.5 per cent 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 (Damaodaran *et al.*, 1966); 12 per cent sucrose for annona (Sulikeri *et al.*, 1975); 15 per cent sucrose for cocoa (Ravindran, 1977); 10 per cent sucrose for jack (Prasad and Trivedi, 1978; Gopinathan *et al.*, 1983); 4 per cent sucrose (Nazeem, 1979) or 5 per cent sucrose for nutmeg (Bavappa and Banda ,1981).

*2.2.2.4. Effect of boric acid in pollen germination*

Boron was found to occur in the tissues of the pistil of the angiosperms. Many workers studied the role of boric acid and boron in germination and pollen tube growth. Nair (1960) revealed that 1 per cent to 10 per cent boric acid stimulated pollen germination and pollen tube growth in more than 60 species of angiosperms. Nair and Mehra (1961) reported 10 per cent to 15 per cent increase in pollen germination of citrus by the addition of boric acid at concentrations ranging from 10 mg $l^{-1}$ to 100mg $l^{-1}$. Nair *et al.* (1964) in their studies on the pollen of different species of fruit trees found that boron or boric acid in low concentrations such as 25 mg $l^{-1}$ to 40 mg $l^{-1}$ stimulated pollen germination and pollen tube growth. Beneficial effect of boric acid on the germination of pollen grains in many other crops like sapota (Rao and Khader, 1960), mango (Singh, 1961a), cocoa (Ravindran, 1977), nutmeg (Nazeem, 1979), jack (Joseph, 1983) and cashew (Rao, 1998).

*2.2.2.5. Pollen storage*

Storage of pollen has got great significance in plant breeding especially when the two parents involved in a cross do not synchronise 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 dioecious fruits and found that the optimum temperature for storing the pollen was 30°F. Nebel (1939) was able to store the pollen of apple, ber, plum, peach and apricot for 2 to 5 years in desiccator over sulphuric acid with 50 per cent relative humidity at 28°C.

Pollen longevity studies were conducted in relation to temperature and humidity in papaya (Traub and O'Rork, 1936;Cohen *et al.*, 1989), in mango and litchi (Singh, 1962a and b), in grapes (Nagarajan *et al.*, 1965), in jack (Sinha, 1975 and Joseph 1983) and in nutmeg (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 per centage 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), kagzhi lime (Shukla and Misra, 1975) and papaya (Cohen *et al.*, 1989). Lyophilisation or freeze-drying of pollen is reported to be one of the efficient methods of pollen storage (Nair *et al.*, 1964;Stanley and Linskens, 1974) in guava.

## 2.3. 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),annona, jack (Krishnamoorthi and Rao, 1965) and in apple (Teskey and Shoemaker, 1972).

Gonzalez and Feliciano (1953) examined flowering in 'Ponderosa' sapodilla and found that trees could not be self pollinated, either naturally or artificially. The best method of pollination was cross-pollination by hand, which resulted in 39.6 per cent fruit set. Open pollination resulted in only 5 per cent fruit set in that study. Similar results were observed in 'Kalipatti' sapodilla by Relekar *et al.* (1991). Sambamurthy and Ramalingam (1954) suggested that wind is an important factor in sapodilla pollination. Picatos and Knight (1975) found sapodilla to be self-incompatible indicating that cross-pollination might be necessary. Reddi (1989) showed that sapodilla flowers are not self-pollinating, although pollen transfer is generally limited to a single tree unless trees are closely spaced. Mulla and Desle (1990) found that the highest per cent fruit set was observed in trees cross-pollinated with pollen of the same cultivar, which ranged from 20 per cent to 34 per cent. There was no sign of parthenocarpy and self-pollination resulted in only negligible fruit set in some of the cultivars examined.

## 2.4. FRUIT SET

Problems of shedding and low fertility in sapota were reported by Cheema *et al.* (1954) and Hayes (1957). In cultivar Kalipatti, 22 per cent natural fruit set was observed and the maximum fruit drop occurred immediately after fruit setting (Patil and Narwadkar, 1974). It was observed that the flowers situated at the base of inflorescence opened and set earlier. Gunaki *et al.* (1999) reported that highest per centage of fruit set occurred in July-August flush; fruit set was lower in the March flush. Fruit set was highest in DHS-1 when compared to DHS-2, Kalippati and Cricket Ball.

## 2.5. FRUIT DROP

Mone *et al.* (1991) reported that major fruit drop in sapota occurred in the first five weeks after fruit set and was highest during the first week after fruit set. Of the total 171 fruits set on 150 shoots, only 9.36 per cent were retained to maturity. Gunaki *et al.* (1999) reported that highest fruit drop was noticed in Cricket Ball, and lowest fruit drop in DHS-1 for all flushes.

## 2.6. FRUIT DEVELOPMENT

Fruit development followed a sigmoidal pattern in sapota (Sulladmath *et al.*, 1979; Karim *et al.*, 1987). The initial growth phase is due to cell division and involves maturation of the embryo within the fruit. A phase of greatly reduced growth follows, until a second rapid growth phase occurs, during which time growth is due to cell enlargement. This second growth phase is the time when maximum growth occurs between 5 and 7.5 months from fruit set (Lakshminarayana and Subramanyam, 1966). The fruits are suitable for harvesting after the second growth phase, when they attained maximum size. Rao *et al.* (1995) reported that sapota fruits experienced a protracted period of growth, which was not commensurate with the rate of mature fruit weight gain as in other species. This protracted period could be partly attributable to the long phase. Advani (1998) developed a double logistic model for the cultivar Kalipatti by monitoring the changes in fruit weight fortnightly.

## 2.7. HARVEST MATURITY

Purseglove (1968) reported that the maturity at harvest in sapota plays a significant role in the post harvest behaviour of the fruits. Fruits of different stages are available all through the year leading to practical difficulties in harvesting of fruits of definite maturity. Sapota matures 8-10 months after fruit set depending upon the cultivar and available heat units. Fruits harvested earlier than physiological maturity take too long to soften and have poor quality while those harvested later soften quickly resulting in fast spoilage during handling and transport.

The time taken from fruit set to maturity was an important factor with respect to harvesting and maturity. It varied from 120 days to 245 days to mature after anthesis depending on the cultivar, agro climatic location and available heat units (Purseglove, 1968; Sulladmath, 1975). The TSS, total and reducing sugar content, acidity, pH and tannins which showed distinct trends during fruit growth and development could be considered as chemical indices of maturity (Paralkar *et al.*, 1987).

The maturity of the sapota fruit could be judged on the basis of several external signs viz., peel developed a dull orange or potato colour with a yellowish tinge, a yellow streak rather than a green one was seen on light scratching of the skin, the brown scaly material disappeared from the fruit surface, milky latex content dropped to almost zero and dried spine like stigma fell from the tip of the fruit (Sulladmath and Reddy, 1990).

## 2.8. VARIETAL EVALUATION

Varietal collections were made systematically at Pune, Coimbatore and Kodur during 1940. At Kodur, variety Guthi with oval shaped fruits was found to be the most prolific and superior in eating quality. The diversity in fruit shape is an interesting feature in sapota. Calcutta round and Cricket Ball produce oval or elliptical fruits whereas Kalipatti and Chatri have a special feature of producing both round and elliptical fruits simultaneously in the same tree during the same season. According to Lakshminarayana (1980) the fruits generally weighed about 75g to 200 g but in exceptional case fruits even up to 1 kg was also recorded. In1964, a trial with five varieties was laid out at Periyakulam in Tamil Nadu and Junagadh in Gujarat for production and quality evaluation. Results revealed that Kalipatti and Pilipatti were superior in terms of production and quality while Cricket Ball had most attractive and large sized fruits (Chundawat and Bhuva, 1982). The specific gravity of the mature graded sapota varied from 1.016 to 1.086 (Sawant, 1989). At maturity, Guthi and Oval recorded 0.95 and 1.06 respectively (Durairaj *et al.*, 1991) while in Kalipatti it varied between 1.025 and 1.057 (Shende, 1993).

## 2.9.YIELD

The yield depends upon several factors, such as the age of the tree, cultivar, agroclimatic conditions of the locality, nutrition and plant protection measures. In round and large sized cultivars, such as Cricket Ball and Calcutta round, less number of fruits is obtained, while in others with oval or long fruits is produced but their size is small. On an average, a 3 year old tree can yield about 100 fruits; a 5 year old tree, 250 fruits; a 7 year old tree, 700 fruits; a 8 year old tree, 800 fruits; a 10year old tree, 1000 fruits per year (Singh, 1969). Gunaki *et al.* (1999) reported that DHS-1 recorded the highest yield per tree (104.97 kg) and Kalipatti recorded the lowest yield per tree (38.64 kg).

## 2.10.IMPACT OF WEATHER

A high temperature above 41° C during summer causes drying up of stigmatic fluid, flower drop and fruit scorching. In severe cases, leaves and fruits undergo scorching. Dry and strong winds also cause damage to flowers, leaves and fruits (Gopalaswamiengar, 1970). Shirsath *et al.* (1998) examined data on average temperature, relative humidity, rainfall, soil temperature, sunshine hours and evapotranspiration in relation to yields of sapota cv. Kalipatti at Rahuri. Maximum and minimum temperature had a negative correlation with yield while relative humidity, rainfall and sunshine hours were positively correlated with yield under Rahuri condition.

## 2.11. COMPATIBILITY STUDIES

Incompatibility is the failure of plants with viable pollen and ovule to set seed due to some physiological hindrances which prevents fertilization (Crane and Lawrence, 1952). According to Brewbacker (1957) incompatibility mechanism is in operation in members of 66 plant families.

Cooper (1938) studied the various aspects of fruit set in apple and reported that all the varieties studied are self- incompatible. He also reported that the system

available in this crop was due to the presence of certain inhibitory substances in the pistil considerably retarded the growth of pollen tube. Seth (1962) reported varietal cross- incompatibility in guava since neither fruit nor seed set was obtained when crosses were made between Behat coconut and Lucknow-49, Behat coconut and Apple colour. Bhartiya *et al.* (1986) reviewed the pollinizing ability of different apple cultivars.

Self- incompatibility in loquat was of gametophytic nature. In self incompatible varieties, pollen tubes penetrated the stylar canal up to one fourth to one third of its length and did not go further even after 72 hours of pollination (Singh and Rajput, 1962).

Rao and Khader (1961) observed inter-varietal specificity for pollen in sapota.Self- incompatibility has been reported in pummelo, sweet lime and lemon. In sweet lime, maximum set was recorded with the pollen of Duncan grapefruit (Shinde and Dhuria, 1960; Kumar *et al.*, 1976). Nauriyal (1962) reported better fruit set by cross-pollination than by self or open pollination in pummelos indicating self – incompatibility.Seedless lemon is self- incompatible and the fruits develop parthenocarpically (Diware *et al.*, 1970; Chakrawar and Warke, 1983).

Thakur and Singh (1965) reported that in *Annona*, interspecific cross fertility was observed when *Annona cherimola* was pollen parent and *Annona reticulata* and *Annona squamosa* were female parents. With *Annona cherimola* as pollen parent, there was a higher per cent of fruit set, *viz.*, 48.8 in *A.squamosa* (green), 52.5 in *A. squamosa* (red) and 37.5 in *A. reticulata*. Inter and intra specific cross combinations among six species of annona revealed the effectiveness of *Annona squamosa* as pollen parent on *A. atemoya* and *A.cherimola*. The *A.squamosa* was not an effective female parent with *A.atemoya* but *A.cherimola* was compatible with both *A.squamosa* and *A.cherimola*. *A.atemoya* can be freely crossed with *A.reticulata*, *A.glabra* and *A.cherimola* (Sampath kumar and Jalikop, 2000).

### 2.11.1. Breaking of incompatibility barrier

A number of methods have been tried by various workers to induce fertility by breaking the incompatibility barrier in crop plants. They include surgical techniques, bud pollination, hormonal treatment, polyploidy, irradiation etc. According to

Mangelsdorf and Reeva (1931) hybrid seeds could b obtained from a cross between two genera of *Zea mays* and *Tripsacum* by employing the technique of cutting of portion of the style before pollination. Davis (1957) used the technique of cutting off portions of the style before pollination and crossed two incompatible species of *Lathyrus* and removal of upper one-third portion of the style caused greater increase in pod and seed formation.

Togeri and Kawahara (1942) in their effort to induce pseudofertility in sweet potato by means of bud pollination, observed that since the stigma of the sweet potato flower would become receptive only a few hours before anthesis, bud pollination offered little prospect in overcoming self incompatibility. Haruta (1960) reported details regarding the use of bud pollination in *Brassica* and *Raphanus*.

According to Brewbaker (1957) stigma is the site of incompatibility for species with trinucleate pollen grains, which remain viable only for a short period of time and do not germinate readily in vitro. The physiological explanation for this phenomenon was later given by Harrison *et al.* (1975). According to them pollen inhibited in the stigma because the stimulus from the stigma which is essential for pollen germination is blocked by the incompatibility reaction.

Allard (1960) reported that end of season pollination was found to be effective in breaking the incompatibility barrier in crops like tobacco. Charles *et al.* (1974) reported the suppression of floral abscission by the application of 2,4-D 100 mg $l^{-1}$ to the pedicels, which resulted in successful seed set. Gradziel and Robinson (1989) reported that stylar self- incompatibility barrier in *Lycopersicon peruvianum* could be avoided if pollen germination and growth through immature pistils was promoted under specific environmental conditions approximately two to three days before the initiation of anthesis. In *Brassica*, self- incompatibility can be overcome by carbon–di-oxide treatment (Nakanishi and Sawano, 1989). Aneja *et al.* (1994) found out that carbon-di-oxide treatment partially overcomes self- incompatibility in certain genotypes of Cacao. Kashyap and Gupta (1989) reported that self incompatibility can be partially overcome *in vitro* by treating pollen and / or stigma with gibberellic acid ($GA_3$) in *Ipomoea cairica*, *Brassica campestris* and *Raphanus sativus* which was due to callose deposition in the stigmatic papillae and hence total inhibition of pollen

germination. Illieva and Alipieva (1996) reported that self – incompatibility can be broken in certain lines of cabbage by means of pollen irradiation treatment.

**2.11.2.Pollen –pistil interaction**

Inhibition of pollen tube growth or its abnormally slow development inside the stylar column was reported to be one cause of incompatibility in angiosperms by Sears (1937). The preliminary studies conducted by Miller (1938) in sweet potato revealed that lack of fertility might be due to the style being deficient in an unknown substance which might initiate pollen germination or it may contain some substances which act as inhibitor of pollen germination.

Hogenboon (1972) reported abnormally slow growth of *Lycopersicon esculentum* pollen in styles of self-incompatible *L. peruvianum* and the hybrids of such crosses showed embryo abortion. Nettencourt (1973) studied the ultra structural aspects of self – incompatible mechanism in *L. peruvianum* and reported that the incompatible pollen tubes were not only slow in their growth through the style, but were destroyed of the inner wall and lysis of the pollen tube occurred. Rugkhla *et al.* (1997) observed that on selfing, growth of pollen tube was arrested in the style, ovary and around the embryo sac, a few penetrated the embryo sac in *Santalum album*. Damri *et al.* (1998) observed swelling and bursting of pollen tubes in the stigma in selfed flowers of lemon.

## 2.12.SEED GERMINATION

Sapota seeds are hard, black and can be easily separated from pulp. The optimum temperature for germination is 20°C - 30°C. Shanmugavelu (1970) also obtained higher germination and better seedling growth of sapota by $GA_3$ treatment. Seed germinability varies from 58 per cent in cv. PKM-1, 50 per cent in Oval and Cricket Ball. Soaking of seeds in $GA_3$ 50 mg $l^{-1}$ or $GA_3$ and IAA at 50 mg $l^{-1}$ each for 24 hours hastened germination (Ponnuswami *et al.*, 1988).

## 2.13.VARIABILITY

Variability indicates the differences present among the individuals belonging to the single species or among different species. Variation may be due to environment or due to genotype or both. For successful plant breeding programme, an insight into the magnitude of variability present in a crop species is of utmost importance as it provides the basis for effective selection. Subramanyan and Iyer (1981) reported a wide variability in terms of number of fruits per plant, seed weight, number of seeds per fruit, pulp weight, fruit weight and peel weight in papaya (*Carica papaya*). Ponnuswami and Irulappan (1989) reported a wider variability in terms of tree height, canopy spread, tree volume and girth, number of fruits per tree and quality characters like TSS, sugars and acidity in sapota.

Ponnuswamy and Irulappan (1989) reported a wide range of tree height in Co-1 and Co-2 while it was narrow in Oval and PKM-1 of sapota and wide range of tree volume was wider in Kirtabarthi and Co-1 and narrower in Guthi, Dwarapudi and Kirtabarthi varieties. Ray and Sharma (1988) reported the high GCV associated with high heritability for peel weight followed by seed weight, aril weight and fruit weight of litchi. Kumar and Singh (1993) reported a wide variability in fruit characters like fruit weight, number of seeds per fruit and biochemical characters like moisture, TSS, acidity, ascorbic acid, reducing sugar, non-reducing sugar, total sugar, anthocyanin pigment, total carotenoids,iron content in karonda (*Carissa carandas* L.). Ghanta *et al.* (1994) reported a wide variability for peel weight, seed weight, aril weight and fruit weight in litchi.

Ranpise and Desai (1994) reported that higher values of GCV and PCV were observed for yield per plant, number of fruits per plant, flowers per twig and tree volume of acid lime. Dwivedi *et al.* (1995) reported that the PCV was higher than corresponding GCV for all the characters studied in papaya, which might be due to the modifying effect of environment at the phenotypic level. The highest PCV (35.50) as well as GCV (32.50) were recorded for seed weight, followed by number of seeds per fruit and number of fruits per plant.

## 2.14. HERITABILITY

Heritability in broad sense provides a measure of relationship between real or genetic advance and the observed or phenotypic variance. It helps to separate out that part of total variability, which is environmental and hence unfixable. According to Lush (1949), heritability in broad sense concerns about the functioning of the genotype or both genotype and phenotype as whole. Knowledge on heritability and genetic advance is important for effective crop improvement programmes. High heritability in broad sense indicated that large proportion of phenotypic variances was attributed to the genotypic variances and the character differences among genotypes were real and less influenced by the environment. High heritability along with high genetic advance is due to additive gene action and those traits are likely to respond better to selection. Manohar *et al.* (1981) studied phenotypic variance and genotypic variance in 16 pomegranate varieties and concluded that individual plant selection for rind weight, per cent acidity, fruit weight, arils per fruit, yield per tree and fruits per tree could be satisfactory effective as these characters exhibit high heritability as well as high genetic advance.

Subramanyan and Iyer (1981) observed high heritability estimates along with genetic advance for seed weight, number of fruits per plant, number of seeds per fruit, pulp weight, fruit weight and peel weight in papaya suggesting that further selection for improvement in number of fruits per plant, pulp weight and fruit weight would be effective. Genetical studies conducted in guava indicated that seed pulp colour is dominated to white and that this character is governed monogeneically (Subramanyam and Iyer, 1982). Bold seeds in guava were found to be dominant over soft seeds and this was also found to be dominant monogenically. Sharma (1987) considered that additive gene action might be involved in the inheritance of flesh colour in mango. Iyer (1991) reported that in Alphonso and Neelum mango varieties light yellow colour is dominant over orange yellow. Ghanta *et al.* (1994) reported high heritability and genetic advance for peel weight, aril weight and seed weight in litchi. Ranpise and Desai (1994) reported that in acid lime, heritability was higher for fruits per plant, yield per plant, average fruit weight, fruit volume and juice per centage, while genetic advance was higher for fruits per plant, yield per plant, tree volume and flowers per twig and low for rind thickness, ascorbic acid, TSS and

acidity. Attri *et al.* (1999) observed remarkable variability in qualitative character in mango collections of South Andaman. All the qualitative characters showed higher estimates of broad sense heritability, whereas genetic advance was recorded very high in carotenoids, fruit weight, fruit volume and ascorbic acid.

## 2.15. CORRELATION STUDIES

Economic characters are genetically complex in nature and influenced by many plant characters through different physio-biochemical mechanism. Knowledge on the association of character is essential to identify the character, which could influence the economic traits. Correlation co-efficient analysis measures the mutual relationship between various plant characters and determines the component character on which selection can be based for improvement in yield. Johnson *et al.* (1955) reported that estimates of genotypic correlation among characters are useful in planning and evaluation of breeding programmes. In sapota, a correlation was worked out between the shape index and seed number per fruit and also between fruit weight and seed number. A positive correlation was present between number of seed per fruit and fruit weight. Round fruits were heavier (101g) than oval fruits (69.7g) (Tendolkar, 1978).

A positive association between peel weight and seed weight and aril size was estimated in litchi by Huang and Qiu (1987). Ray and Sharma (1988) reported a negative correlation between fruit weight and yield in litchi. Bandyopadhyaya *et al.* (1990) reported strong association between aril weight and all other quantitative traits associated with fruit quality in litchi (*Litchi sinensis* Sonn.). Dwivedi *et al.* (1994) observed a high positive correlation between aril weight and fruit weight and fruit diameter, high coheritability for aril weight and fruit weight and aril weight and fruit diameter. Ranpise and Desai (1994) reported that growth parameters (plant height, tree volume and stem girth) were positively correlated with each other in kagzhi lime (*Citrus aurantifolia*). They were also positively correlated with number of fruits per plant and yield. They also had favourable association with most of the fruit quality parameters. The number of fruits per plant and yield had also favourable association with fruit quality attributes.

MATERIALS AND
METHODS

# 3. MATERIALS AND ME

The investigations were carried out on the trees maintained in the orchard Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from April 2001 to March 2002.

The experiment aimed at studying the performance of the sapota varieties and to assess the compatibility within and among varieties under the humid tropical conditions of Kerala.

The study was carried under the following heads

- Growth characters
- Flowering characters
- Fruit set and development
- Self and cross compatibility aspects

## 3.1. SELECTION OF VARIETIES

The varieties selected for the study were Co-2, Oval, Gavarayya, Cricket Ball, PKM-1 and Local. The trees were 20 years old and were grown under uniform conditions as per package of practices recommendations (KAU, 1996). Six trees, each in the above six varieties 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 quadrant, 100 shoots were selected randomly for taking up the following observations,

The growth of shoots for a period of one year

Flowering and floral characters

Fruit set, fruit development, fruit drop and yield

## 3.2. PLANT CHARACTERS

### 3.2.1. Height of the tree

Height of the tree was measured by using a graduated pole, which gave direct reading of the height in metres.

### 3.2.2. Girth of the tree

The girth of the tree was measured at 50 centimetre above the ground using the tape and expressed in metres.

$$\text{Girth (m)} = \frac{\text{Average diameter}}{\pi}$$

### 3.2.3. Canopy spread

The distance from the centre to the leaves at the peripheral area of the crown was measured in East-West and North-South directions and the average value was computed as canopy spread in metres.

### 3.2.4. Number of primary branches

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

### 3.2.5. Tree volume

Tree volume was worked out using the formula.

$$V = \frac{\pi h (2r)^2}{6}$$

Where, V - is the volume of the tree in cubic metre

h- is the height of the trees (m)

r - is the canopy radius (m)

## 3.3. FLUSH CHARACTERS

### 3.3.1. Shoot extension

One hundred lateral shoots on each quadrant we
individual trees of all the six varieties selected for the study. The shoots were tagged and numbered serially during April 2001. The extension growth was measured in centimetre at monthly interval for a period of one year.

### 3.3.2. Season of flushing

The week and month of flushing was observed and recorded for each variety

### 3.3.3. Number of flushes per unit area [metre square]

The number of flushes per metre square were counted and recorded at weekly interval during the time of flushing. This was done with the help of half metre square wooden frame and the number of shoots that came in the frame was noted on four sides of the tree canopy.

### 3.3.4. Flush length

Average length of ten flushes was recorded on four sides of the canopy after floral differentiation started on the flushes and expressed in centimeter.

### 3.3.5. Number of leaves per flush

The number of leaves on the flushes were counted and recorded at weekly interval during the time of flushing.

### 3.3.6. Shoot girth

Shoot girth was recorded at one centimetre apart from the base of ten randomly selected flush shoots after cessation of leaf emergence and expressed in centimetre.

## 3.4. FLOWERING AND FLORAL CHARACTERS

### 3.4.1.Season and pattern of flowering

Season of flowering was studied in all the six varieties by observing 100 shoots selected at random on each tree. Observations on the number of shoots flowered, number of flowers per inflorescence and time of anthesis were recorded.

### 3.4.2. Flower bud development

The shoots in trees tagged for shoot 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 were

studied by labelling and closely watching flower buds randomly selected on each tree. Tagging of buds was done soon after emergence of buds as a brownish green protuberance. Observations were made on the time taken from the emergence of flower bud to flower opening and time taken for complete opening of all flowers in an inflorescence.

### 3.4.3.Floral biology

Observations on various aspects of floral biology, viz., morphology of flowers, anthesis, stigma receptivity and pollen studies were done for all the six varieties.

#### *3.4.3.1.Anthesis*

Preliminary observations showed that flower opening takes place in the early morning hours. In order to know the exact time of anthesis, 60 mature buds were tagged and observations were made at half hourly intervals from 5.30 hours. The maturity of buds was determined from the size of the buds. The experiment was repeated over a period of one week.

#### *3.4.3.2. Anther dehiscence*

The period of anther dehiscence was studied by tagging 60 mature buds of uniform size in all the six varieties. 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.

#### *3.4.3.3.Stigma receptivity*

The receptivity of stigma was judged by milky exudation on the stigmatic surface. This was further confirmed by controlled pollination and observing the fruit set. Mature buds were emasculated and covered for this purpose. They were later pollinated with pollen collected from dehisced male buds using a camel hairbrush. Pollination was done at two 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. This was carried out in all the six varieties.

**3.4.4.Pollen studies**

Pollen studies with respect to pollen morphology, viability and storage were conducted. For the study, anthers were collected from mature buds of all the varieties. 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.

***3.4.4.1. Morphology and fertility***

Twenty-five well-shaped mature buds were selected from all the six varieties. 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 pollen grains was ascertained 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 from ten microscopic fields 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 ten microscopic fields in each slide and the average was worked out.

***3.4.4.2. In vitro pollen germination***

Different concentrations of sucrose, ranging from 5.0 per cent to 25 per cent, with 0.5 per cent agar were tried initially. Germination was well observed at 15 per cent sucrose concentration. 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 per cent, 0.50 per cent, 0.75 per cent and 1.00 per cent with sucrose 15 per cent concentration.

The effect of boric acid was studied by adding it at various levels of concentration (25 mg $l^{-1}$, 50mg $l^{-1}$, 75mg $l^{-1}$ and 100 mg $l^{-1}$) to the basal medium. The effect of calcium nitrate on *in vitro* pollen germination was also studied by adding it

to the basal medium at the various concentrations (0.01 per cent, 0.03 per cent and 0.05 per cent).

### *3.4.4.3. Estimation of pollen production*

The number of pollen per anther was estimated using haemocytometer as suggested by Rao and Khader (1960). Mature buds just prior to anther dehiscence were collected. The anthers were observed under a hand lens for non-dehiscence. Hundred such anthers were gathered in small vials and stored in desiccators over calcium chloride for 4 hours to 6 hours to facilitate dehiscence. Anthers that failed to dehisce were forced upon. To the contents 2.5 ml of water containing 0.05 per cent teepol was added and stirred thoroughly in order to obtain an even dispersion of the pollen grains in the suspension. A drop of suspension drawn in a fine pipette was transferred to each of the two counting chambers of a Spencer Bright Line Haemocytometer. Each chamber has an area of nine square millimeter ruled into smaller divisions. Each of the four corner square millimetre areas is ruled into small divisions. The counting chambers are 0.1 mm in depth so that the volume over one $mm^2$ is 0.1 $mm^3$. On this basis, the number of pollen grains per anther can be derived as follows,

The contents of 100 anthers are suspended in a 2.5 ml of solution. Thus the contents of each anther are suspended in 0.025 ml of the solution or 25 $mm^3$.

If N=average number of pollen grains counted per square and

X=number of pollen grains per anther

N: X=0.1:25

0.1X=25N

X=250N

The pollen grains in each of the four corner squares of each counting chambers were counted using low power (10X) objective of the microscope.

### *3.4.4.4. Pollen storage*

In order to understand the optimum storage conditions for the pollen grains, mature buds 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

$T_1$- keeping over calcium chloride in a desiccator at room temperature

$T_2$- keeping in refrigerator at 4 $^0$C

$T_3$- keeping over calcium chloride in desiccator under refrigerated condition at 4$^o$C.

$T_4$- keeping at room temperature without any treatment

Pollen grains were collected from each treatment and were tested daily for their viability by germination test. The pollen viability was expressed in percentage.

**3.4.5.Flower drop**

To know the extent of flower drop, fifty flower buds immediately after emergence were tagged and observed at two days interval. Extent of flower bud drop during different stages of development was recorded in each variety.

3.5.FRUIT SET

A total of 100 flowers on each tree were assessed for natural fruit set. Observations were made at weekly interval for a period of one month in all the six varieties.

3.6.FRUIT DROP

Fruits immediately after set were tagged and extent of fruit drop during different stages of development was recorded in each variety.

3.7.FRUIT DEVELOPMENT

**3.7.1.Physical changes during fruit development**

In order to study the changes with respect to physical parameters, fruit samples were picked at fortnightly interval commencing from fruit set till harvest and observations were recorded.

***3.7.1.1.Fruit shape***

Fruits were categorized into round, oval, oblong or obovate shape by visual assessment.

*3.7.1.2. Fruit weight*

Weight of ten individual fruit was taken using an electronic balance and average was expressed in grams.

*3.7.1.3. Fruit length and girth*

Fruit length was measured in centimeter from the stalk end to the apex and girth on the equatorial plane using a scale (cm).

*3.7.1.4. Volume*

Fruit volume was determined in millilitres by water displacement method using a measuring cylinder.

*3.7.1.5. Specific gravity*

Specific gravity was computed by dividing weight by volume of the fruit.

*3.7.1.6. Pulp to seed ratio*

The weight of pulp and seeds were recorded separately and pulp to seed ratio was calculated.

*3.7.1.7.Seed characters*

The seed characters, viz., number of seeds per fruit, length (cm), breadth (cm) and weight of the seed (gm) were observed for their changes during fruit development in ten fruits each in all the six varieties.

**3.7.2. Biochemical changes during fruit development**

Fruit samples were drawn at fortnight intervals from fruit set to harvest and subjected to biochemical analysis in order to know the chemical composition of fruits during the different stages of fruit development. The methodologies followed for the analysis of chemical characters are given below:

*3.7.2.1. Total soluble solids (TSS)*

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

*3.7.2.2. Total sugars, reducing sugar 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) and expressed in per centage.

*3.7.2.3. Titrable acidity*

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

*3.7.2.4. Sugar: acid ratio*

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

3.8. HARVEST INDEX

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

3.9. YIELD

The yield of the tree (Kilograms) was recorded during each harvest from each variety.

**3.9.1 Fruit weight**

Weight of the total fruits of all the trees of each variety was determined at the time of harvest. Total fruit weight in Kilograms was recorded tree-wise for each variety.

### 3.9.2. Number of fruits

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

## 3.10.METEOROLOGICAL EFFECT

The meteorological data were collected from the Agro met observatory of the College of Horticulture, Vellanikkara. The daily data on the maximum and minimum temperature (°C), sunshine (hours $day^{-1}$), rainfall (mm), relative humidity (%), wind speed (km/hr) and soil temperature (°C) were recorded for the period of investigation. The details of the meteorological observations for this period are presented in Appendix-I. Simple correlations were computed between the growth and yield characters with the monthly mean values of maximum temperature, minimum temperature, relative humidity, rainfall, sunshine hours, wind speed and soil temperature to determine the effect of the weather elements on the growth and yield of sapota.

### 3.10.1.Total heat requirement

Thermal days for various phenological events were worked out. A thermal day or degree-days or a heat unit, is the departure from the mean daily temperature above the minimum threshold temperature(° C) . Thermal days for each phenological event was worked out from the following

$$\text{Thermal days} = \sum_{i=1}^{n} \frac{(T_{max}+T_{min})}{2} - T_{base}$$

$T_{max}$ -Maximum temperature of the day (°C)

$T_{min}$ - Minimum temperature of the day (° C)

n

Σ- Summation for day '1' to day 'n' within which the event occurred.

i=1

The base temperature is assumed as 10°C for sapota, as its growth ceases if it is below this minimum of 10 °C

## 3.11. COMPATIBILITY STUDIES

### 3.11.1.Self compatibility

Self-compatibility was assessed in all the six varieties. Pollen grains from just dehisced anthers of same tree were used for pollination

### 3.11.2.Cross compatibility

All the six varieties were crossed in all possible combinations. Pollen grains from just dehisced anthers of the variety were used for pollination.

### 3.11.3.Techniques of artificial pollination

Mature buds of female parent were emasculated by circumcising the base of corolla where the anthers are attached, on the evening prior to expected date of flower opening. Pollination was done by brushing the stigma with anther just dehisced with fresh pollen adhering to it. After pollination, covering the flower with butter paper and tagging were done.

### 3.11.4. Observations

#### *3.11.4.1.Fruit set*

Ten days after pollination, number of fruits set was observed and e... ... percentage

#### *3.11.4.2.Fruit drop*

Number of fruits dropped was assessed at weekly interval and expressed in percentage

#### *3.11.4.3.Days taken for maturity*

Number of days taken for maturity was recorded for all the crossed fruits.

#### *3.11.4.4.Physical characters*

Fully matured crossed fruits were harvested and physical characters like weight of the fruit (gm), shape of the fruit, length and girth (cm) of the fruit, volume (ml), specific gravity and pulp to seed ratio and seed characters were recorded.

*3.11.4.5.Biochemical characters*

Biochemical characters like TSS (°Brix), moisture (%), acidity (%), total sugars (%), reducing sugars (%) and non-reducing sugars (%) and sugar: acid ratio were analysed by adopting the procedure followed in 3.7.2.

**3.11.5.Seed germination**

All the seeds from hybridized fruits were broken but with intact seed coat and alternate wetting and drying were done. Observations on germination percentage and germination period were recorded.

**3.11.6.Pollen pistil interaction**

Pollen germination and tube growth after *in vivo* pollination in selected incompatible cross combinations were examined using fluorescence microscopic technique proposed by Kho and Baer (1968) and Kho *et al.* (1980). The pollinated flowers after *in vivo* pollination were fixed in FAA mixture (Formalin 10 ml, acetic acid 10 ml and ethanol 80 ml) at 6 hours, 12 hours, 24 hours and 48 hours after pollination. After 24 hours of fixation, the material was transferred into glass vial containing 1*N* NaOH for 8 hours at room temperature in order to soften the tissues. The softened material was washed thoroughly with distilled water and then transferred to 0.1 per cent aniline blue in 0.1*N* $K_2HPO_4$. It was retained in aniline blue solution for 18 hours for staining. The prepared specimen was then mounted on a microscopic slide with a drop of glycerin and viewed through fluorescence microscope and documented by photomicrography.

**3.11.7.Effect of different methods to overcome the incompatibility barrier**

A number of techniques have been tried by various workers to induce fertility by breaking the incompatibility barrier in crop plants. In the methods listed below, flower buds, which would open on the next day, were selected and bagged. After pollination, the flowers were bagged and labelled properly.

The various techniques followed were as follows,

$T_1$-Bud pollination

$T_2$-Pollination after cutting the stigma

$T_3$- Removal of stigma and pollination with help of *in vitro* basal medium

$T_4$- Removal of stigma and a part of style and pollination with *in vitro* basal medium

$T_5$- Pollination with *in vitro* germinated pollen grains

$T_6$- End of season pollination

$T_7$- Pollination with NAA 5.0 $mgl^{-1}$

$T_8$- Pollination with kinetin 5.0 $mgl^{-1}$

$T_9$- Pollination with 2,4-D 0.5 $mgl^{-1}$

$T_{10}$- Pollination with 2,4-D 1.0 $mgl^{-1}$

$T_{11}$- Double pollination

$T_{12}$- Removal of style and direct application of pollen on ovary

$T_{13}$- Pollination with irradiated pollen @10 Gy

$T_{14}$- Pollination with irradiated pollen @20 Gy

$T_{15}$-Pollination with irradiated pollen @30 Gy

$T_{16}$-Pollination with irradiated pollen @40 Gy

$T_{17}$-Pollination with irradiated pollen @50 Gy

$T_{18}$-Pollination with irradiated pollen @75 Gy

$T_{19}$-Pollination with irradiated pollen @100 Gy

#### *3.11.7.1. Observations*

##### *3.11.7.1.1.Fruit set*

Number of fruit set after each treatment was observed and expressed as percentage.

##### *3.11.7.1.2.Fruit drop*

Fruit drop was noted at weekly interval and expressed as percentage

## 3.12. STATISTICAL ANALYSIS

The data generated on morphological characters of all the six varieties were analysed using MSTAT-C (Freed, 1986) package available at College of Horticulture, Vellanikkara. Analysis of variance was performed on morphological characters and whenever the treatments were found significantly different their means were

compared using DMRT. (Duncan's Multiple Range Test). Genotypic and phenotypic co-efficient of variation, heritability and genetic advance were worked out for each character separately. Morphological characters associated with yield were identified through genotypic and phenotypic correlation co-efficient.

**3.12.1.Phenotypic and genotypic variance**

Variance components were estimated using the formula suggested by Burton (1952).

Genotypic variance (Vg) $=(V_T-V_E)/N$

Where, VT = mean sum of squares due to treatment

VE = mean sum of squares due to error

N = number of replication

Phenotypic variance (Vp) = Vg + Ve

Where, Vg = Genotypic variance

Ve = Environmental variance

**3.12.2.Phenotypic and Genotypic co- efficient of variation**

The phenotypic and genotypic co-efficient of variation were calculated as follows

The Phenotypic co efficient of variation (PCV) = $(Vp^{1/2}/\overline{X}) \times 100$

The Genotypic co efficient of variation (GCV) = $(Vg^{1/2}/\overline{X}) \times 100$

Where, $\overline{X}$ is the overall mean

**3.12.3.Heritability**

Heritability in the broad sense was estimated as follows

Heritability in broad sense =(Vg/Vp) x100

**3.12.4.Expected genetic advance**

The genetic advance expected under five per cent selection pressure was calculated using the formula suggested by Lush (1949) and Johnson *et al.* (1955).

Expected genetic advance (GA) $=k \times (Vg/Vp) \times Vp^{½}$

Where, Vg =Genetic variance

Vp = Phenotypic variance

k = Selection intensity which is equal to 2.06 for selection of five per cent individuals.

### 3.12.5.Phenotypic and genotypic correlation coefficients

Phenotypic and genotypic correlation coefficients were worked out to study the extent of association between characters. The phenotypic and genotypic variance was worked out for calculating the variance. The different covariance estimates were calculated by the method suggested by Fisher (1954).

RESULTS

# 4. RESULTS

The results of the experiment on varietal evaluation and compatibility studies in sapota (*Manilkara achras* (Mill.) Fosberg) were presented below under the following heads,

Vegetative characters

Flowering, yield and yield attributing characters and

Compatibility between the varieties.

## 4.1. VEGETATIVE CHARACTERS

The vegetative characters recorded were presented in Table 1.

### 4.1.1. Height of the tree

Height of the tree was maximum in the variety Cricket Ball (7.68m) followed by Oval (5.88m). The local variety was the least short in stature (2.72 m). Height of the varieties like Co-2 and Gavarayya was on par with each other. Mean height of the variety PKM-1 was 4.28m.

### 4.1.2. Girth of the tree

Maximum girth of the tree was recorded in the variety Cricket Ball (0.63m) followed by Oval (0.54m). Least girth of the tree was recorded in the Local variety.

### 4.1.3. Canopy spread

The variety Cricket ball recorded the maximum canopy spread (7.40m) followed by Co-2 (5.16m). Canopy spread was minimum in the variety PKM-1 (2.99m). The variety Oval and Gavarayya were on par with each other in canopy spread (4.21m and 4.17m respectively).

### 4.1.4. Volume of the tree

Volume of the tree was greatest in Cricket Ball (151.90 $m^{3)}$. Varieties PKM-1 and Local recorded lower tree volume and they were on par with each other (13.65$m^3$ and 11.17 $m^3$ respectively).

**4.1.5.Number of primary branches**

Number of primary branches was greatest in Cricket Ball (3.0) followed by Co-2 and Oval (2.50). Varieties PKM-1 and Local variety recorded minimum number of primary branches and they were on par with each other (1.83 and 2.17 respectively).

4.2. FLUSH CHARACTERS

**4.2.1. Number of flushes per square metre**

Number of flushes per square metre was maximum in the varieties Cricket Ball (11.90) and Oval (9.70) and they were on par with each other (Table 2a). The varieties Local (6.70), PKM-1 (6.80) and Co-2 (7.20) recorded minimum number of flushes per square metre.

**4.2.2. Length of the flush**

Maximum length of the flush was recorded in the varieties Oval (13.10 cm), Cricket Ball (12.68 cm) and Co-2 (12.54 cm)(Table 2a). Length of the flush was minimum in the variety Local (8.87 cm).

**4.2.3. Number of leaves per flush**

Maximum number of leaves which are considered as photosynthetically active young leaves per flush was recorded in the variety Cricket Ball (14.60cm) followed by Oval (10.90 cm). The varieties Local (8.50 cm) and PKM-1 (9.10 cm) recorded lowest number of leaves per flush (Table 2a).

**4.2.4. Girth of the shoot**

Girth of the shoot was maximum in the variety Cricket Ball (2.50 cm) followed by the variety Oval (1.79 cm)(Table 2a). The variety Local recorded the minimum girth of the shoot (0.91 cm).

**4.2.5. Flushing span**

Total duration of flushing was maximum in the variety Oval (28.7 days) followed by Cricket Ball (27.6 days) and Gavarayya (27.2 days). The flushing span was lowest in the variety Local (18.0 days)(Table 2a).

**Table 1.Vegetative characters of sapota varieties**

| Sl.No. | Variety | Height of the tree (m) | Girth of the tree (m) | Canopy spread (m) | Volume of the tree ($m^3$) | Number of primary branches |
|---|---|---|---|---|---|---|
| 1 | Co-2 | $5.09^c$ | $0.49^c$ | $5.16^b$ | $49.07^b$ | $2.50^b$ |
| 2 | Cricket Ball | $7.68^a$ | $0.63^a$ | $7.40^a$ | $151.9^a$ | $3.00^a$ |
| 3 | Oval | $5.88^b$ | $0.54^b$ | $4.21^c$ | $39.88^c$ | $2.50^b$ |
| 4 | Gavarayya | $5.38^c$ | $0.48^c$ | $4.17^c$ | $33.40^c$ | $2.50^b$ |
| 5 | PKM-1 | $4.28^d$ | $0.41^d$ | $2.99^c$ | $13.65^d$ | $1.83^c$ |
| 6 | Local | $2.71^e$ | $0.32^c$ | $3.46^d$ | $11.17^d$ | $2.17^c$ |

**Table 2a. Flush characters of sapota varieties**

| Sl.No. | Variety | Number of flushes per square meter | Length of flushes (cm) | Number of leaves per flush | Flushing span (days) | Girth of the shoot (cm) |
|---|---|---|---|---|---|---|
| 1 | Co-2 | $7.2^d$ | $11.54^b$ | $10.00^c$ | $20.4^c$ | $1.73^b$ |
| 2 | Cricket Ball | 11.9a | $12.68^a$ | $14.60^a$ | $27.6^b$ | $2.50^a$ |
| 3 | Oval | $9.7^b$ | $13.10^a$ | $10.90^b$ | $28.7^a$ | $1.79^b$ |
| 4 | Gavarayya | $8.2^c$ | $10.18^c$ | $7.20^c$ | $26.8^b$ | $1.10^c$ |
| 5 | PKM-1 | $6.8^d$ | $9.56^d$ | $8.50^d$ | $27.2^b$ | $1.63^b$ |
| 6 | Local | $6.7^d$ | $8.87^d$ | $9.10^d$ | $18.0^d$ | $0.91^c$ |

Values with similar superscript letter did not differ significantly


Plate : 1. Morphological characters of different sapota varieties

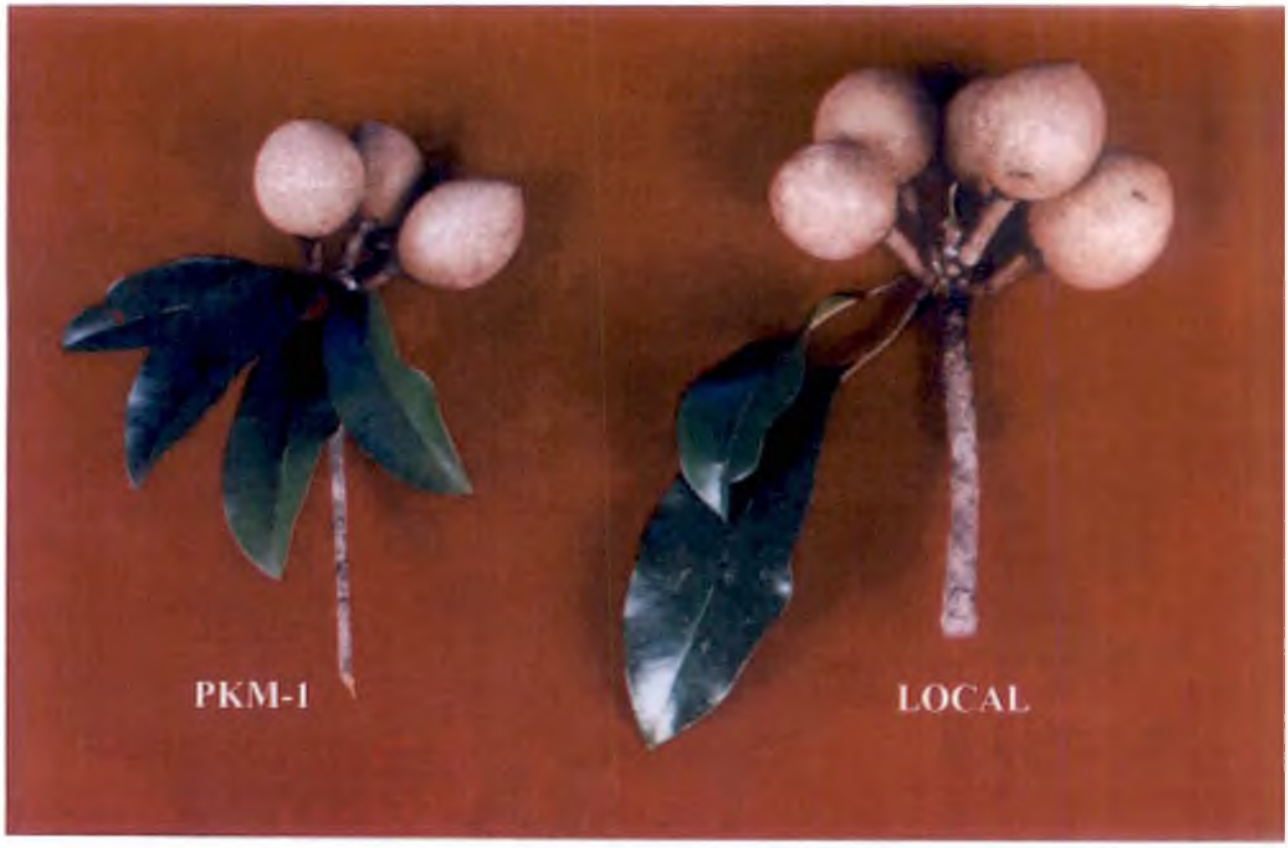



Plate : 2. Cluster fruit bearing habit of sapota varieties

**4.2.6. Peak flushing period**

Though periodical flushing occurred throughout the year in all the six sapota varieties under study, two seasons were observed as main seasons viz., May –July (first season) and September –November (second season)(Table 2b). In the first season peak flushing period occurred between June 14$^{th}$ to July 8$^{th}$ in Co-2, 14 $^{th}$ June to 24 $^{th}$ June in Cricket Ball, June 10$^{th}$ to June 28$^{th}$ in Oval, June 14$^{th}$ to June 20$^{th}$ in Gavarayya, June 7$^{th}$ to June 15$^{th}$ in PKM-1 and by June 21$^{st}$ to July12$^{th}$ in Local. Similarly, in second season, early flushing started in PKM-1 by September 7$^{th}$,Gavarayya and Local were late in flushing (September 14$^{th}$ and 15$^{th}$ respectively). The peak flushing period for different varieties were presented in the Table 2b.

**4.2.7.Mean monthly growth of shoots**

Maximum mean monthly extension growth of shoots was recorded in June followed by October for all the varieties. A similar trend was also observed in percentage of shoots showing growth in all the six varieties under study. There was no shoot extension growth in March, April, August and December. Of the total extension growth of shoots, maximum percentage contribution to growth was recorded in June and October in all the six varieties. Maximum mean extension growth was recorded in the variety Oval (12.9 cm) followed by Co-2 (11.45 cm). Minimum mean extension growth of shoots was recorded in Gavarayya and PKM-1 (9.2 cm each). The percentage of shoots showing growth was maximum in June followed by October in all the six varieties. There was no growth in shoots during April, August, December and March. The mean monthly growth of shoots of all the varieties was given in Table 3(a, b and c).

**4.2.8. Annual growth of shoots in different trees**

In the variety Co-2, tree no.1, 2and 6.recorded the maximum annual growth of shoots and minimum was recorded in tree No.4 and 3.A similar trend was recorded in all the six varieties under study .In all the trees selected for study, tree No. 1 of Oval recorded maximum mean extension growth (16.4 cm). The annual growth of shoots in different trees was given in Table 3(d).

**Table 2b.Peak flushing period of sapota varieties**

| Season | Co-2 | | Cricket Ball | | Oval | | Gavarayya | | PKM-1 | | Local | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | From | To | From | To | From | To | From | To | From | To |
| I (May-July) | 14th June | 8th July | 14th June | 24th June | 10th June | 28th June | 14th June | 21st June | 7th June | 15th June | 21st June | 12th July |
| II (Sept-October) | 12th Sept | 10th Oct | 10th Sept | 12th Oct | 10th Sept | 10th Oct | 14th Sept | 10th Oct | 7th Sept | 4th Oct | 15th Sept | 10th Oct |

**Table 3a.Mean monthly growth and percentage of growing shoots**

| Month | Co-2 | | | Cricket Ball | | |
|---|---|---|---|---|---|---|
| | Mean extension growth (cm) | Percentage contribution to growth | % shoots showing growth | Mean extension growth (cm) | Percentage contribution to growth | % shoots showing growth |
| 2001 April | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| May | 10.38 | 20.54 | 13.52 | 10.75 | 14.02 | 13.4 |
| June | 11.45 | 22.66 | 72.30 | 11.20 | 14.61 | 76.50 |
| July | 2.52 | 4.99 | 10.25 | 2.29 | 2.98 | 12.30 |
| August | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| September | 2.30 | 4.55 | 23.50 | 3.25 | 4.24 | 26.20 |
| October | 11.20 | 22.16 | 70.40 | 12.60 | 16.44 | 77.30 |
| November | 1.46 | 2.89 | 6.75 | 1.26 | 1.64 | 7.70 |
| December | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2002 January | 5.65 | 11.18 | 16.75 | 5.50 | 7.17 | 11.20 |
| February | 5.57 | 11.02 | 14.72 | 6.42 | 8.37 | 23.50 |
| March | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 3b.Mean monthly growth and percentage of growing shoots**

| Season | Oval | | | Gavarayya | | |
|---|---|---|---|---|---|---|
| | Mean extension growth (cm) | Percentage contribution to growth | % shoots showing growth | Mean extension growth(cm) | Percentage contribution to growth | % shoots showing growth |
| 2001 April | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| May | 12.30 | 20.46 | 12.00 | 8.50 | 18.62 | 16.17 |
| June | 12.90 | 21.45 | 75.50 | 9.20 | 20.16 | 70.20 |
| July | 2.47 | 4.11 | 11.50 | 2.54 | 5.56 | 14.50 |
| August | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| September | 5.25 | 8.73 | 22.30 | 5.57 | 12.20 | 5.44 |
| October | 12.52 | 20.82 | 70.20 | 10.38 | 22.74 | 23.50 |
| November | 2.29 | 3.81 | 7.30 | 1.44 | 3.16 | 3.20 |
| December | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2002 January | 5.80 | 9.65 | 12.32 | 4.32 | 9.47 | 5.83 |
| February | 6.60 | 10.98 | 18.20 | 3.69 | 8.09 | 9.25 |
| March | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 3c.Mean monthly growth and percentage of growing shoots**

| Season | PKM-1 | | | Local | | |
|---|---|---|---|---|---|---|
| | Mean extension growth (cm) | Percentage contribution to growth | % shoots showing growth | Mean extension growth(cm) | Percentage contribution to growth | % shoots showing growth |
| 2001 April | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| May | 8.80 | 20.98 | 14.72 | 8.40 | 22.39 | 6.70 |
| June | 9.20 | 21.93 | 78.30 | 9.70 | 25.85 | 76.30 |
| July | 2.22 | 5.29 | 10.50 | 2.62 | 6.98 | 8.20 |
| August | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| September | 2.64 | 6.29 | 7.55 | 1.93 | 5.14 | 6.50 |
| October | 9.50 | 22.65 | 25.70 | 6.70 | 17.86 | 67.80 |
| November | 1.37 | 3.27 | 5.20 | 1.79 | 4.77 | 5.40 |
| December | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2002 January | 4.50 | 10.73 | 6.70 | 3.20 | 8.53 | 4.40 |
| February | 3.72 | 8.87 | 7.80 | 3.18 | 8.48 | 6.50 |
| March | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

## 4.3. FLORAL CHARACTERS

### 4.3.1. Extent and season of flowering

Percentage of shoots flowered was maximum in the variety Cricket Ball (89.83 %) followed by Co-2 (89.17%) and minimum number of shoots flowered was recorded in PKM-1 (80.0%). The varieties like Co-2, Cricket Ball and Local started flowering by second week of May and extends up to first week of June in the first season. Varieties Oval and PKM-1 started flowering by first week of June and extends only up to June last week whereas Gavarayya started flowering by first week of June, it ceased by first week of July. But, in second season, flowering started by second week of September and ceased by October last week in Co-2, Oval, Gavarayya and PKM-1.In Cricket Ball and Local, flowering in second season started by third week of September and extends up to last week of October. The extent and season of flowering of all the varieties were given in Table 4a.

### 4.3.2. Extent of flowering in different directions of tree

In all the six varieties maximum per cent of shoots flowered were observed in the shoots oriented in the North followed by South. In northern side, Co-2 recorded maximum number of flowering shoots (95%) followed by Cricket Ball (94%). In southern side, maximum per cent of flowering shoots were observed in Co-2 and Cricket Ball (90%, each). Minimum per cent of flowering shoots were in East-West orientation. The per cent of shoots flowered in different directions in all the varieties were given in Table 4b.

### 4.3.3. Number of inflorescence per square metre

Maximum number of inflorescence per square metre was recorded in the variety PKM-1 (12.5) and Cricket Ball (11.8) and these varieties were on par with each other (Table 5). Minimum number of inflorescence per square metre was recorded in Local (6.5) and Co-2 varieties (6.9).

**Table 3d.Annual growth of shoots (cm) in different trees**

| Tree Number | Co-2 | Cricket Ball | Oval | Gavarayya | PKM-1 | Local |
|---|---|---|---|---|---|---|
| 1 | $15.85^{a}$ | $13.20^{a}$ | $16.40^{a}$ | $14.4^{b}$ | $9.26^{b}$ | $9.50^{a}$ |
| 2 | $15.40^{a}$ | $13.60^{a}$ | $16.00^{a}$ | $13.5^{b}$ | $8.90^{c}$ | $9.00^{b}$ |
| 3 | $7.30^{b}$ | $6.80^{c}$ | $5.20^{b}$ | $12.8^{bc}$ | $9.20^{b}$ | $6.50^{c}$ |
| 4 | $7.10^{b}$ | $5.26^{d}$ | $4.75^{b}$ | $10.8^{d}$ | $9.01^{bc}$ | $6.20^{c}$ |
| 5 | $9.87^{b}$ | $12.80^{ab}$ | $4.06^{b}$ | $15.6^{a}$ | $10.00^{a}$ | $9.20^{b}$ |
| 6 | $15.26^{a}$ | $14.20^{a}$ | $15.50^{a}$ | $13.6^{b}$ | $9.50^{b}$ | $9.00^{b}$ |

Values with similar superscript letter did not differ significantly

**Table 4a.Extent and season of flowering**

| Sl.No. | Variety | Season of flowering | Percentage of shoots flowered |
|---|---|---|---|
| 1 | Co-2 | May 2nd week to June 1st week<br>Sept- 2nd week to Oct- last week | 89.17 |
| 2 | Cricket Ball | May 2nd week to June 1st week<br>Sept- 3rd week to Oct- last week | 89.83 |
| 3 | Oval | June 1st week to June 4th week<br>Sept- 2nd week to Oct- last week | 86.83 |
| 4 | Gavarayya | June 1st week to July 1st week<br>Sept- 2nd week to Oct- last week | 85.00 |
| 5 | PKM-1 | June 1st week to June 4th week<br>Sept- 2nd week to Oct- last week | 80.00 |
| 6 | Local | May 2nd week to June 1st week<br>Sept- 3rd week to Oct- last week | 83.33 |

### 4.3.4.Number of flowers per inflorescence

Maximum number of flowers was observed in Cricket Ball (6.1), Co-2 (5.9), Gavarayya (5.7) and PKM-1 (5.6) and all these varieties do differ significantly. Minimum number of flowers per inflorescence was recorded in Local (4.4) and Oval varieties (4.6)(Table 5).

### 4.3.5. Number of days taken for complete opening of an inflorescence

Minimum number of days taken for complete opening of an inflorescence was recorded in the variety Oval (5.6). The varieties Co-2 (7.1) and Cricket Ball (7.3) took more number of days for complete opening of an inflorescence (Table 5).

### 4.3.6. Stages of flower bud development

The stages of sapota flower bud development were conveniently divided into seven and the length and girth recorded in each stage were presented in Table 6a. Significant difference in length and girth of the buds was noted in all the stages. The length and girth of flower bud was significantly higher in the variety Oval. Maximum length and girth of Oval flower bud at stage 7 was 2.1cm and 2.5 cm respectively. Minimum length and girth of the flower bud at stage 7 was observed in the variety Local followed by PKM-1 (1.2 cm and 1.8 cm respectively). The length and girth of flower bud of all the varieties at different stages were given in Table 6a. At stage 1 flower buds were protuberance like structure fully covered with brownish sepal. At stage 4 stigma extruded out but there is no stigmatic fluid. At stage 6 flower buds swell and stigma well extruded with profuse stigmatic fluid (Table 6b).

### 4.3.7. Duration from bud emergence to bud opening

Number of days taken for bud emergence to bud opening was maximum for the variety Cricket Ball (28 days) followed by Oval (24 days)(Table 6b). PKM-1 and Local recorded minimum number of days for bud emergence to bud opening (19 days).

**Table 4b.Extent of flowering in different directions of trees**

| Variety | Percentage of shoots flowered | | | |
|---|---|---|---|---|
| | East | West | North | South |
| Co-2 | 75 | 74 | 95 | 90 |
| Cricket Ball | 77 | 79 | 94 | 90 |
| Oval | 80 | 80 | 90 | 87 |
| Gavarayya | 85 | 85 | 92 | 87 |
| PKM-1 | 80 | 80 | 90 | 85 |
| Local | 80 | 80 | 90 | 87 |

**Table 5.Inflorescence characters**

| Variety | Number of inflorescence per $m^2$ | Number of flowers per inflorescence | Days taken for complete opening of inflorescence |
|---|---|---|---|
| Co-2 | $6.9^{c}$ | $5.9^{b}$ | $6.0^{c}$ |
| Cricket Ball | $11.8^{a}$ | $6.1^{a}$ | $6.2^{c}$ |
| Oval | $8.2^{b}$ | $4.6^{d}$ | $5.6^{d}$ |
| Gavarayya | $8.2^{b}$ | $5.7^{c}$ | $7.1^{a}$ |
| PKM-1 | $12.5^{a}$ | $5.6^{c}$ | $7.3^{a}$ |
| Local | $6.5^{c}$ | $4.4^{e}$ | $6.9^{b}$ |

Values with similar superscript letter did not differ significantly

**Table 6a.Stages of flower bud development**

| Variety | Length (cm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stages | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Co-2 | 0.20$^{c}$ | 0.40$^{b}$ | 0.70$^{b}$ | 0.85$^{b}$ | 1.05$^{c}$ | 1.45$^{c}$ | 1.75$^{b}$ |
| Cricket Ball | 0.29$^{b}$ | 0.50$^{b}$ | 0.75$^{b}$ | 1.00$^{b}$ | 1.25$^{b}$ | 1.60$^{b}$ | 1.80$^{b}$ |
| Oval | 0.32$^{a}$ | 0.64$^{a}$ | 0.89$^{a}$ | 1.25$^{a}$ | 1.65$^{a}$ | 1.85$^{a}$ | 2.10$^{a}$ |
| Gavarayya | 0.15$^{d}$ | 0.20$^{d}$ | 0.83$^{a}$ | 1.03$^{b}$ | 1.05$^{c}$ | 1.45$^{e}$ | 1.50$^{c}$ |
| PKM-1 | 0.15$^{d}$ | 0.29$^{c}$ | 0.66$^{c}$ | 0.92$^{b}$ | 1.04$^{c}$ | 1.15$^{d}$ | 1.20$^{d}$ |
| Local | 0.15$^{d}$ | 0.25$^{c}$ | 0.34$^{d}$ | 0.40$^{c}$ | 0.50$^{d}$ | 0.68$^{e}$ | 0.80$^{e}$ |

| Variety | Girth (cm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stages | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Co-2 | 0.75b$^{c}$ | 1.05$^{a}$ | 1.46$^{b}$ | 1.75$^{b}$ | 2.00$^{a}$ | 2.15$^{b}$ | 2.30$^{b}$ |
| Cricket Ball | 0.80$^{b}$ | 1.00$^{a}$ | 1.55$^{a}$ | 1.60$^{c}$ | 1.80$^{b}$ | 2.15$^{b}$ | 2.30$^{b}$ |
| Oval | 0.90$^{a}$ | 1.05$^{a}$ | 1.53$^{a}$ | 1.85$^{a}$ | 2.00$^{a}$ | 2.23$^{a}$ | 2.50$^{a}$ |
| Gavarayya | 0.80$^{b}$ | 1.00$^{a}$ | 1.45$^{b}$ | 1.60$^{c}$ | 1.76$^{b}$ | 1.89$^{c}$ | 2.00$^{c}$ |
| PKM-1 | 0.70$^{c}$ | 0.85$^{b}$ | 1.25$^{c}$ | 1.36$^{d}$ | 1.55$^{c}$ | 1.75$^{d}$ | 1.80$^{d}$ |
| Local | 0.70$^{c}$ | 0.90$^{b}$ | 1.20$^{c}$ | 1.42$^{d}$ | 1.50$^{c}$ | 1.67$^{d}$ | 1.70$^{d}$ |

Values with similar superscript letter did not differ significantly

**Table 6b. Duration and characters of each stages of flower bud development**

| Stages | Co-2 | Cricket Ball | Oval | Gavarayya | PKM-1 | Local | Characters |
|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | Small protuberance |
| 2 | 5.0 | 7.0 | 5.0 | 5.0 | 4.0 | 4.0 | Small, covered with brownish sepals |
| 3 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | Pedicel short, bud emerge out of sepals |
| 4 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | Pedicel slightly elongate, stigma extruded out |
| 5 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | Stigma fully extruded out |
| 6 | 4.0 | 7.0 | 6.0 | 5.0 | 3.0 | 3.0 | Swollen bud,presence of stigmatic fluid |
| 7 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | Swollen bud,presence of stigmatic fluid |
| Days from bud emergence to bud opening | 21 | 28 | 24 | 22 | 19 | 19 | |

### 4.3.8. Anthesis time of sapota varieties

In sapota, anthesis time occurred between 7.00 a.m. and 8.00 a.m. in all the six varieties under study (Table 7a). But the peak anthesis period occurred between 7.00 a.m. and 7.30 a.m.

### 4.3.9. Anther dehiscence period

The period of anther dehiscence occurred at one day before the anthesis. It suggests that it was protandry in nature. There was no anther dehiscence during the day of opening and one day after anthesis (Table 7b).

### 4.3.10. Stigma receptivity

Maximum receptivity of stigma in all the six varieties was found at the time of anthesis (Table 8). The receptivity of stigma gradually decline even after on the same day of anthesis. The receptivity of stigma ascertained by the per cent fruit set was absent by 8.00 hours to 10.00 hours after anthesis.

### 4.3.11.Pollen fertility

Pollen fertility percentage ascertained by acetocarmine staining test was not significantly differ among the varieties (Table 9a and Plate 3&4). Maximum pollen fertility (96%) was observed in the varieties Cricket Ball and PKM-1.The diameter of the viable pollen grain was maximum (94.75 micron) in Gavarayya and minimum in Local variety. The maximum and minimum diameter of non-viable pollen was recorded in Cricket Ball (58.65 micron) and PKM-1 (53.18 micron).

### 4.3.12. Standardization of *in vitro* medium for pollen germination of sapota

Maximum germination (90.5%) of sapota pollen was observed in the basal medium containing sucrose 15 per cent combined with agar 0.5 per cent, boric acid 100 mg $l^{-1}$ and calcium nitrate 0.03 per cent. Pollen germination occurred at sucrose 5.0 per cent and gradually increased up to 15 per cent concentration but thereafter germination per cent showed a declining trend. Maximum tube length (197.6) was recorded in the

**Table 7a.Anthesis period of sapota varieties**

| Time | Percentage | | | | | |
|---|---|---|---|---|---|---|
| | Co-2 | Cricket Ball | Oval | Gavarayya | PKM-1 | Local |
| 5.30a.m.-6.00a.m. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.00a.m.-630a.m. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6.30a.m.-7.00a.m. | 2.0 | 6.0 | 4.0 | 2.0 | 2.0 | 2.0 |
| 7.00a.m.-7.30a.m. | 80.0 | 80.0 | 80.0 | 80.0 | 76.0 | 84.0 |
| 7.30a.m-8.00a.m. | 20.0 | 20.0 | 20.0 | 20.0 | 24.0 | 16.0 |
| 8.00a.m.-8.30a.m. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8.30a.m.-9.00a.m. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9.00a.m.-9.30a.m. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table 7b.Anther dehiscence of sapota varieties**

| Time | Dehiscence Percentage | | | | | |
|---|---|---|---|---|---|---|
| | Co-2 | Cricket Ball | Oval | Gavarayya | PKM-1 | Local |
| One day before anthesis | 100 | 100 | 100 | 100 | 100 | 100 |
| On the day of anthesis | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| One day after anthesis | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table 8.Stigma receptivity of sapota varieties**

| Time | Fruit set (%) | | | | | |
|---|---|---|---|---|---|---|
| | Co-2 | Cricket Ball | Oval | Gavarayya | PKM-1 | Local |
| 24 hours before anthesis | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| At anthesis | 36.0 | 28.0 | 24.0 | 22.0 | 30.0 | 20.0 |
| 2 hours after anthesis | 12.0 | 14.0 | 14.0 | 18.0 | 16.0 | 14.0 |
| 4 hours after anthesis | 8.0 | 8.0 | 8.0 | 10.0 | 8.0 | 6.0 |
| 6 hours after anthesis | 6.0 | 8.0 | 6.0 | 10.0 | 8.0 | 8.0 |
| 8 hours after anthesis | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 hours after anthesis | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 hours after anthesis | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table 9a.Pollen fertility in sapota varieties**

| Variety | No. of pollen grains observed | No. of fertile grains | Pollen fertility (%) | Diameter of pollen | |
|---|---|---|---|---|---|
| | | | | Viable (µ) | Non-Viable (µ) |
| Co-2 | 100 | 95 | 95 | 93.42 | 53.32 |
| Cricket Ball | 100 | 96 | 96 | 92.65 | 58.65 |
| Oval | 100 | 94 | 94 | 92.45 | 58.55 |
| Gavarayya | 100 | 95 | 95 | 94.75 | 53.68 |
| PKM-1 | 100 | 96 | 96 | 86.13 | 53.18 |
| Local | 100 | 97 | 97 | 84.41 | 53.47 |
| | | | 1.16 | 0.08 | 1.52 |

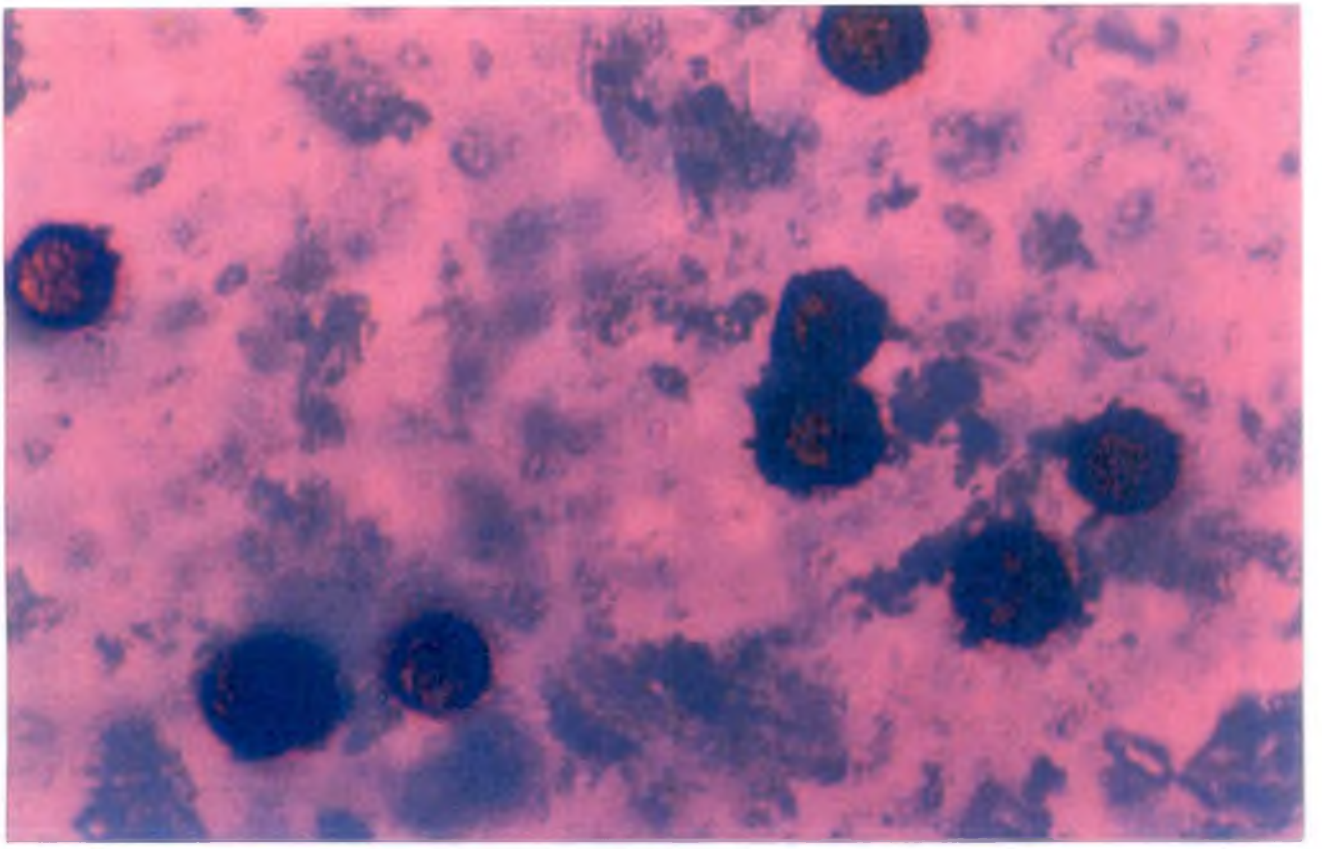


Plate : 3. Acetocarmine stained pollen grain fertility of sapota variety Cricket Ball (x10X)

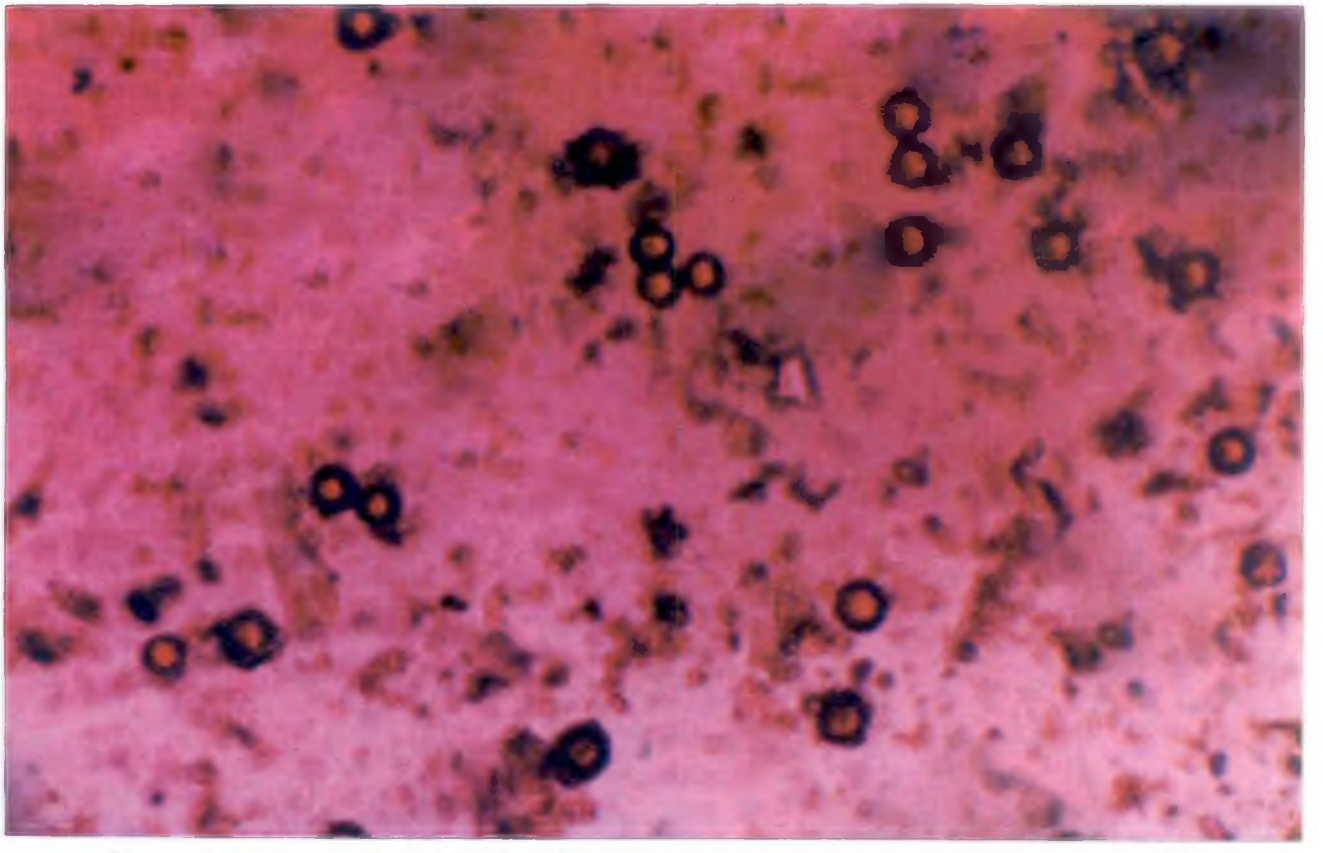


Plate : 4. Acetocarmine stained pollen grain fertility of sapota variety PKM-1 (x10X)

basal medium supplemented with agar 0.5 per cent + boric acid 100mg $l^{-1}$ + calcium nitrate 0.03 per cent (Table 9b and Plate 5&6).

**4.3.13.Pollen germination in sapota varieties**

Maximum pollen germination percentage was recorded in the variety Co-2 (85.40%) followed by Oval (84.25%). In Local variety minimum pollen germination percentage (75.50%) was recorded. Mean value for maximum pollen tube length was recorded in Cricket Ball (196.7 micron) followed by Gavarayya (193.8 micron) and Co-2 (193.4 micron). Longest pollen tube length of 215.6 micron was recorded in Co-2 variety and lowest in the variety Local (188.3 micron)(Table 9c).

**4.3.14.Pollen production per anther**

Maximum pollen production per anther was recorded in the variety Cricket Ball (2871.60) and Co-2 (2655.90) and the minimum were recorded in the variety Local (1261.60)(Table 9d).

**4.3.15.Pollen storage**

Viability of pollen in all the storage conditions showed gradual declining trend. Pollen viability was maximum (83.80 per cent) when pollen grains were stored in refrigerator at 4°C followed by pollen storage at calcium chloride in desiccator (60.70 per cent) at 5 days after storage. Pollen viability was minimum in keeping pollen grains at room temperature followed by pollen grains over calcium chloride in desiccator under refrigerator at 4°C followed by control (Table 9e).

**4.3.16.Rate of *in vitro* pollen germination**

Pollen grains started to germinate 4 hours after incubation and gradually increased. Both germination percentage and pollen tube length were reached a peak at 9 hours after incubation and thereafter remains constant (Table 9f).

**Table 9b. *In vitro* media for germination of sapota pollen**

| Sl.No. | Medium | Pollen germination (%) | Mean pollen tube length (µ) |
|---|---|---|---|
| 1 | Sucrose-5 % | 66.67$^{f}$ | 78.30$^{f}$ |
| 2 | Sucrose-10% | 71.40$^{e}$ | 129.5$^{e}$ |
| 3 | Sucrose-15 % | 84.50$^{c}$ | 184.4$^{d}$ |
| 4 | Sucrose-20 % | 80.50$^{d}$ | 181.7$^{d}$ |
| 5 | Sucrose-15 %+Agar 0.25% | 83.50$^{c}$ | 183.0$^{d}$ |
| 6 | Sucrose-15 %+Agar 0.5% | 86.50$^{b}$ | 184.50$^{d}$ |
| 7 | Sucrose-15 %+Agar 0.75% | 84.00$^{c}$ | 183.50$^{d}$ |
| 8 | Sucrose-15 %+Agar 1.00% | 84.00$^{c}$ | 183.00$^{d}$ |
| 9 | Sucrose-15 %+Agar 0.5%+Boric acid25mgl$^{-1}$ | 85.00$^{c}$ | 190.00$^{c}$ |
| 10 | Sucrose-15 %+Agar 0.5%+Boric acid50mgl$^{-1}$ | 85.00$^{c}$ | 190.60$^{c}$ |
| 11 | Sucrose-15 %+Agar 0.5%+Boric acid75mgl$^{-1}$ | 87.00$^{b}$ | 192.70$^{c}$ |
| 12 | Sucrose-15 %+Agar 0.5%+Boric acid100mgl$^{-1}$ | 90.00$^{a}$ | 195.60$^{b}$ |
| 13 | Sucrose-15 %+Agar 0.5%+Boric acid100mgl$^{-1}$+Calcium nitrate 0.01% | 87.00$^{b}$ | 195.30$^{b}$ |
| 14 | Sucrose-15 %+Agar 0.5%+Boric acid100mgl$^{-1}$+Calcium nitrate 0.03% | 90.50$^{a}$ | 197.60$^{a}$ |
| 15 | Sucrose-15 %+Agar 0.5%+Boric acid100mgl$^{-1}$+Calcium nitrate 0.05% | 86.50$^{b}$ | 194.50$^{b}$ |

Values with similar superscript letter did not differ significantly

**Table 9c. Pollen germination**

| Sl.No. | Variety | Pollen germination (%) | Mean pollen tube length (Micro meter) | Longest pollen tube length (Micrometer) |
|---|---|---|---|---|
| 1 | Co-2 | 85.40[a] | 193.4[b] | 215.6[b] |
| 2 | Cricket Ball | 81.55[c] | 196.7[a] | 212.0[c] |
| 3 | Oval | 84.25[b] | 192.7[c] | 212.5[c] |
| 4 | Gavarayya | 83.68[b] | 193.8[b] | 205.8[a] |
| 5 | PKM-1 | 82.20[c] | 186.4[d] | 201.7[d] |
| 6 | Local | 75.50[d] | 179.5[e] | 188.3[e] |

**Table 9d.Pollen production per anther in sapota varieties**

| Sl.No. | Variety | Number of pollen grains per anther |
|---|---|---|
| 1 | Co-2 | 2655.90[b] |
| 2 | Cricket Ball | 2871.60[a] |
| 3 | Oval | 2381.00[c] |
| 4 | Gavarayya | 2331.90[c] |
| 5 | PKM-1 | 1796.20[d] |
| 6 | Local | 1261.60[e] |

Values with similar superscript letter did not differ significantly

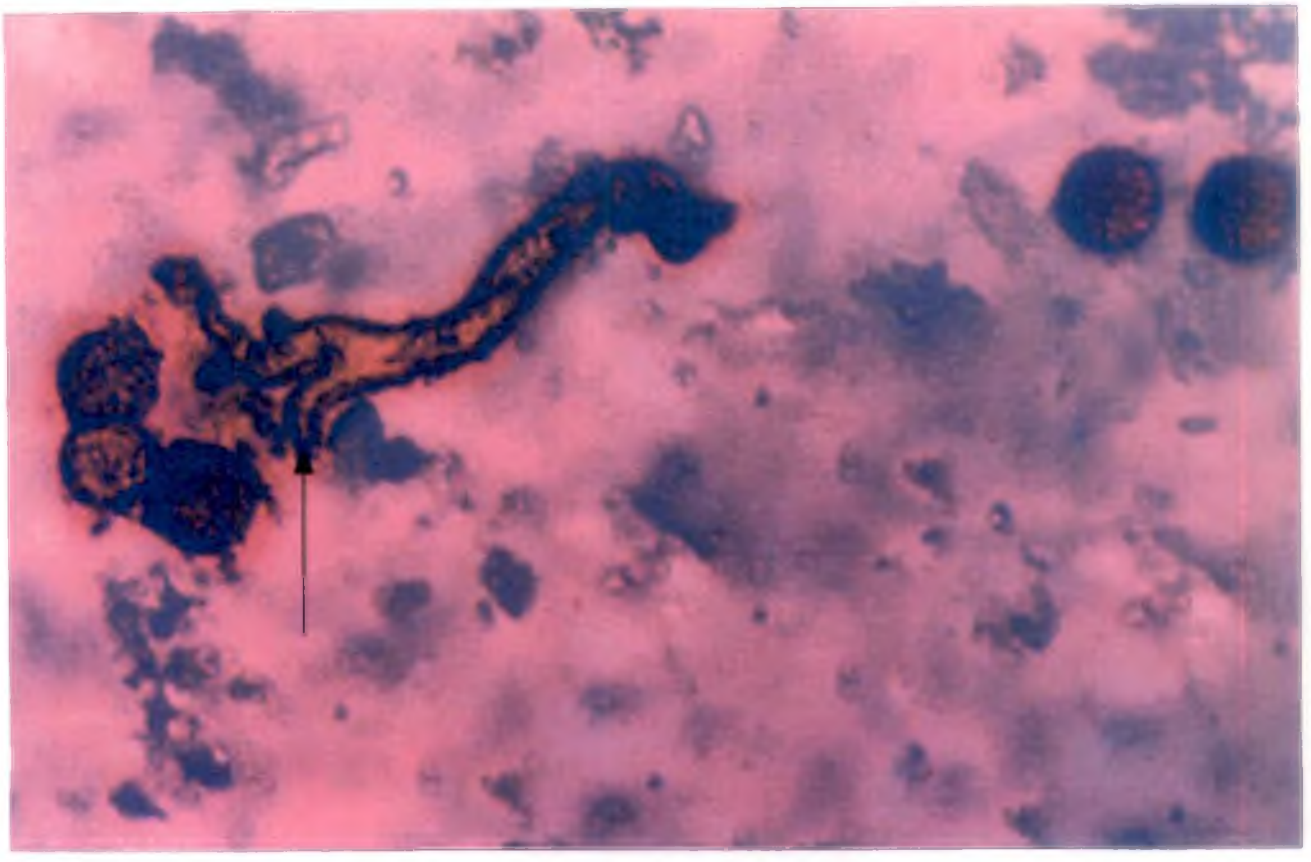


Plate : 5. Apex distorted pollen tube growth of sapota (x 10 X)

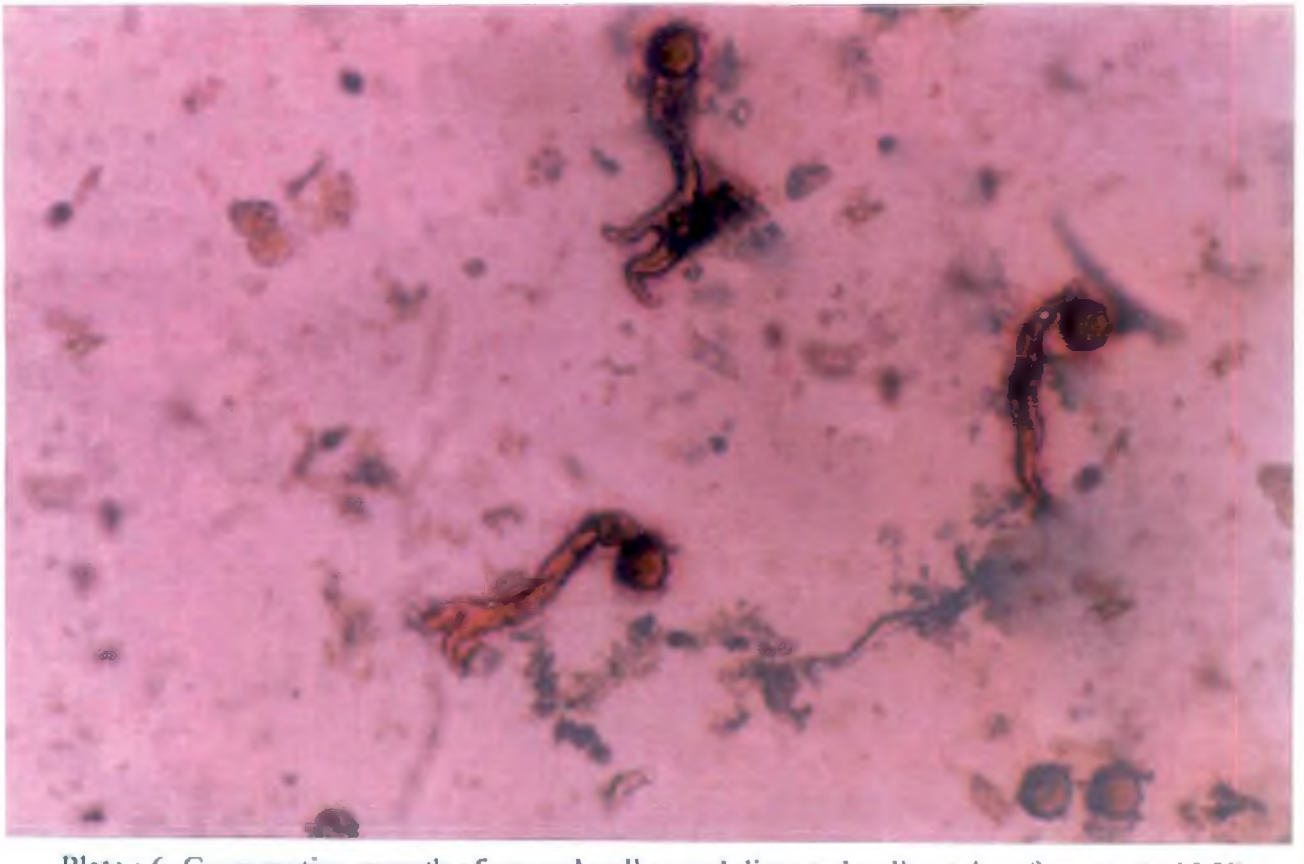


Plate : 6. Comparative growth of normal pollen and distorted pollen tube of sapota (x 10 X)

**Table 9e. Pollen storage**

| Sl. No. | Treatments | Pollen viability (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Days after storage | | | | | |
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| 1 | Keeping over calcium chloride in desiccator at room temperature | 78.50[b] | 76.79[b] | 70.92[b] | 68.23[b] | 65.50[b] | 60.77[b] |
| 2 | Keeping in refrigerator at 4°C | 83.80[a] | 80.79[a] | 78.64[a] | 78.12[a] | 76.50[a] | 76.30[a] |
| 3 | Keeping over calcium chloride in desiccator under refrigerator at 4°C | 76.96[c] | 64.95[d] | 55.20[c] | 50.50[c] | 40.22[c] | 35.85[c] |
| 4 | Keeping at room temperature | 79.50[b] | 70.80[c] | 50.60[d] | 43.22[d] | 39.50[d] | 30.70[d] |

**Table 9f. Rate of *in vitro* pollen germination in sapota**

| Sl.No. | Hours after incubation | Germination percentage | Pollen tube length (Micrometer) |
|---|---|---|---|
| 1 | 1 | 0.0 | 0.0 |
| 2 | 2 | 0.0 | 0.0 |
| 3 | 3 | 0.0 | 0.0 |
| 4 | 4 | 3.5 | 78.70 |
| 5 | 5 | 16.5 | 110.40 |
| 6 | 6 | 50.4 | 140.20 |
| 7 | 7 | 71.3 | 163.30 |
| 8 | 8 | 80.3 | 184.50 |
| 9 | 9 | 87.0 | 184.50 |
| 10 | 10 | 87.5 | 184.60 |
| 11 | 11 | 87.5 | 184.60 |
| 12 | 12 | 87.5 | 184.60 |

## 4.4.FLOWER BUD DROP

Flower bud drop occurred at regular interval at each stage of flower bud development. Maximum flower bud drop occurred at stage 4 followed by stage 5 and maximum flower bud drop occurred in the variety Oval (24.%) followed by Cricket Ball and Gavarayya (22.0 %, each). Minimum flower bud drop was recorded in Local variety (16.0%)(Table 10 and Plate 7).

## 4.5.FRUIT SET

Fruit set was maximum in the variety PKM-1 (41.25%) followed by Local variety (31.75%). Oval recorded minimum number of fruit set (19.50%)(Table 13 a).

### 4.5.1.Variation in fruit set in different directions of tree

Maximum number of fruit set occurred in northern direction of tree (Table 13 b). In the northern side of the tree, maximum fruit set of 70 per cent was recorded in the variety PKM-1 followed by Co-2 (40%). In all other directions the fruit set percentage varied from 8 to 20 in all these six varieties.

### 4.5.2.Days taken from pollination to fruit set

Number of days taken from pollination to fruit set was minimum in the variety PKM-1 followed by Local variety and Co-2 variety. The varieties Cricket Ball and Oval took more number of days from pollination to fruit set (Table 11 and Plate 9&10).

## 4.6.FRUIT DROP

Maximum fruit drop occurred in Cricket Ball (86.1%) followed by Gavarayya (85.5%) and Local (84.6%)varieties. Minimum fruit drop was recorded in the variety Co-2 (79.4%). Maximum fruits retained were observed in the variety Local (17.9%) followed by Co-2 (20.2 %). Per cent fruit retained was minimum in Cricket Ball (13.93%)(Table 15 and Plate 8). Maximum fruit drop percentage occurred in first and second fortnight

**Table 10. Extent of flower bud drop in sapota varieties**

| No. of flowers observed | Variety | Number of flowers dropped | | | | | | | Flower drop percentage | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stages | | | | | | | Stages | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 50 | Co-2 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 6 | 2 | 2 | 2 | 18 |
| | Cricket Ball | 1 | 1 | 1 | 4 | 2 | 1 | 1 | 2 | 2 | 2 | 8 | 4 | 2 | 2 | 22 |
| | Oval | 1 | 1 | 1 | 4 | 2 | 2 | 1 | 2 | 2 | 2 | 8 | 4 | 4 | 2 | 24 |
| | Gavarayya | 1 | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | 6 | 4 | 4 | 2 | 22 |
| | PKM-1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 4 | 4 | 4 | 2 | 2 | 2 | 20 |
| | Local | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 16 |

**Table 11.Duration from pollination to fruit set**

| Sl.No. | Variety | Days from pollination to fruit set |
|---|---|---|
| 1 | Co-2 | $7.7^{c}$ |
| 2 | Cricket Ball | $10.2^{a}$ |
| 3 | Oval | $9.2^{b}$ |
| 4 | Gavarayya | $8.4b^{c}$ |
| 5 | PKM-1 | $7.0^{c}$ |
| 6 | Local | $7.4^{c}$ |

Values with similar superscript letter did not differ significantly

**Table 12.Intensity of fruit drop**

| Variety | Duration | Fruit drop percentage | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days after fruit set | | | | | | | | | | |
| | | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 | Total |
| Co-2 | East | 41.9 | 21.9 | 3.10 | 1.9 | 1.8 | 2.0 | 1.6 | 1.9 | 1.7 | 2.0 | 79.7 |
| | West | 30.5 | 25.3 | 4.60 | 4.5 | 4.0 | 4.0 | 3.5 | 3.0 | 3.0 | 3.0 | 85.6 |
| | North | 28.5 | 26.5 | 4.50 | 4.0 | 4.0 | 3.5 | 3.5 | 3.0 | 3.0 | 2.9 | 83.4 |
| | South | 22.6 | 18.5 | 4.40 | 4.5 | 4.0 | 3.5 | 3.0 | 3.0 | 2.9 | 2.6 | 68.9 |
| | Mean | | | | | | | | | | | 79.4 |
| Cricket Ball | East | 40.5 | 35.5 | 3.0 | 3.5 | 2.5 | 2.0 | 2.0 | 1.9 | 1.8 | 1.5 | 94.2 |
| | West | 30.8 | 16.8 | 4.8 | 5.0 | 4.5 | 4.5 | 4.0 | 3.5 | 3.7 | 3.0 | 80.6 |
| | North | 30.6 | 26.2 | 4.0 | 4.0 | 3.8 | 3.8 | 3.7 | 3.6 | 3.5 | 3.3 | 86.4 |
| | South | 20.4 | 21.5 | 5.2 | 6.0 | 5.5 | 6.1 | 5.5 | 5.0 | 4.5 | 3.5 | 83.2 |
| | Mean | | | | | | | | | | | 86.1 |
| Oval | East | 23.7 | 23.8 | 4.4 | 4.0 | 4.5 | 4.0 | 3.5 | 3.5 | 3.5 | 3.5 | 78.3 |
| | West | 23.0 | 24.0 | 5.0 | 5.1 | 4.8 | 4.7 | 5.0 | 4.5 | 3.5 | 3.0 | 81.7 |
| | North | 38.1 | 32.6 | 3.0 | 3.0 | 2.5 | 3.5 | 3.0 | 3.5 | 3.0 | 3.0 | 95.2 |
| | South | 22.7 | 24.8 | 5.0 | 3.0 | 4.0 | 3.5 | 3.0 | 4.0 | 3.0 | 3.3 | 76.3 |
| | Mean | | | | | | | | | | | 82.9 |
| Gavarayya | East | 32.2 | 30.8 | 4.0 | 4.5 | 4.3 | 3.5 | 3.0 | 3.3 | 3.5 | 3.3 | 92.3 |
| | West | 32.0 | 30.5 | 3.5 | 3.6 | 3.5 | 3.4 | 3.0 | 3.0 | 2.0 | 2.0 | 88.7 |
| | North | 30.6 | 34.5 | 3.5 | 3.4 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | 2.5 | 89.1 |
| | South | 20.5 | 15.4 | 5.0 | 5.0 | 4.4 | 4.5 | 4.7 | 4.5 | 4.0 | 4.0 | 72.0 |
| | Mean | | | | | | | | | | | 85.5 |
| PKM-1 | East | 21.6 | 20.5 | 4.5 | 4.4 | 4.0 | 4.0 | 3.8 | 4.0 | 3.5 | 3.7 | 74.0 |
| | West | 28.5 | 28.6 | 4.5 | 4.0 | 3.3 | 3.5 | 3.8 | 3.6 | 3.5 | 3.8 | 74.7 |
| | North | 35.0 | 30.3 | 3.5 | 4.0 | 5.0 | 5.5 | 4.0 | 3.2 | 2.5 | 3.0 | 90.5 |
| | South | 30.0 | 26.5 | 4.0 | 4.5 | 6.0 | 7.0 | 4.5 | 4.0 | 3.5 | 3.0 | 93.0 |
| | Mean | | | | | | | | | | | 83.1 |
| Local | East | 28.5 | 27.5 | 3.5 | 3.6 | 3.8 | 4.0 | 4.2 | 3.3 | 3.0 | 3.0 | 81.4 |
| | West | 27.0 | 27.5 | 4.5 | 4.4 | 4.0 | 4.6 | 4.5 | 4.4 | 4.0 | 3.3 | 88.2 |
| | North | 30.0 | 25.0 | 5.7 | 4.3 | 4.5 | 3.5 | 4.0 | 4.0 | 4.0 | 3.9 | 87.9 |
| | South | 28.0 | 26.4 | 3.5 | 4.0 | 3.4 | 3.2 | 3.1 | 3.2 | 3.0 | 3.0 | 70.9 |
| | Mean | | | | | | | | | | | 82.1 |
| | | 1.23 | 1.16 | 0.98 | 0.75 | 0.79 | 0.76 | 0.91 | 0.88 | 0.86 | 0.24 | 2.83 |


Plate : 7. Different stages of flower bud drop in sapota

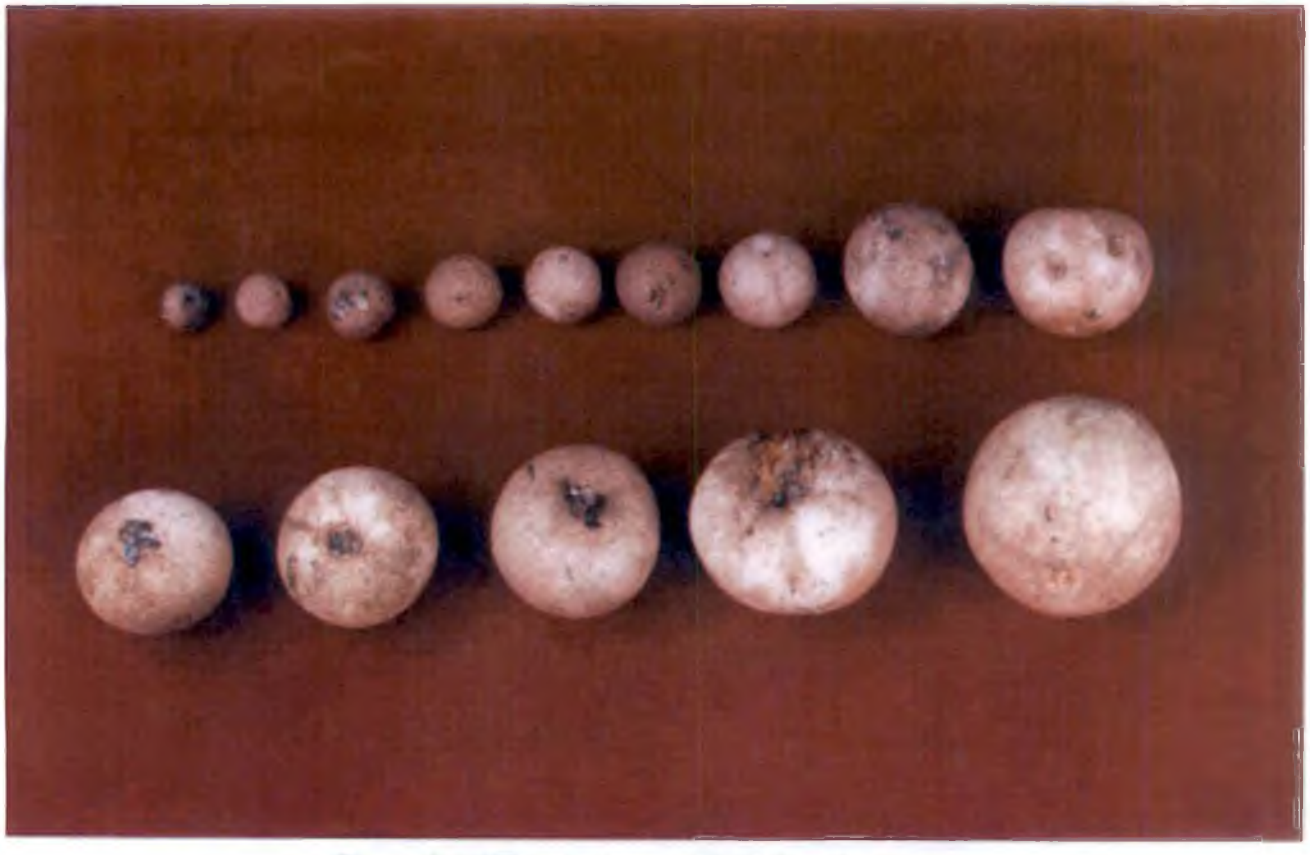


Plate : 8. Different stages of fruit drop in sapota

**Table 13a. Fruit set in sapota varieties**

| Sl.No. | Number of flowers observed | Variety | Fruit set percentage |
|---|---|---|---|
| 1 | 600 | Co-2 | 27.25[c] |
| 2 | | Cricket Ball | 22.75[d] |
| 3 | | Oval | 19.50[e] |
| 4 | | Gavarayya | 25.00[e] |
| 5 | | PKM-1 | 41.25[a] |
| 6 | | Local | 31.75[b] |

Values with similar superscript letter did not differ significantly

**Table 13b.Variation in fruit set in different directions of sapota tree**

| Sl.No. | Variety | Fruit set (%) | | | |
|---|---|---|---|---|---|
| | | East | West | North | South |
| 1 | Co-2 | 12 | 15 | 40 | 18 |
| 2 | Cricket Ball | 11 | 16 | 35 | 8 |
| 3 | Oval | 10 | 8 | 30 | 10 |
| 4 | Gavarayya | 20 | 15 | 35 | 10 |
| 5 | PKM-1 | 20 | 10 | 70 | 20 |
| 6 | Local | 12 | 15 | 30 | 10 |
| CD(0.05) | | 0.19 | 0.19 | 15.88 | 0.17 |

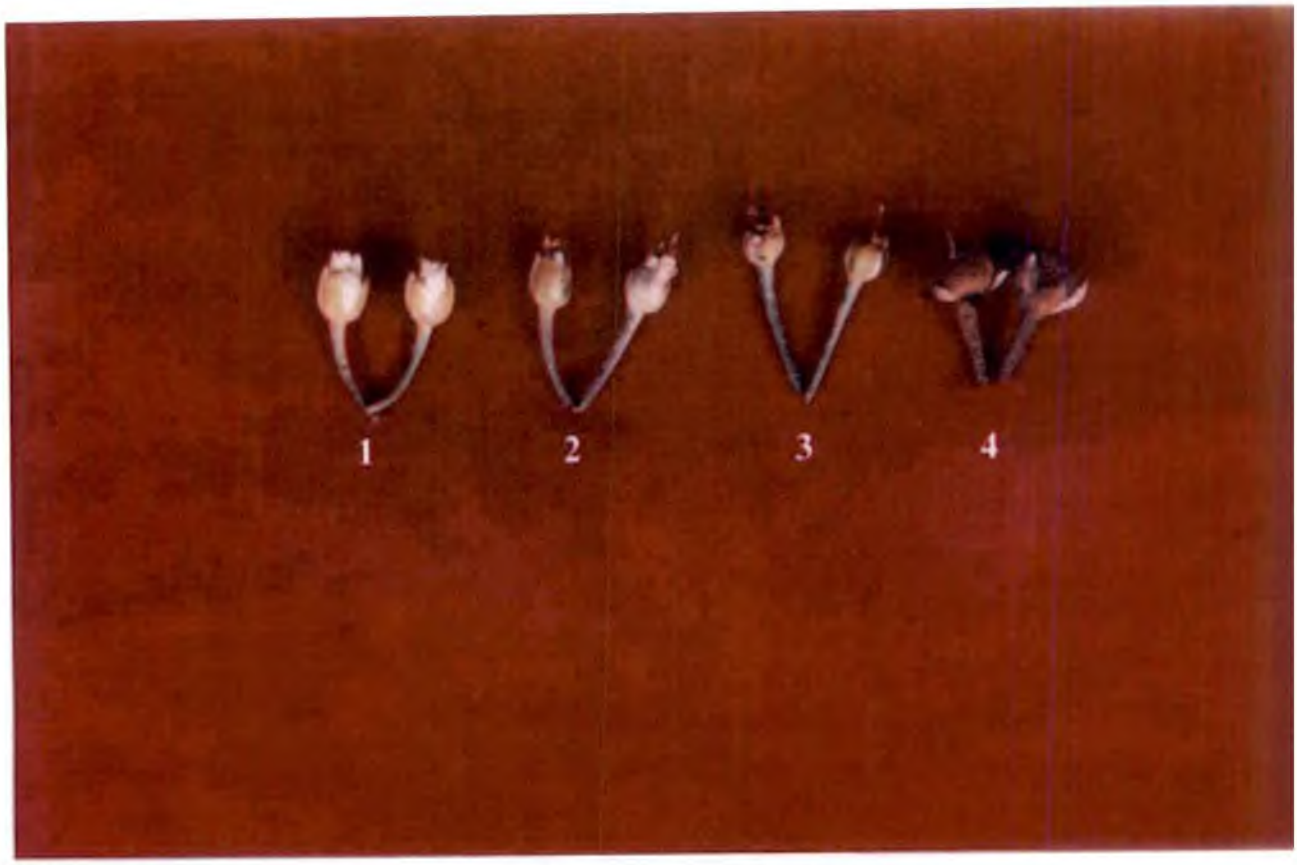



Plate : 9. Major stages of fruit set in sapota

1. Before anthesis
2. After anthesis
3. Swollen ovary
4. Fruit set

Plate : 10. Fruit set in basipetal opened flowers


Plate : 9. Major stages of fruit set in sapota

1. Before anthesis
2. After anthesis
3. Swollen ovary
4. Fruit set

Plate : 10. Fruit set in basipetal opened flowers

after fruit set in all the six varieties under study. Maximum fruit drop percentage occurred in western and northern side of trees in Co-2, Oval, PKM-1 and Local. In Cricket Ball and Gavarayya fruit drop was maximum in east and north direction of trees (Table 12).

## 4.7.PHYSICAL CHANGES DURING FRUIT DEVELOPMENT

### 4.7.1.Fruit weight

Weight of the fruit gradually increased in all the six varieties from fruit set up to 75 days after fruit set. There was sudden increase in fruit weight of the varieties Gavarayya and PKM-1 from 90 days after fruit set. Whereas, in varieties Cricket Ball, Co-2 and Oval the sudden increase in fruit weight occurred at 105 days after fruit set. In the variety Local gradual increase in the weight of the fruit was noticed. Maximum fruit weight was recorded in Cricket Ball (188.80 g) followed by Oval (155.85 g) and minimum fruit weight was recorded in Local (35.40 g). The changes in fruit weight over the period of fruit development in all the six varieties were given in Table 13a and Fig.1 (Plate11 A-F).

### 4.7.2.Fruit girth

Girth of the fruit increased gradually from fruit set to maturity. Maximum fruit girth was recorded in Cricket Ball (17.4 cm) followed by Oval (16.50 cm) and Co-2 (16.42 cm). Fruit girth was minimum in Local (4.85 cm). The changes in fruit girth over the period of fruit development in all the six varieties were given in Table 14 and Fig 2( Plate11 A-F).

### 4.7.3.Fruit length

Fruit length was gradually increased from fruit set to harvest maturity in all the six varieties under study (Table 14c and Fig.3). Varieties Oval and Gavarayya recorded a sudden increase in length after 135 days after fruit set. Maximum fruit length was recorded in variety Oval (12.50 cm) followed by Gavarayya (10.50 cm). Minimum fruit length was recorded in Co-2 (5.25 cm) and Local (5.4 cm) (Plate11 A-F).

**Table 14a.Changes in fruit weight during fruit development**

| Variety | Fruit weight (g) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 2.29 | 2.43 | 3.50 | 4.60 | 6.70 | 9.40 | 24.90 | 48.55 | 75.70 | 116.40 |
| Cricket Ball | 3.51 | 7.50 | 8.10 | 8.40 | 8.80 | 9.30 | 47.60 | 120.50 | 164.00 | 188.80 |
| Oval | 2.43 | 7.70 | 8.60 | 8.80 | 9.50 | 11.40 | 34.50 | 89.70 | 135.60 | 155.85 |
| Gavarayya | 1.29 | 2.40 | 3.60 | 6.60 | 9.80 | 21.50 | 48.70 | 73.50 | 110.40 | 124.50 |
| PKM-1 | 0.89 | 1.35 | 2.45 | 3.90 | 9.80 | 20.00 | 30.50 | 40.40 | 48.10 | 58.60 |
| Local | 0.35 | 0.95 | 1.50 | 2.30 | 3.80 | 11.00 | 13.60 | 14.50 | 24.80 | 35.40 |
| CD (0.05) | 0.16 | 0.11 | 0.11 | 0.12 | 0.17 | 1.23 | 1.28 | 2.25 | 5.39 | 8.10 |

**Table 14b. Changes in fruit girth during fruit development**

| Variety | Fruit girth (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 4.40 | 5.10 | 7.50 | 8.20 | 9.21 | 10.30 | 11.20 | 12.60 | 14.20 | 16.42 |
| Cricket Ball | 4.86 | 5.40 | 7.90 | 8.80 | 9.18 | 10.01 | 12.60 | 14.10 | 16.50 | 17.40 |
| Oval | 4.85 | 5.80 | 7.80 | 8.85 | 9.45 | 10.67 | 10.80 | 12.75 | 14.35 | 16.50 |
| Gavarayya | 5.50 | 5.90 | 6.50 | 6.85 | 7.40 | 7.95 | 7.97 | 9.50 | 9.90 | 12.20 |
| PKM-1 | 3.10 | 3.40 | 3.70 | 4.76 | 5.20 | 6.38 | 7.90 | 8.60 | 8.80 | 10.25 |
| Local | 1.14 | 1.20 | 1.21 | 1.49 | 2.34 | 2.62 | 2.90 | 3.40 | 3.79 | 4.85 |
| CD(0.05) | 0.18 | 0.17 | 0.22 | 0.39 | 0.76 | 0.84 | 1.65 | 1.68 | 2.27 | 3.12 |

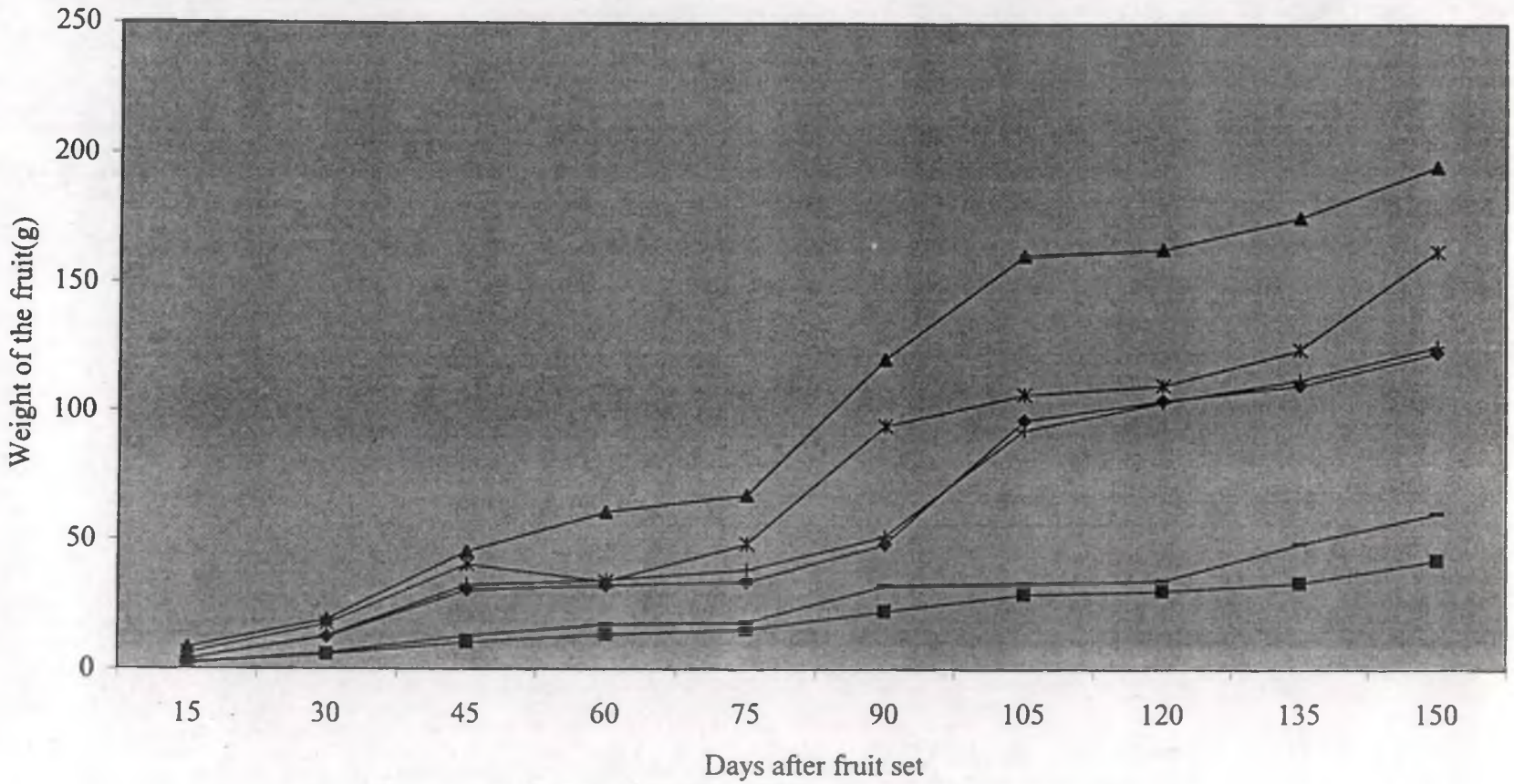



**Fig.1.Changes in fruit weight (g) during fruit development**

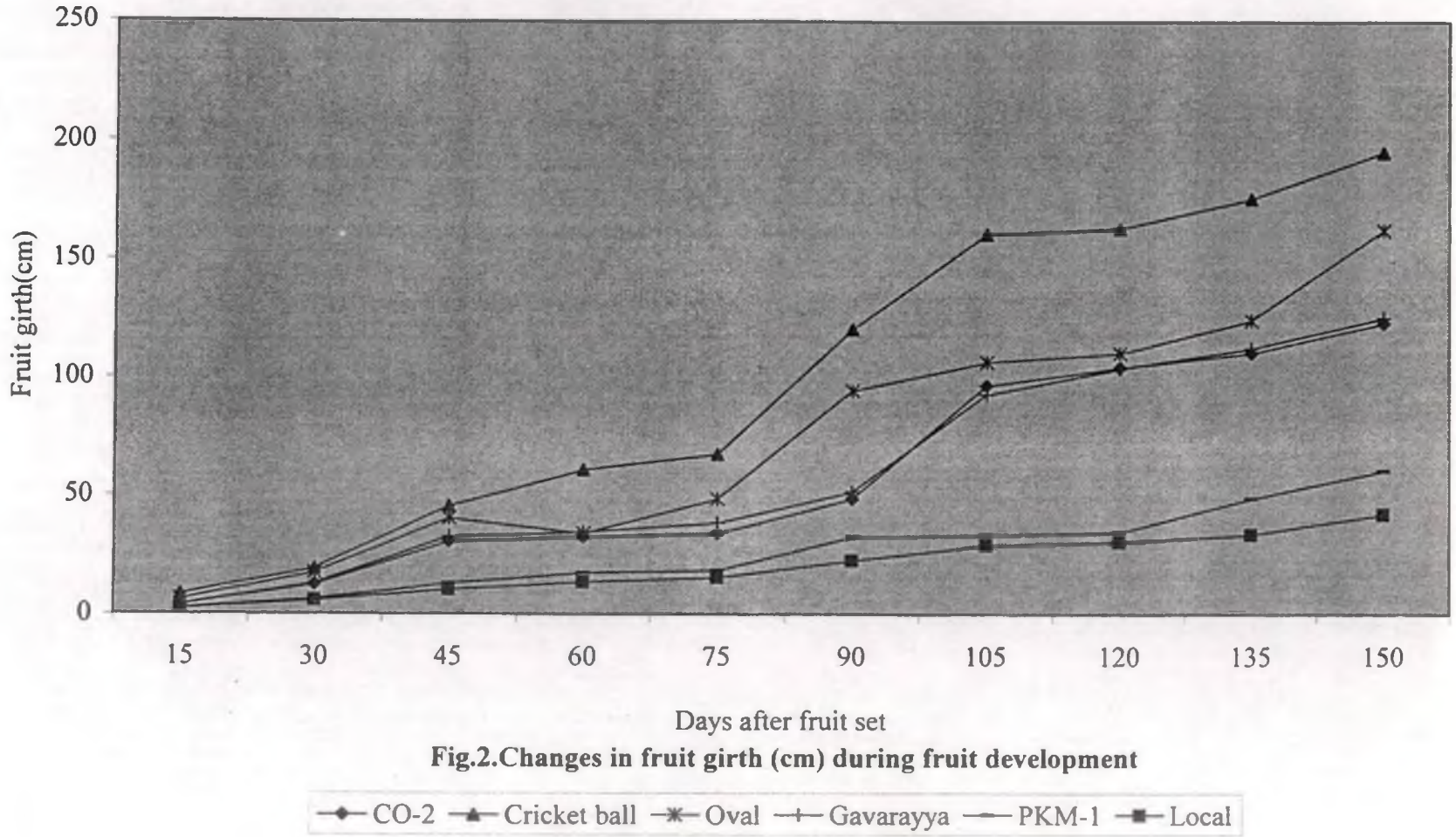
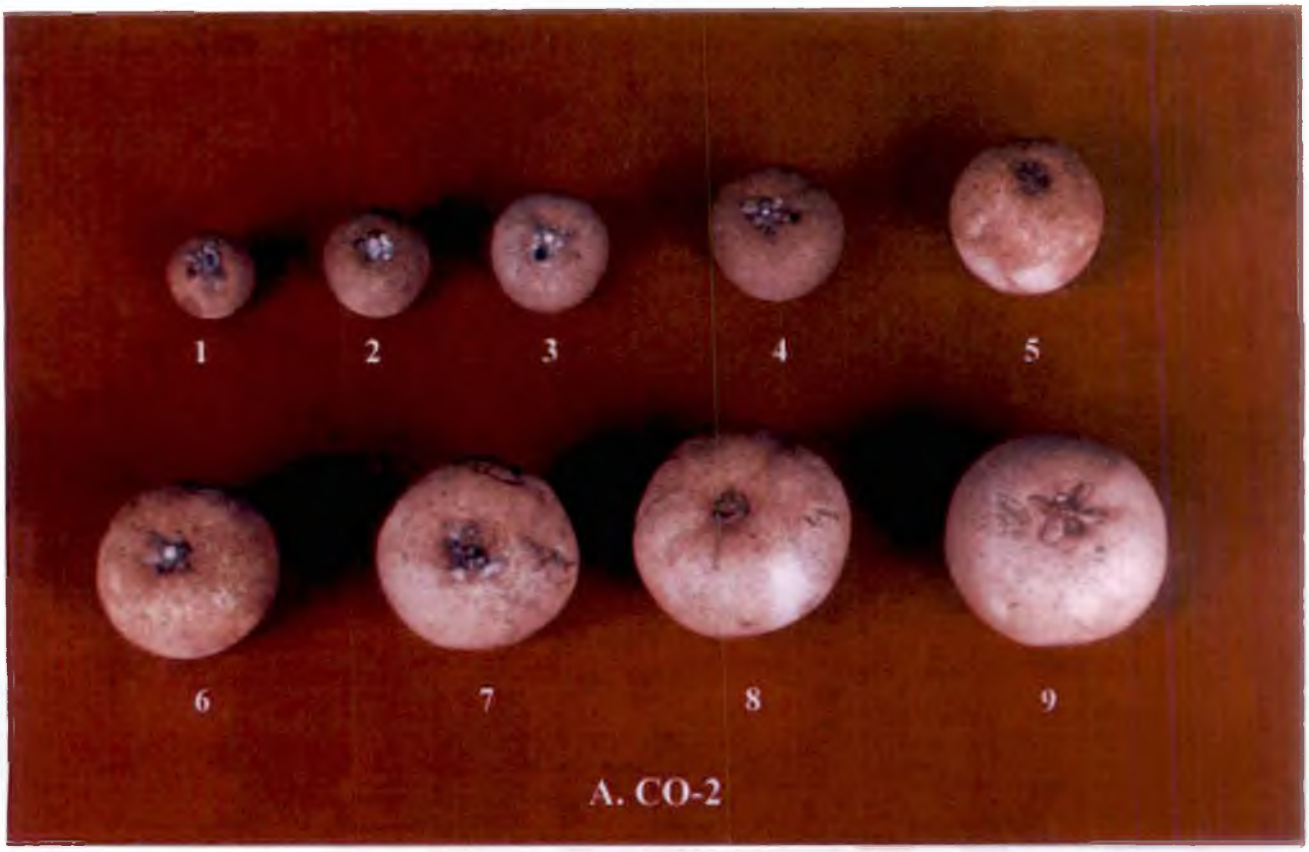



**Fig.2.Changes in fruit girth (cm) during fruit development**



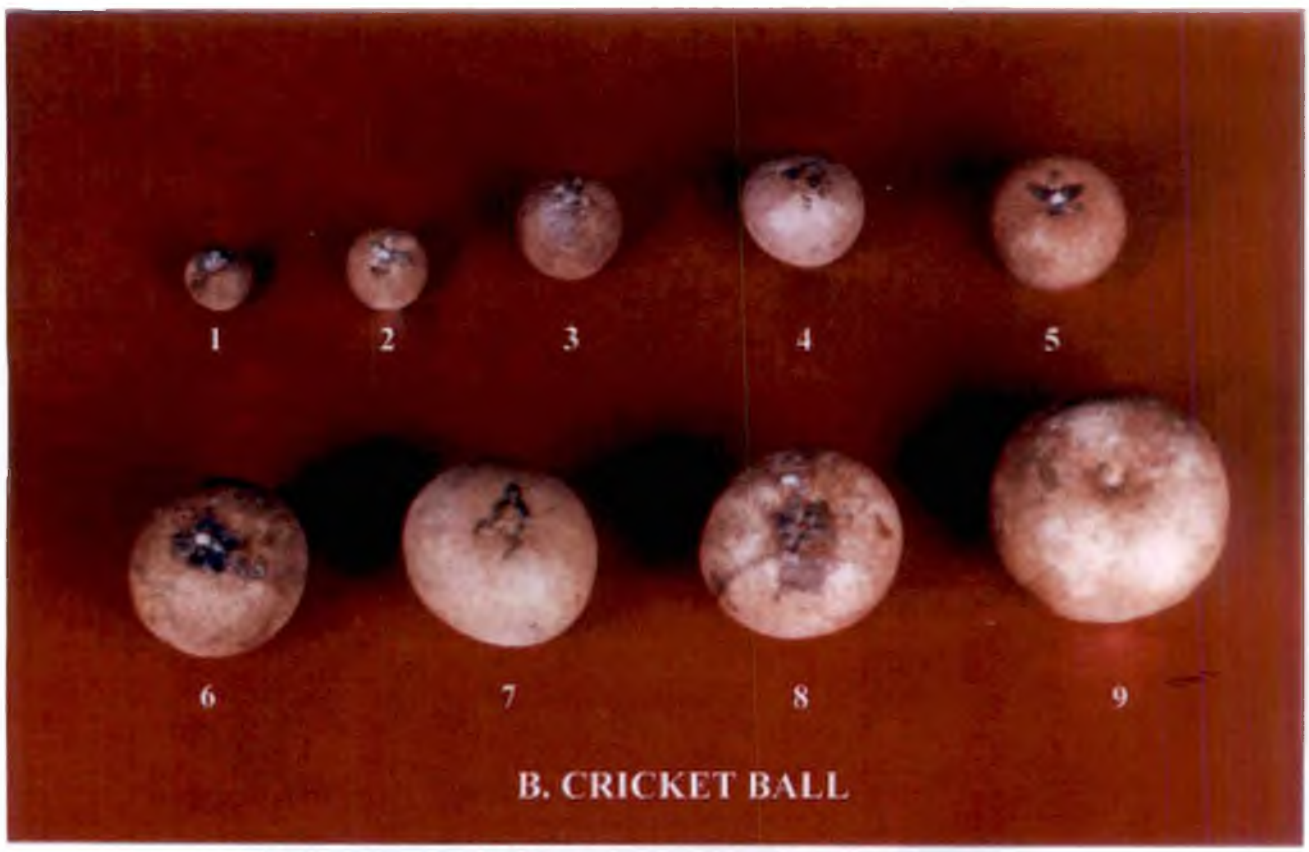
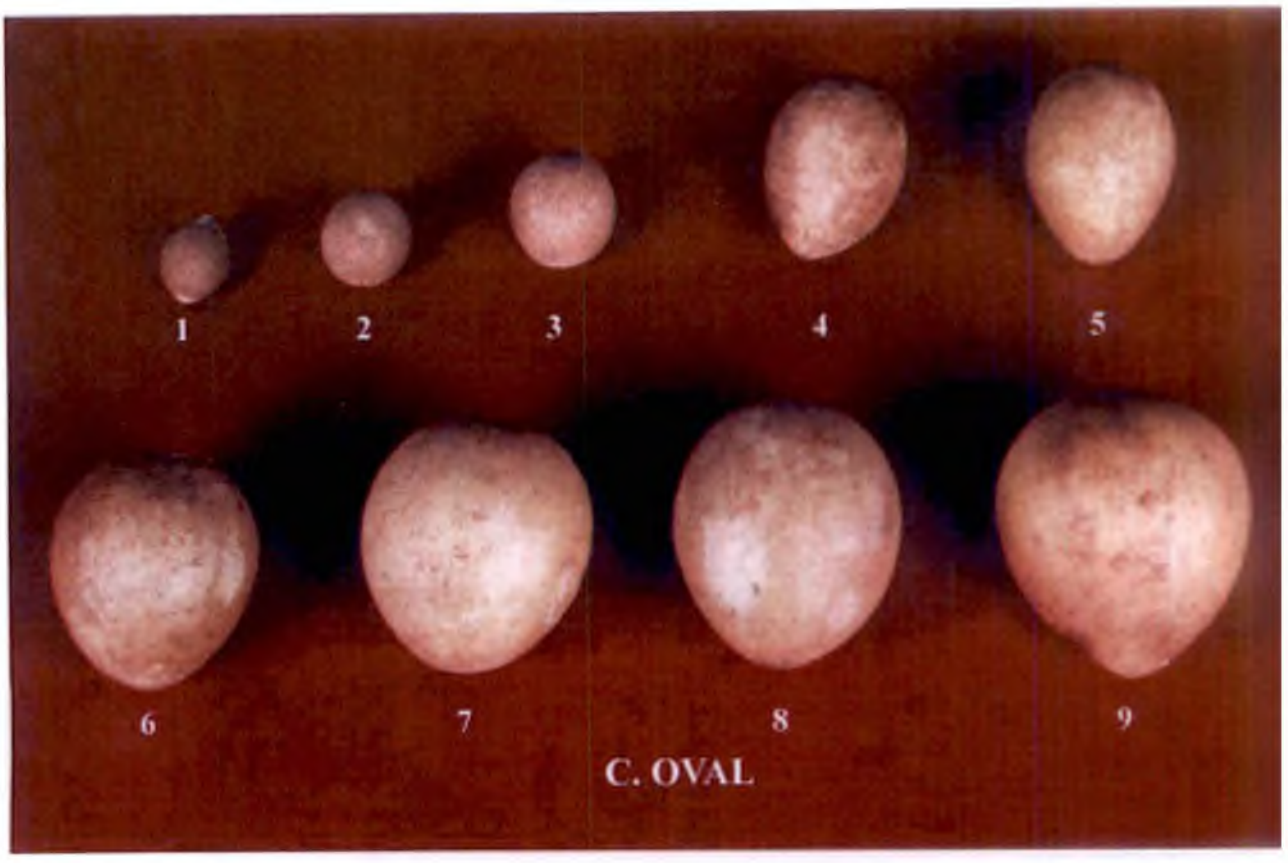




Plate : 11. Different stages of fruit development of sapota

A. Co-2 B.Cricket Ball



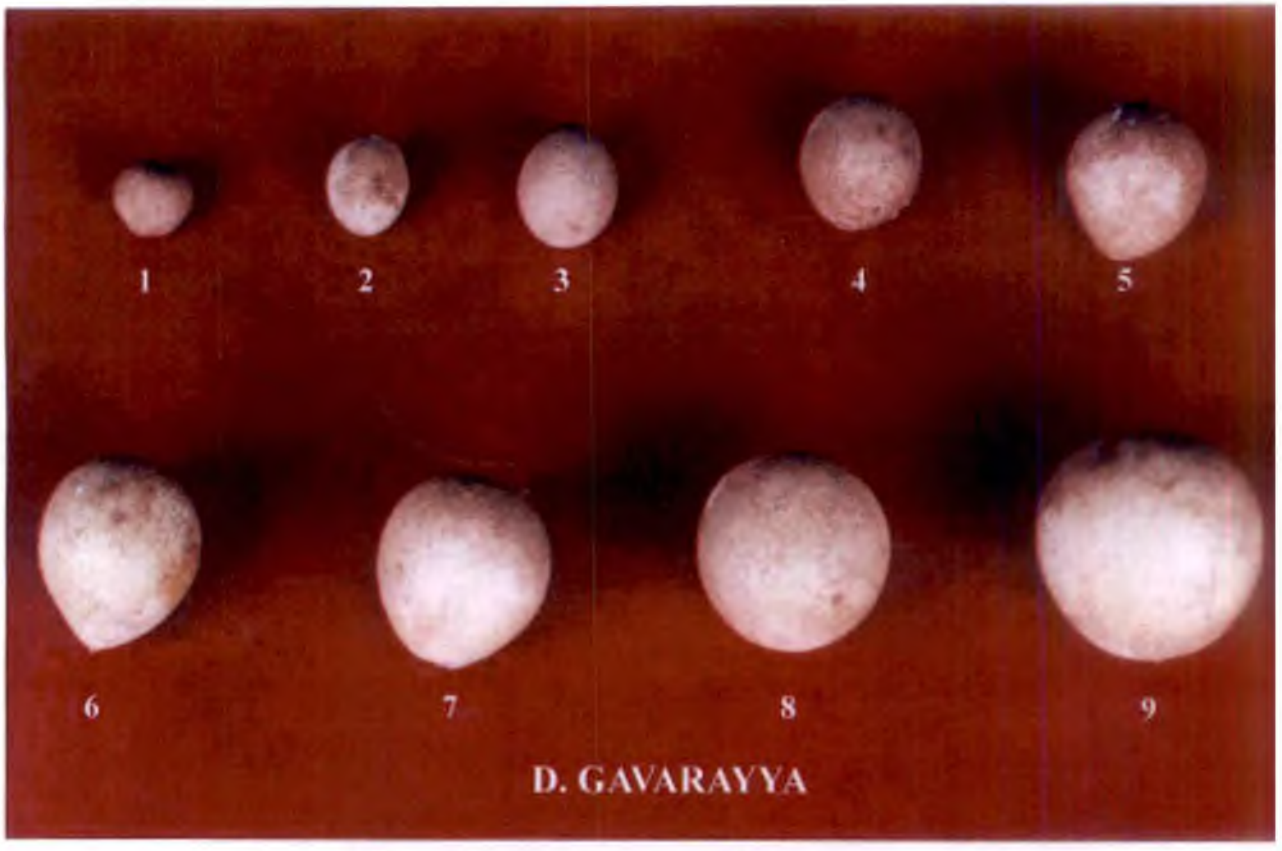
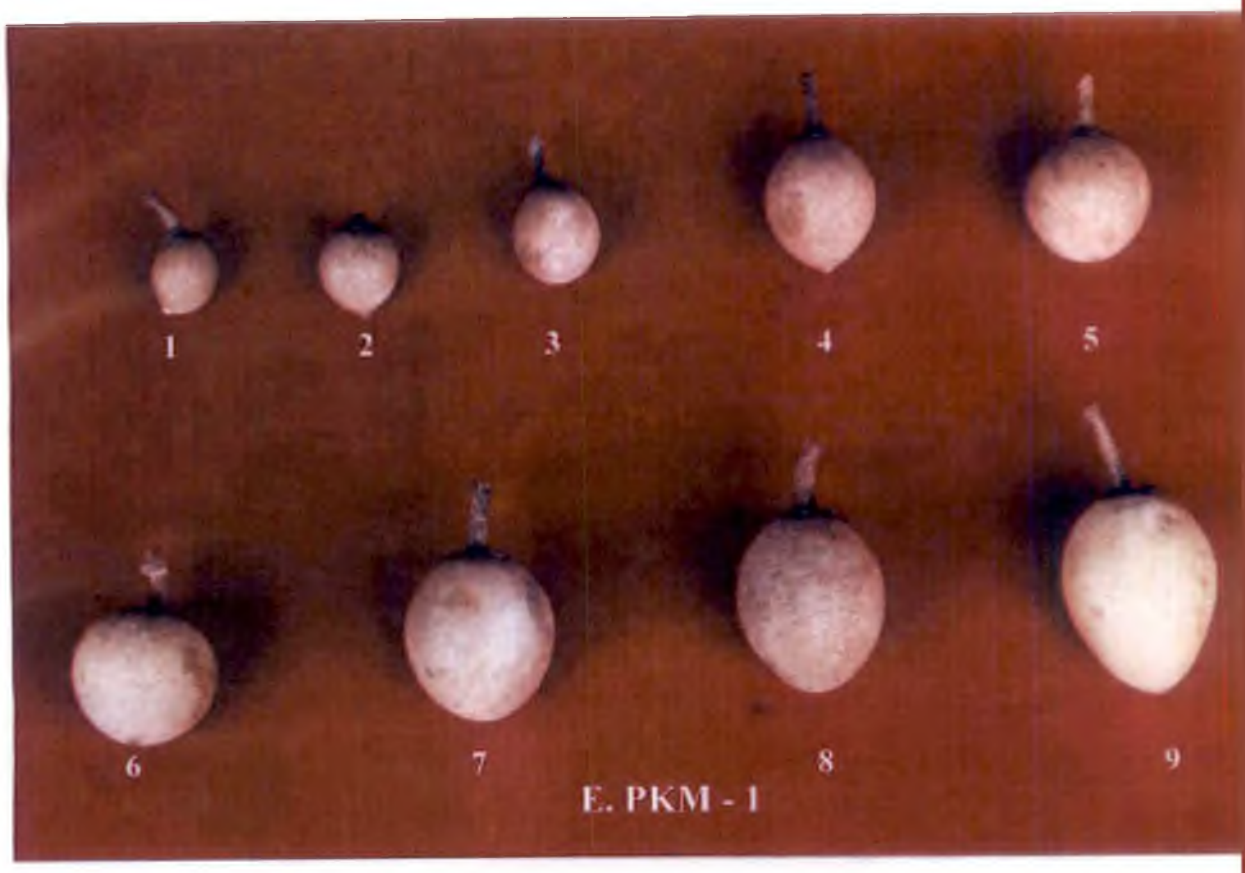




Plate : 11.(Contd.) Different stages of fruit development of sapota

C. OVAL D. GAVARAYYA



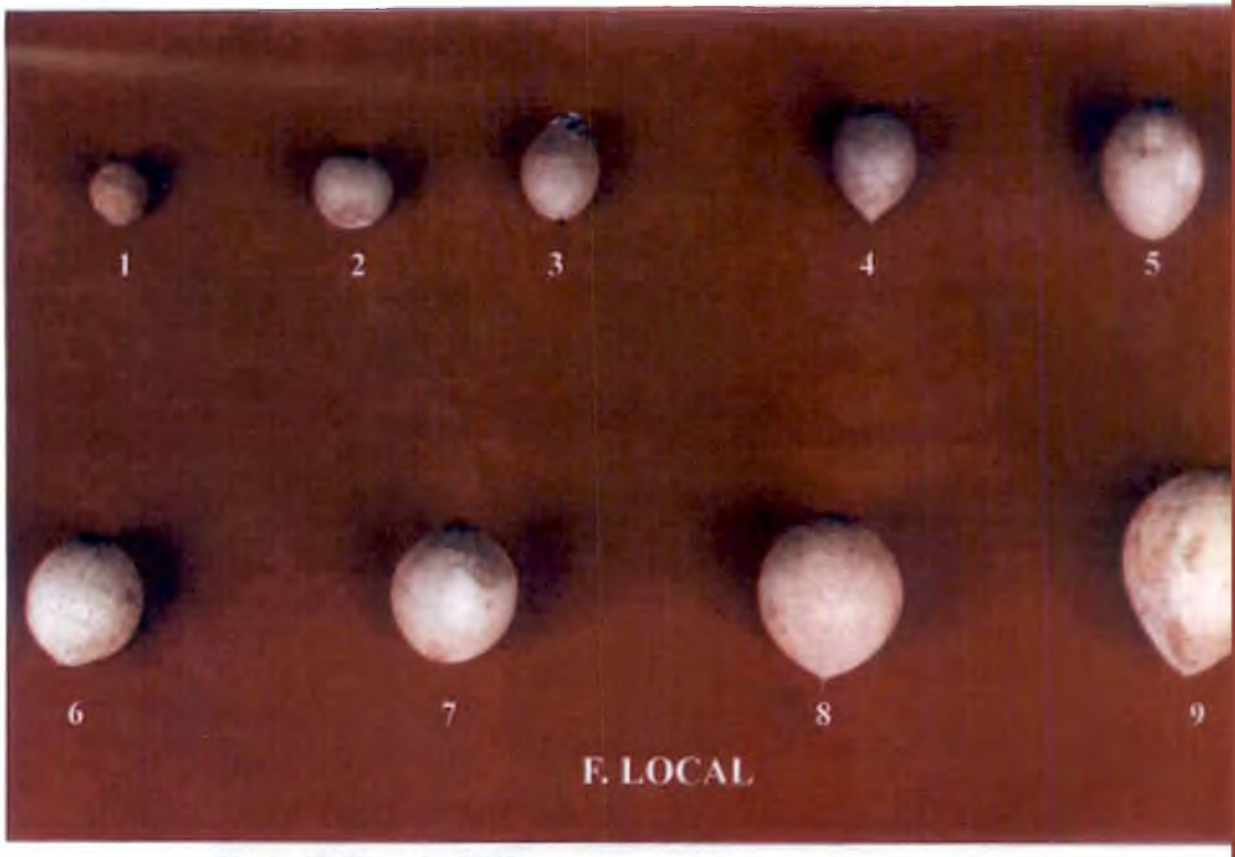




Plate : 11.(Contd.) Different stages of fruit development of sapota

E.PKM-1 F. Local

**4.7.4.Fruit volume**

Volume of the fruit had sudden increase from 75 days after fruit set in all the varieties except Co-2 and Gavarayya where it was 90 days after fruit set. Maximum volume of the fruit was recorded in the variety Cricket Ball (195.25 ml) followed by Oval (162.5 ml). Volume of the fruit was minimum in Local (42.20 ml). The changes in fruit volume at fortnight intervals after fruit set were given in Table 14d and Fig 4.

**4.7.5.Specific gravity**

Specific gravity of fruit is more at the initial days after fruit development (15-30 days after fruit set). Then it shows a declining trend and afterwards increased gradually with an increase at 90 –105 days after fruit set. Specific gravity of the fruit was maximum in Cricket Ball (0.99) followed by Gavarraya (0.97). Specific gravity was minimum in the variety Local (0.83). The changes in fruit specific gravity at fortnight intervals after fruit set were given in Table 14e.

**4.7.6.Pulp: seed ratio**

Changes in pulp: seed ratio of the varieties was shown in Table 14f. Pulp: seed ratio recorded from 60 $^{th}$ days after fruit set showed a gradual increase upto 150 days. A sudden increase in this character was noticed 75 days after fruit set in the variety Oval and 105 days after fruit set in the variety Gavarayya. Maximum pulp: seed ratio was recorded in Oval (94.53) followed by Co-2 (66.23). Pulp: seed ratio was minimum in Local variety (22.54).

**4.7.7.Seed length**

Maximum seed length was recorded in Cricket Ball (3.5 cm) followed by Oval (3.3 cm). Seed length was minimum in the variety Local (2.2 cm) and PKM-1 (2.5 cm) The changes in seed length per fruit at fortnight intervals after fruit set were given in Table 43g.

**Table 14c. Changes in fruit length during fruit development**

| Variety | Fruit length (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 1.80 | 2.20 | 3.10 | 3.30 | 3.41 | 3.50 | 3.56 | 3.65 | 4.26 | 5.25 |
| Cricket Ball | 2.29 | 2.31 | 3.23 | 3.72 | 4.09 | 4.56 | 4.69 | 5.13 | 5.27 | 6.55 |
| Oval | 2.31 | 4.65 | 5.25 | 5.45 | 6.25 | 6.26 | 7.26 | 8.80 | 8.82 | 12.50 |
| Gavarayya | 4.60 | 6.95 | 7.01 | 7.05 | 7.54 | 7.55 | 8.80 | 9.35 | 9.40 | 10.50 |
| PKM-1 | 3.25 | 3.75 | 4.95 | 5.00 | 5.35 | 5.88 | 5.94 | 6.05 | 6.90 | 7.47 |
| Local | 1.50 | 2.29 | 2.30 | 2.20 | 2.50 | 2.70 | 4.15 | 4.70 | 5.10 | 5.40 |
| CD (0.05) | 0.05 | 0.18 | 0.09 | 0.09 | 0.05 | 0.06 | 0.27 | 0.05 | 0.08 | 0.12 |

**Table 14d. Changes in fruit volume during fruit development**

| Variety | Fruit Volume (ml) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 4.0 | 12.5 | 30.6 | 32.5 | 33.9 | 48.5 | 96.5 | 104.4 | 110.5 | 123.2 |
| Cricket Ball | 8.5 | 19.2 | 45.5 | 60.8 | 67.4 | 120.5 | 160.8 | 163.4 | 175.9 | 195.3 |
| Oval | 6.4 | 17.5 | 40.4 | 33.9 | 48.5 | 94.4 | 106.6 | 110.4 | 124.4 | 162.5 |
| Gavarayya | 4.0 | 12.9 | 32.6 | 34.5 | 38.5 | 51.5 | 92.8 | 103.9 | 112.5 | 125.5 |
| PKM-1 | 2.5 | 6.4 | 12.9 | 17.5 | 18.5 | 32.5 | 33.4 | 34.5 | 48.8 | 60.5 |
| Local | 2.5 | 5.8 | 10.5 | 13.5 | 15.6 | 22.5 | 29.1 | 30.5 | 33.6 | 42.2 |
| CD(0.05) | 0.05 | 0.11 | 0.16 | 0.16 | 0.11 | 2.51 | 1.61 | 0.15 | 0.38 | 0.82 |

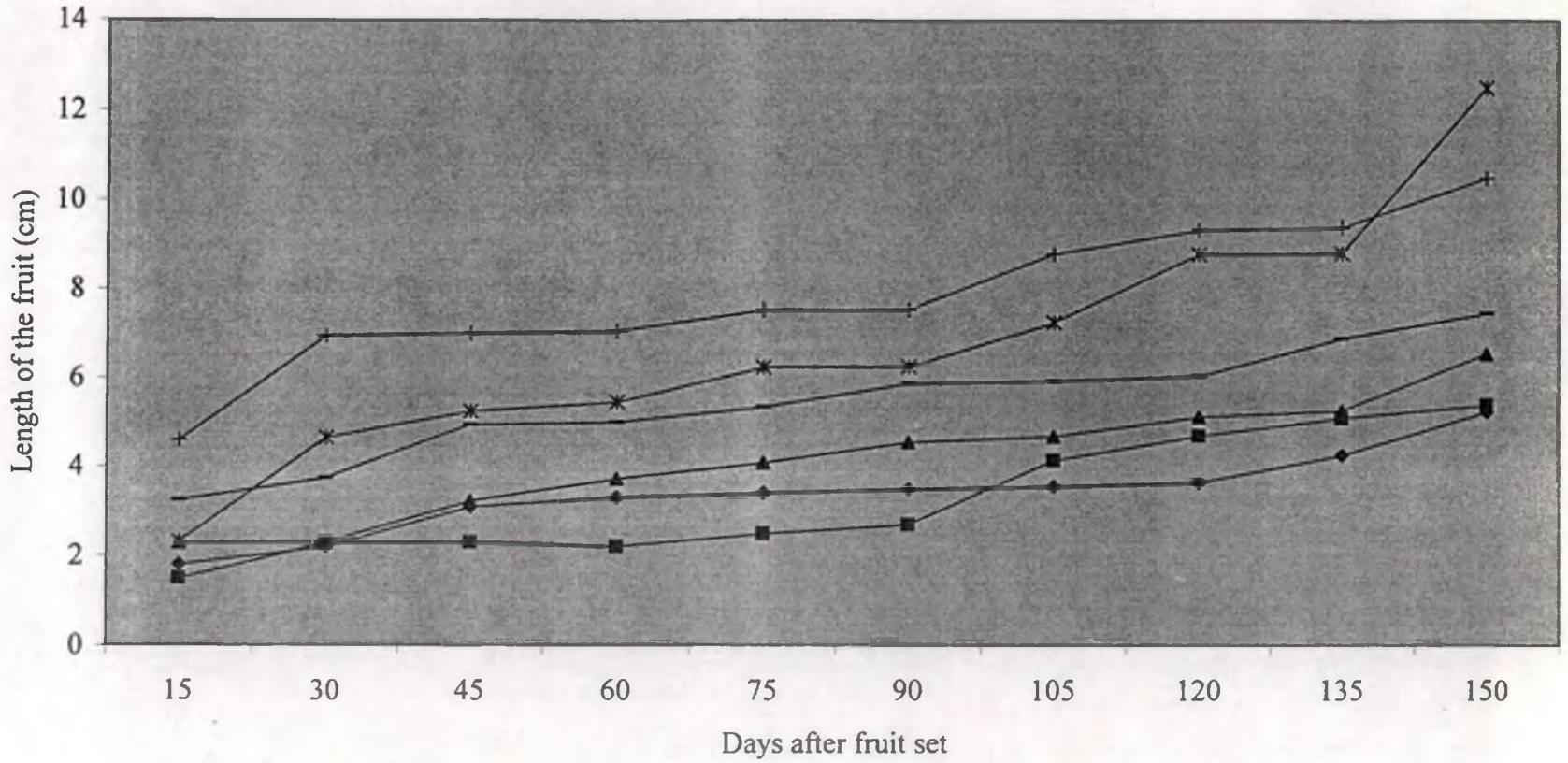



**Fig .3.Changes in fruit length (cm) during fruit development**

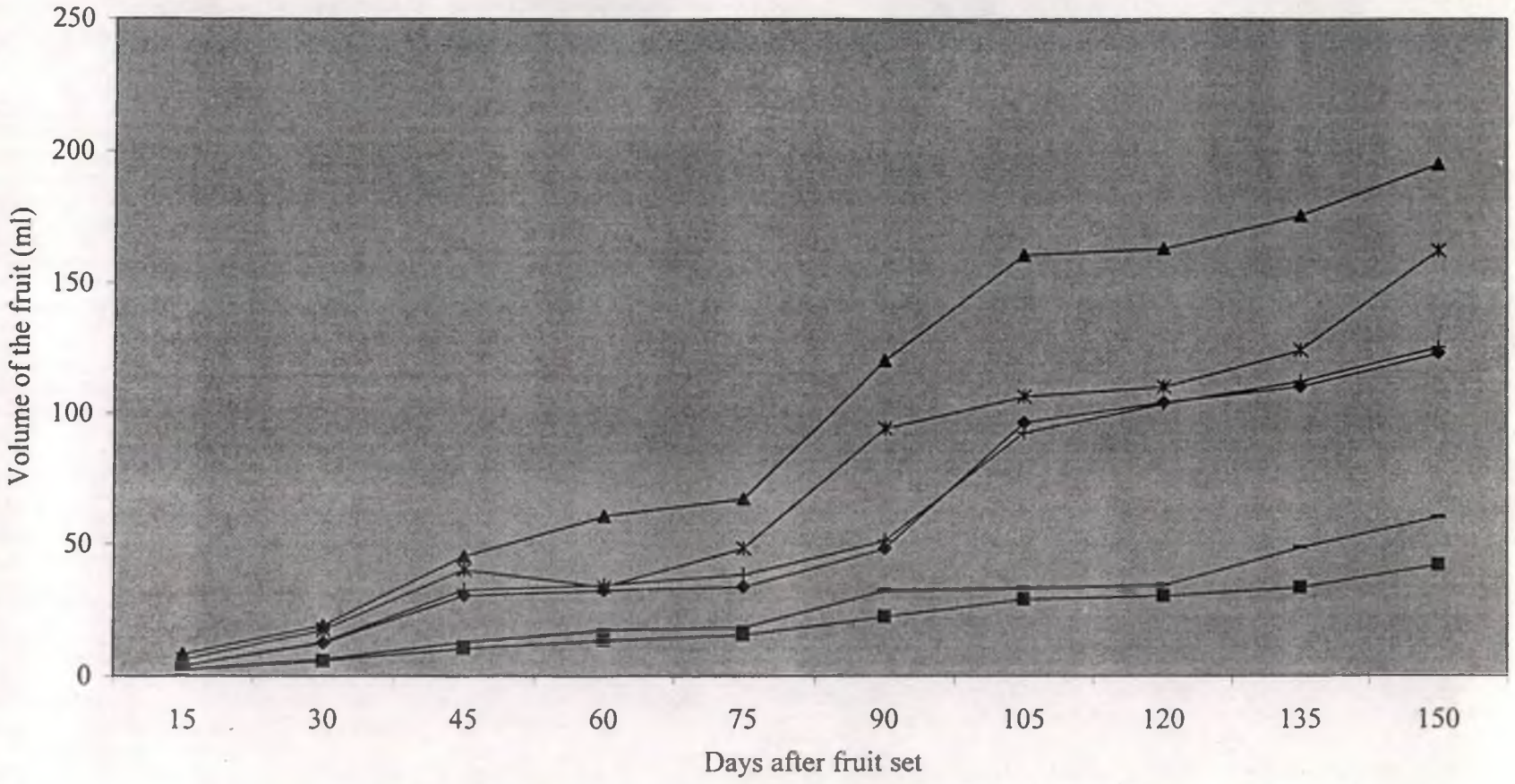



**Fig.4.Changes in fruit volume (ml) during fruit development**

**Table 14e. Changes in fruit specific gravity during fruit development**

| Variety | Specific gravity | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 0.57 | 0.14 | 0.14 | 0.15 | 0.19 | 0.19 | 0.26 | 0.47 | 0.69 | 0.95 |
| Cricket Ball | 0.41 | 0.39 | 0.15 | 0.15 | 0.14 | 0.18 | 0.29 | 0.74 | 0.93 | 0.99 |
| Oval | 0.38 | 0.44 | 0.21 | 0.26 | 0.19 | 0.12 | 0.32 | 0.81 | 0.89 | 0.96 |
| Gavarayya | 0.32 | 0.38 | 0.11 | 0.19 | 0.25 | 0.42 | 0.52 | 0.70 | 0.88 | 0.97 |
| PKM-1 | 0.36 | 0.41 | 0.19 | 0.23 | 0.53 | 0.62 | 0.71 | 0.81 | 0.89 | 0.92 |
| Local | 0.14 | 0.17 | 0.18 | 0.20 | 0.24 | 0.49 | 0.47 | 0.48 | 0.74 | 0.83 |
| CD(0.05) | 0.16 | 0.14 | 0.17 | 0.19 | 0.53 | 0.37 | 0.17 | 0.09 | 0.12 | 0.16 |

**Table 14f. Changes in pulp seed ratio during fruit development**

| Variety | Pulp :seed ratio | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | - | - | - | 22.26 | 26.40 | 30.50 | 33.46 | 41.50 | 55.10 | 66.23 |
| Cricket Ball | - | - | - | 17.50 | 25.54 | 30.60 | 31.50 | 37.48 | 40.44 | 55.65 |
| Oval | - | - | - | 26.63 | 31.50 | 52.50 | 57.45 | 60.33 | 80.50 | 94.53 |
| Gavarayya | - | - | - | 21.46 | 27.73 | 30.70 | 32.80 | 48.77 | 52.20 | 60.20 |
| PKM-1 | - | - | - | 12.80 | 13.64 | 17.75 | 18.00 | 18.55 | 21.55 | 26.86 |
| Local | - | - | - | 6.68 | 9.86 | 12.80 | 13.40 | 13.94 | 18.67 | 22.54 |
| CD(0.05) | | | | 0.08 | 1.52 | 2.41 | 2.21 | 1.29 | 2.18 | 3.13 |

**4.7.8.Seed breadth**

Maximum seed breadth was recorded in Oval (2.4 cm) followed by Cricket Ball (2.0 cm) and Gavarayya (2.0 cm). Minimum seed breadth was observed in Local variety (1.60 cm). The changes in seed breadth per fruit at fortnight intervals after fruit set were given in Table 14h.

**4.7.9.Seed weight per fruit**

Maximum seed weight per fruit was recorded in Cricket Ball (8.26 g) followed by Oval (5.04 g). Seed weight per fruit was minimum in Local (1.79 g). The changes in seed weight per fruit at fortnight intervals after fruit set were given in Table 14i.

**4.7.10.Number of seeds per fruit**

Maximum number of seeds per fruit was recorded in Cricket Ball (5.4) followed by Oval (3.6). Minimum number of seeds per fruit was recorded in Local variety (1.5) and PKM-1 (1.8). There were no changes in the number of seeds per fruit at fortnight intervals after fruit set Table 14j.

**4.7.11.Seed shape**

Seeds of Co-2 and Gavarayya were oval in shape and PKM-1 has short stout, oval seeds. Seeds of Cricket Ball were elongated with blunt end whereas seeds of Oval has slight curve at tip.

**4.7.12.Quality characters of sapota varieties**

Scruffness was high in variety Cricket Ball whereas Local and PKM-1 has less scruffness. In Co-2, Oval and Gavarayya moderate level of scruffness was observed. Skin is thin in PKM-1 and Local, whereas it is thick in Cricket Ball and Gavarayya. Flesh colour of Oval variety is reddish brown while other varieties possess light brown colour. Texture of flesh in Cricket Ball was highly gritty. Oval has slightly granular texture whereas, soft buttery, delicious texture was observed in PKM-1 and Local. Co-2 and PKM-1 are very sweeter in taste.

**Table 14g. Changes in seed length during fruit development**

| Variety | Seed length (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | - | - | - | 1.15 | 2.25 | 2.75 | 3.00 | 3.10 | 3.20 | 3.20 |
| Cricket Ball | - | - | - | 1.60 | 2.30 | 2.90 | 3.30 | 3.50 | 3.50 | 3.50 |
| Oval | - | - | - | 1.25 | 2.40 | 2.90 | 3.20 | 3.30 | 3.30 | 3.30 |
| Gavarayya | - | - | - | 1.40 | 2.10 | 2.60 | 2.80 | 2.90 | 2.90 | 2.90 |
| PKM-1 | - | - | - | 1.30 | 2.00 | 2.20 | 2.50 | 2.50 | 2.50 | 2.50 |
| Local | - | - | - | 1.30 | 1.90 | 2.10 | 2.20 | 2.20 | 2.20 | 2.20 |
| CD(0.05) | | | | 0.08 | 0.15 | 0.05 | 0.47 | 0.09 | 0.49 | 0.91 |

**Table 14h. Changes in seed breadth during fruit development**

| Variety | Seed breadth (cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | - | - | - | 0.50 | 1.20 | 1.70 | 1.80 | 1.80 | 1.90 | 1.90 |
| Cricket Ball | - | - | - | 0.60 | 1.26 | 1.60 | 1.80 | 1.90 | 2.00 | 2.00 |
| Oval | - | - | - | 0.50 | 1.30 | 1.70 | 2.00 | 2.20 | 2.10 | 2.40 |
| Gavarayya | - | - | - | 0.40 | 1.20 | 1.50 | 1.80 | 2.00 | 2.00 | 2.00 |
| PKM-1 | - | - | - | 0.40 | 1.40 | 1.50 | 1.60 | 1.70 | 1.80 | 1.80 |
| Local | - | - | - | 0.50 | 1.30 | 1.40 | 1.50 | 1.60 | 1.60 | 1.60 |
| CD(0.05) | | | | 0.10 | 0.04 | 0.08 | 0.13 | 0.11 | 0.14 | 0.12 |

**Table 14i. Changes in seed weight per fruit during fruit development**

| Variety | Seed weight per fruit (g) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | - | - | - | 0.55 | 1.67 | 1.74 | 2.88 | 3.86 | 3.90 | 4.20 |
| Cricket Ball | - | - | - | 1.19 | 2.45 | 3.45 | 3.58 | 4.12 | 5.93 | 8.26 |
| Oval | - | - | - | 1.08 | 1.89 | 2.26 | 2.54 | 3.76 | 4.01 | 5.04 |
| Gavarayya | - | - | - | 0.09 | 1.85 | 2.26 | 2.28 | 2.42 | 2.62 | 3.08 |
| PKM-1 | - | - | - | 0.07 | 1.45 | 1.88 | 2.01 | 2.01 | 2.19 | 2.79 |
| Local | - | - | - | 0.13 | 0.34 | 0.78 | 0.86 | 0.90 | 1.20 | 1.80 |
| CD(0.05) | | | | 0.12 | 0.15 | 0.11 | 0.06 | 0.04 | 0.08 | 0.19 |

**Table 14j. Number of seeds per fruit during fruit development**

| Variety | Number of seeds per fruit | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | N.T | N.T | N.T | 1.40 | 1.80 | 1.80 | 1.90 | 2.80 | 2.80 | 2.80 |
| Cricket Ball | N.T | N.T | Small | 2.60 | 2.90 | 3.50 | 5.20 | 5.20 | 5.40 | 5.40 |
| Oval | N.T | N.T | T. Small | 1.80 | 2.40 | 2.50 | 3.00 | 3.60 | 3.60 | 3.60 |
| Gavarayya | N.T | N.T | T. Small | 1.50 | 1.60 | 1.60 | 1.80 | 2.00 | 2.20 | 2.20 |
| PKM-1 | N.T | N.T | T. Small | 1.20 | 1.40 | 1.40 | 1.50 | 1.50 | 1.80 | 1.80 |
| Local | N.T | N.T | T. Small | 1.00 | 1.20 | 1.20 | 1.40 | 1.50 | 1.50 | 1.50 |
| CD(0.05) | | | | 0.09 | 0.36 | 0.14 | 0.14 | 0.16 | 0.96 | 0.95 |

N.T.-Non- traceable
T-Traceable

## 4.8.BIOCHEMICAL CHANGES DURING FRUIT DEVELOPMENT

### 4.8.1.Total soluble solids (TSS)

In all the six varieties, TSS was very low upto 30 days after fruit set and thereafter increased gradually till maturity. Maximum TSS was recorded in the variety PKM-1 (22.6° Brix) followed by Co-2 (21.25 ° Brix). The changes in TSS during fruit development were given in Table 15a and Fig 5.

### 4.8.2.Reducing sugar

Reducing sugar increased sharply after 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1 and thereafter increased gradually whereas the sharp increase in reducing sugar occurred after 45 days from fruit set in Co-2, Oval and Local varieties and thereafter increased gradually (Table 15 b and Fig.6). Reducing sugar was maximum in the variety Co-2 (15.8%) followed by Oval (12.7 %) and minimum-reducing sugar was recorded in Local (9.5%) variety.

### 4.8.3.Non-reducing sugar

The increases in non-reducing sugar followed the similar pattern like that of the changes in reducing sugar. Non-reducing sugar was more in PKM-1 (6.5%) followed by Local (5.2%). Minimum non-reducing sugar was recorded in Cricket Ball (4.25 %). The changes in non-reducing sugar during fruit development were given in Table 15c and Fig7.

### 4.8.4.Total sugars

Total sugars increases gradually with a sharp increase after 45 days from fruit set in Co-2, Oval and Local varieties, whereas the sudden increase in total sugar occurred at 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1. Highest total sugar content was recorded in Co-2 (20.55%) followed by PKM-1 (19.3%) and Oval (19.0%). Total sugars were minimum in Local variety (14.7%) followed by Cricket Ball (15.0%) and Gavarayya (14.9 %). The changes in total sugars during fruit development were given in Table 15d and Fig 8.

**Table 15a.Changes in Total soluble solids (TSS) during fruit development**

| Variety | Total soluble solids (TSS) ($^0$ Brix) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 3.00 | 3.40 | 9.50 | 13.40 | 13.88 | 14.25 | 14.75 | 16.15 | 18.20 | 21.25 |
| Cricket Ball | 3.80 | 3.90 | 12.60 | 12.60 | 12.80 | 13.10 | 13.45 | 16.00 | 18.20 | 20.50 |
| Oval | 3.70 | 3.80 | 13.00 | 14.00 | 14.00 | 14.40 | 14.75 | 16.20 | 18.00 | 20.56 |
| Gavarayya | 3.50 | 3.80 | 8.50 | 9.60 | 9.80 | 10.20 | 13.80 | 18.40 | 19.60 | 20.50 |
| PKM-1 | 4.00 | 4.40 | 13.00 | 13.50 | 13.80 | 14.40 | 14.40 | 19.80 | 21.60 | 24.60 |
| Local | 3.00 | 3.20 | 9.80 | 10.40 | 13.80 | 14.20 | 14.20 | 16.80 | 18.60 | 20.60 |
| CD(0.05) | 0.09 | 0.03 | 0.63 | 0.96 | 0.03 | 0.08 | 0.03 | 0.31 | 0.37 | 0.46 |

**Table 15b.Changes in reducing sugar during fruit development**

| Variety | Reducing sugar (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 0.20 | 0.34 | 0.80 | 2.00 | 2.20 | 2.30 | 6.95 | 10.15 | 13.15 | 15.80 |
| Cricket Ball | 0.20 | 0.20 | 0.20 | 0.20 | 4.60 | 5.10 | 5.55 | 6.50 | 7.90 | 10.75 |
| Oval | 0.40 | 0.40 | 0.90 | 1.50 | 2.00 | 2.30 | 6.20 | 8.30 | 10.40 | 14.50 |
| Gavarayya | 0.33 | 0.33 | 0.44 | 0.98 | 3.09 | 3.24 | 3.75 | 4.80 | 8.12 | 10.60 |
| PKM-1 | 0.32 | 0.35 | 0.38 | 0.55 | 1.75 | 2.57 | 3.23 | 4.80 | 8.92 | 12.80 |
| Local | 0.57 | 0.28 | 0.30 | 5.70 | 5.90 | 6.10 | 7.30 | 8.00 | 9.10 | 9.50 |
| CD(0.05) | 0.21 | 0.10 | 0.21 | 0.45 | 0.76 | 0.72 | 0.35 | 0.89 | 0.71 | 1.84 |

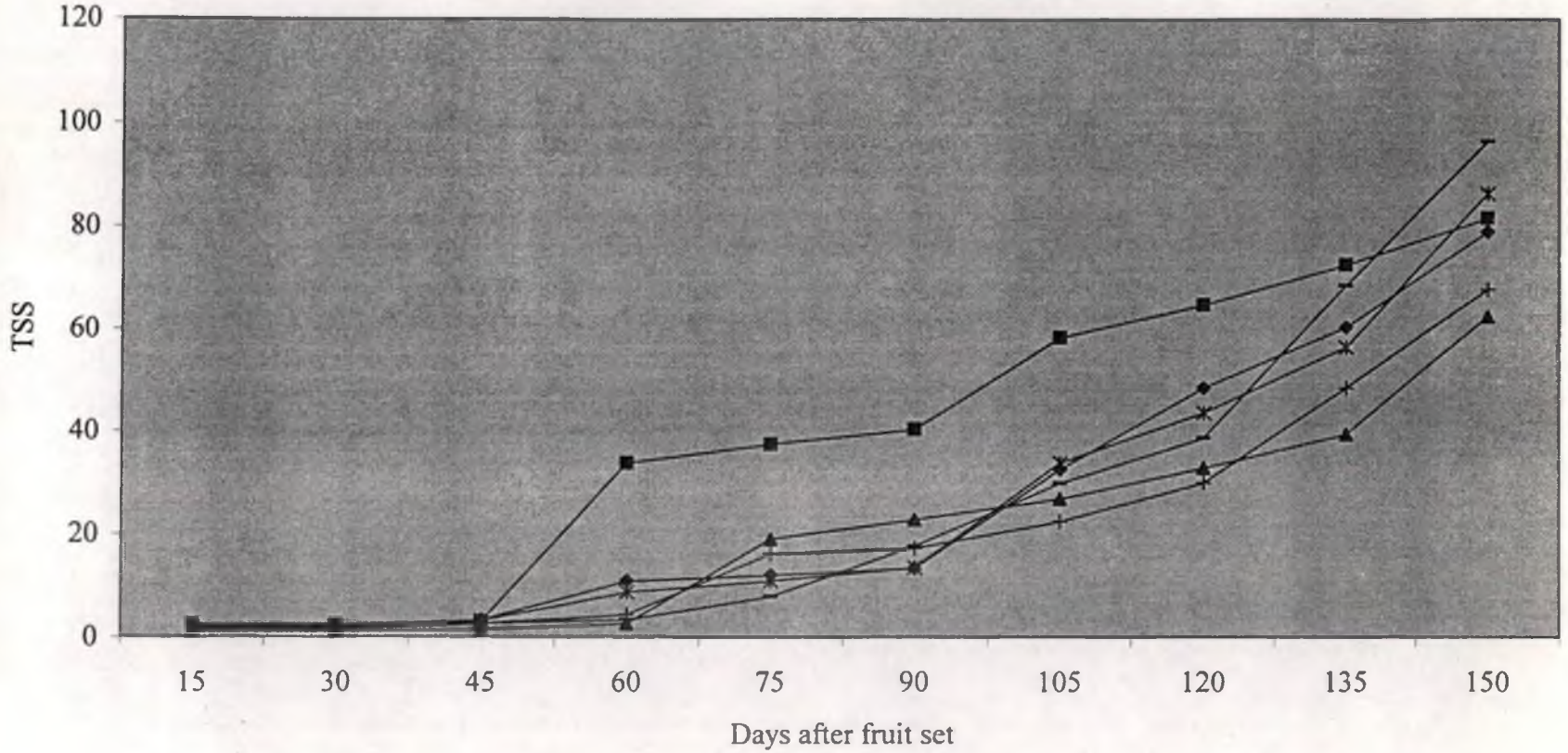



**Fig.5.Changes in TSS during fruit development**

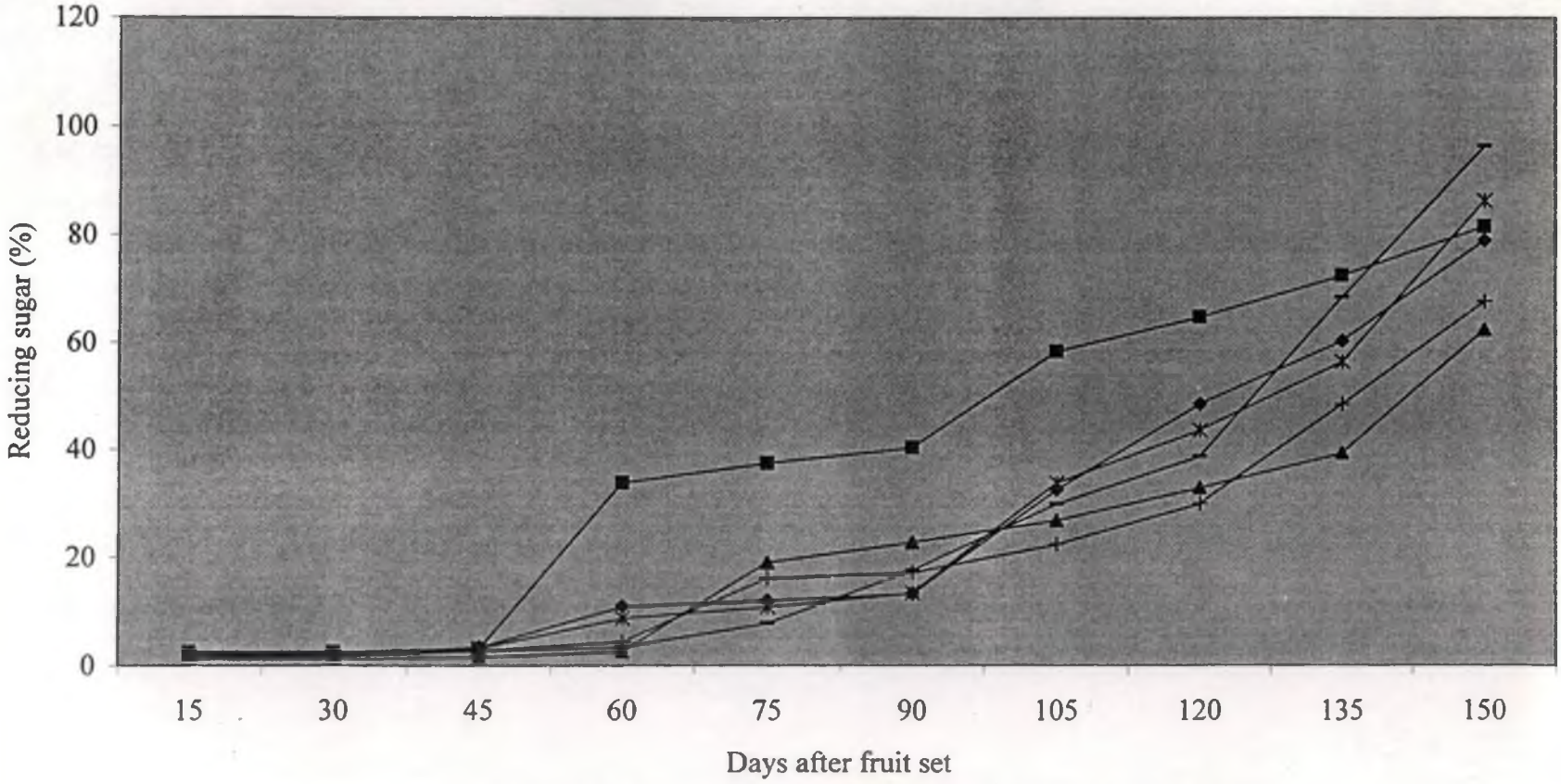



**Fig.6.Changes in reducing sugar (%) during fruit development**

**Table 15c.Changes in Non-Reducing sugar during fruit development**

| Variety | Non-Reducing sugar (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 0.21 | 0.35 | 0.40 | 1.50 | 1.65 | 1.70 | 2.50 | 2.95 | 3.15 | 4.75 |
| Cricket Ball | 0.20 | 0.20 | 0.35 | 0.70 | 1.50 | 1.75 | 2.25 | 3.05 | 3.15 | 4.25 |
| Oval | 0.30 | 0.32 | 0.45 | 0.45 | 1.60 | 1.60 | 2.60 | 3.15 | 3.22 | 4.50 |
| Gavarayya | 0.25 | 0.26 | 0.55 | 0.61 | 2.40 | 2.46 | 3.21 | 3.30 | 3.70 | 4.30 |
| PKM-1 | 0.35 | 0.44 | 0.49 | 0.52 | 0.61 | 2.55 | 5.14 | 5.28 | 5.48 | 6.50 |
| Local | 0.32 | 0.35 | 0.50 | 3.10 | 3.10 | 3.60 | 3.80 | 4.32 | 4.70 | 5.20 |
| CD(0.05) | 0.14 | 0.20 | 0.19 | 0.28 | 0.21 | 0.35 | 0.35 | 0.35 | 0.30 | 0.47 |

**Table 15d.Changes in Total sugars during fruit development**

| Variety | Total sugars (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 0.41 | 0.69 | 1.20 | 3.50 | 3.85 | 4.0 | 9.45 | 13.10 | 16.30 | 20.55 |
| Cricket Ball | 0.40 | 0.40 | 0.55 | 0.90 | 6.10 | 6.85 | 7.80 | 9.55 | 11.05 | 15.0 |
| Oval | 0.70 | 0.72 | 1.35 | 2.90 | 3.60 | 4.05 | 8.80 | 11.35 | 13.55 | 19.0 |
| Gavarayya | 0.58 | 0.59 | 0.95 | 1.59 | 5.49 | 5.70 | 6.96 | 8.10 | 12.62 | 14.9 |
| PKM-1 | 0.67 | 0.75 | 0.87 | 1.07 | 2.36 | 5.12 | 8.37 | 10.08 | 14.40 | 19.3 |
| Local | 0.57 | 0.63 | 0.80 | 8.80 | 9.0 | 9.70 | 11.1 | 12.32 | 13.80 | 14.7 |
| CD(0.05) | 0.17 | 0.10 | 0.21 | 0.21 | 0.45 | 0.76 | 0.82 | 0.71 | 0.49 | 1.75 |

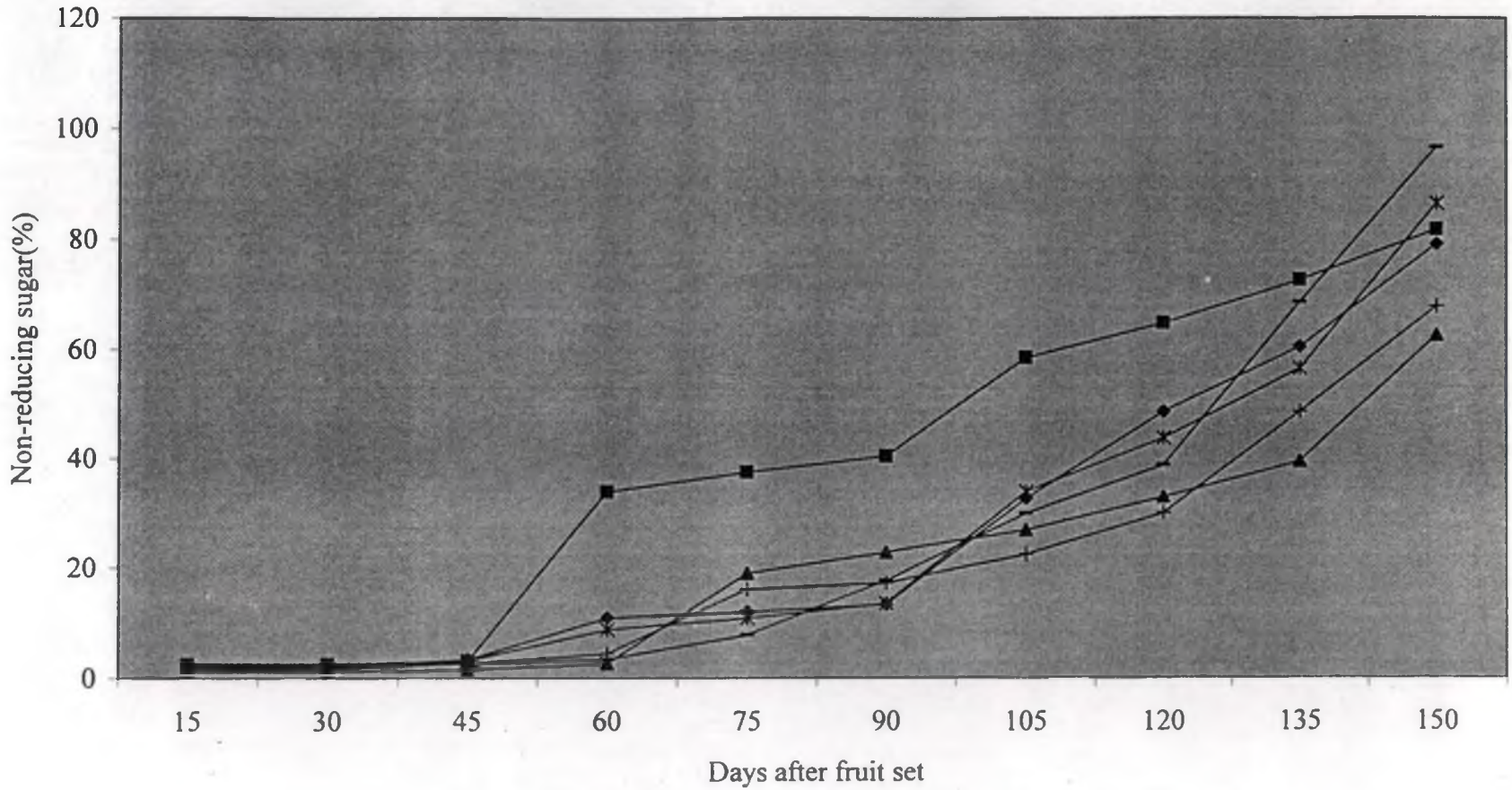



**Fig.7.Changes in non-reducing sugar (% )during fruit development**

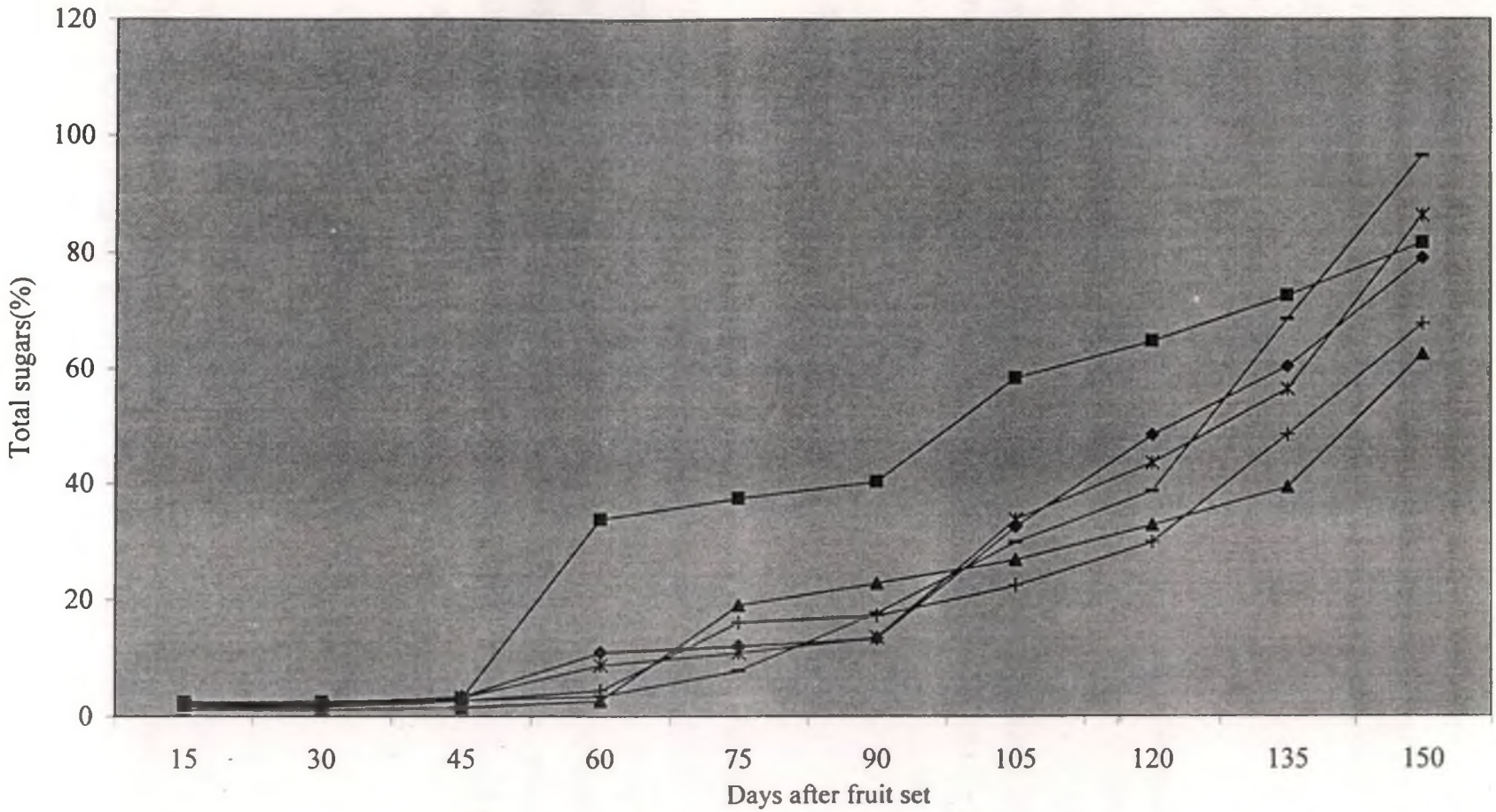



**Fig.8.Changes in total sugars (%) during fruit development**

**Table 15e.Changes in acidity during fruit development**

| Variety | Acidity (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 0.36 | 0.36 | 0.35 | 0.32 | 0.32 | 0.30 | 0.29 | 0.27 | 0.27 | 0.26 |
| Cricket Ball | 0.33 | 0.33 | 0.34 | 0.34 | 0.32 | 0.30 | 0.29 | 0.29 | 0.28 | 0.28 |
| Oval | 0.37 | 0.40 | 0.41 | 0.33 | 0.33 | 0.30 | 0.26 | 0.26 | 0.24 | 0.22 |
| Gavarayya | 0.33 | 0.38 | 0.36 | 0.36 | 0.34 | 0.33 | 0.31 | 0.27 | 0.26 | 0.22 |
| PKM-1 | 0.33 | 0.34 | 0.31 | 0.31 | 0.30 | 0.29 | 0.28 | 0.21 | 0.21 | 0.20 |
| Local | 0.23 | 0.25 | 0.26 | 0.26 | 0.24 | 0.24 | 0.19 | 0.19 | 0.19 | 0.18 |
| CD(0.05) | 0.08 | 0.09 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.03 | 0.03 | 0.08 |

**Table 15f.Changes in sugar-acid ratio during fruit development**

| Variety | Sugar-acid ratio | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 1.14 | 1.92 | 3.43 | 10.94 | 12.03 | 13.33 | 32.59 | 48.52 | 60.37 | 79.04 |
| Cricket Ball | 1.21 | 1.22 | 1.62 | 2.65 | 19.06 | 22.83 | 26.89 | 32.93 | 39.46 | 62.50 |
| Oval | 1.89 | 1.80 | 3.29 | 8.79 | 10.90 | 13.50 | 33.85 | 43.65 | 56.46 | 86.36 |
| Gavarayya | 1.75 | 1.76 | 2.75 | 4.42 | 16.15 | 17.27 | 22.45 | 30.0 | 48.54 | 67.73 |
| PKM-1 | 2.03 | 2.32 | 2.81 | 3.45 | 7.87 | 17.66 | 29.89 | 38.77 | 68.57 | 96.50 |
| Local | 2.48 | 2.52 | 3.08 | 33.85 | 37.50 | 40.42 | 58.42 | 64.84 | 72.63 | 81.67 |
| CD(0.05) | 0.05 | 0.38 | 0.26 | 0.17 | 0.40 | 0.64 | 0.87 | 0.19 | 2.45 | 4.27 |

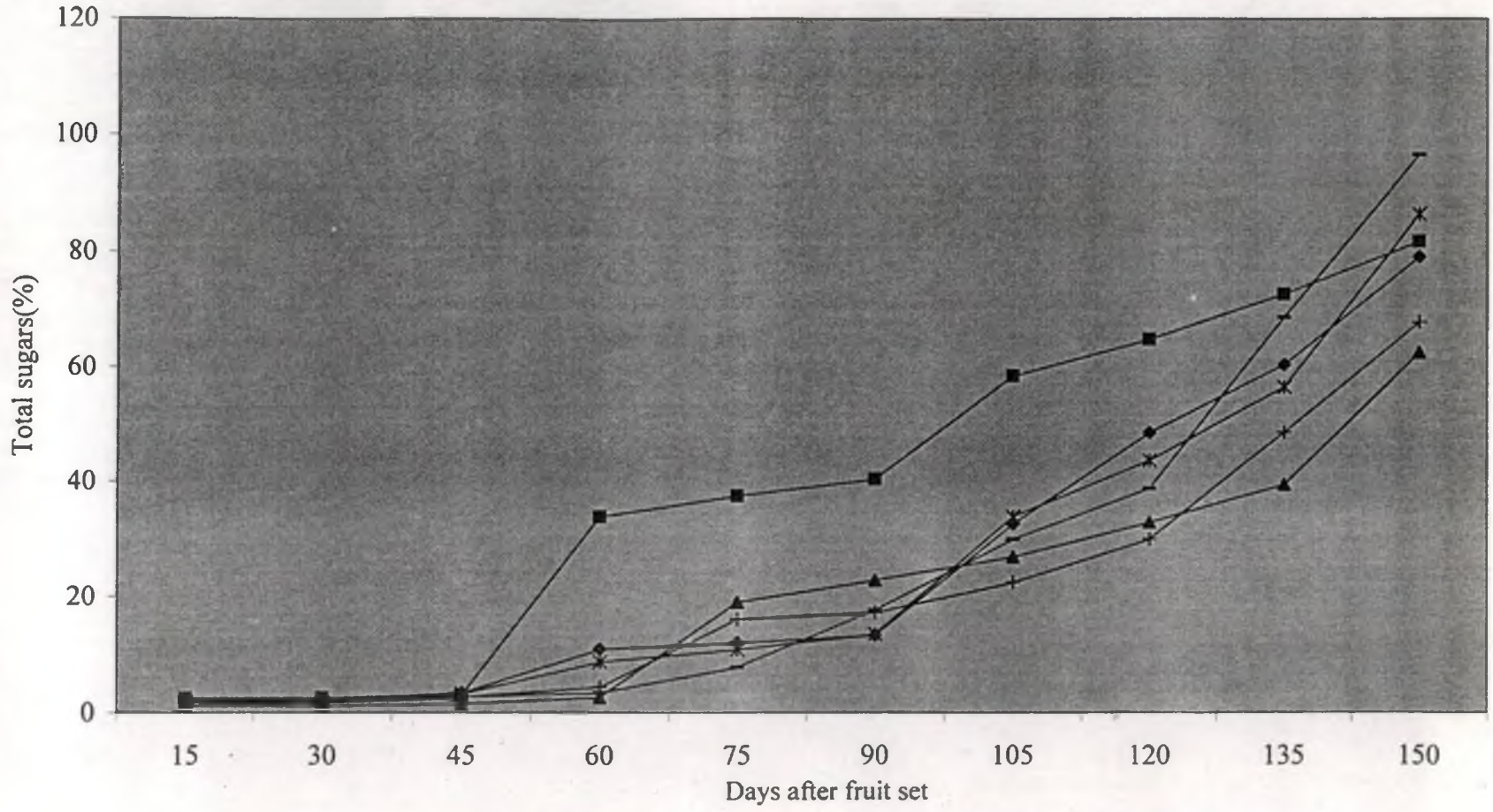



**Fig.8.Changes in total sugars (%) during fruit development**

**4.8.5.Acidity**

There was a gradual decline in acidity in all the six varieties during the span of fruit development (Table 15 e and Fig 9). Maximum acidity was present in Cricket Ball (0.28%) followed by Co-2 (0.26%). Acidity was minimum in Local (0.18%) and PKM-1 (0.20%).

**4.8.6.Sugar: acid ratio**

Sugar: acid ratio increased progressively during the development period with a sudden increase after 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1, whereas in Local, Co-2 and Oval the sudden increase in sugar: acid ratio occurred at 45 days after fruit set. Highest sugar: acid ratio was recorded in PKM-1 (96.50) followed by Oval (86.36). Lowest sugar: acid ratio was recorded in Cricket Ball (62.5). The changes in sugar: acid ratio during fruit development was given in Table 15f and Fig 10.

## 4.9.DAYS FOR FRUIT MATURITY

In the first season, maximum number of days taken for maturity was in Co-2 (167.6 days) followed by Cricket Ball and Gavarayya (164.8 days). Local (150.4 days) and PKM-1 (151.5 days) took less number of days for maturity. In second season, Oval recorded maximum number of days for maturity (154.9 days) followed by Cricket Ball (151.1 days). PKM-1 recorded minimum number of days for maturity (134.8 days) followed by Local (138.5 days). The number of days taken for maturity in two main seasons for all the six varieties is given in Table 16.

## 4.10.HEAT UNIT REQUIREMENT

Heat unit requirement was maximum for the variety Co-2 followed by Cricket Ball and Oval. Heat unit requirement was minimum for the variety PKM-1 and Local (Table 16). Number of days for maturity and heat unit requirement were maximum for the first season of harvest and minimum for second crop.

**Table 15e.Changes in acidity during fruit development**

| Variety | Acidity (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 0.36 | 0.36 | 0.35 | 0.32 | 0.32 | 0.30 | 0.29 | 0.27 | 0.27 | 0.26 |
| Cricket Ball | 0.33 | 0.33 | 0.34 | 0.34 | 0.32 | 0.30 | 0.29 | 0.29 | 0.28 | 0.28 |
| Oval | 0.37 | 0.40 | 0.41 | 0.33 | 0.33 | 0.30 | 0.26 | 0.26 | 0.24 | 0.22 |
| Gavarayya | 0.33 | 0.38 | 0.36 | 0.36 | 0.34 | 0.33 | 0.31 | 0.27 | 0.26 | 0.22 |
| PKM-1 | 0.33 | 0.34 | 0.31 | 0.31 | 0.30 | 0.29 | 0.28 | 0.21 | 0.21 | 0.20 |
| Local | 0.23 | 0.25 | 0.26 | 0.26 | 0.24 | 0.24 | 0.19 | 0.19 | 0.19 | 0.18 |
| CD(0.05) | 0.08 | 0.09 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.03 | 0.03 | 0.08 |

**Table 15f.Changes in sugar-acid ratio during fruit development**

| Variety | Sugar-acid ratio | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after fruit set | | | | | | | | | |
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| Co-2 | 1.14 | 1.92 | 3.43 | 10.94 | 12.03 | 13.33 | 32.59 | 48.52 | 60.37 | 79.04 |
| Cricket Ball | 1.21 | 1.22 | 1.62 | 2.65 | 19.06 | 22.83 | 26.89 | 32.93 | 39.46 | 62.50 |
| Oval | 1.89 | 1.80 | 3.29 | 8.79 | 10.90 | 13.50 | 33.85 | 43.65 | 56.46 | 86.36 |
| Gavarayya | 1.75 | 1.76 | 2.75 | 4.42 | 16.15 | 17.27 | 22.45 | 30.0 | 48.54 | 67.73 |
| PKM-1 | 2.03 | 2.32 | 2.81 | 3.45 | 7.87 | 17.66 | 29.89 | 38.77 | 68.57 | 96.50 |
| Local | 2.48 | 2.52 | 3.08 | 33.85 | 37.50 | 40.42 | 58.42 | 64.84 | 72.63 | 81.67 |
| CD(0.05) | 0.05 | 0.38 | 0.26 | 0.17 | 0.40 | 0.64 | 0.87 | 0.19 | 2.45 | 4.27 |

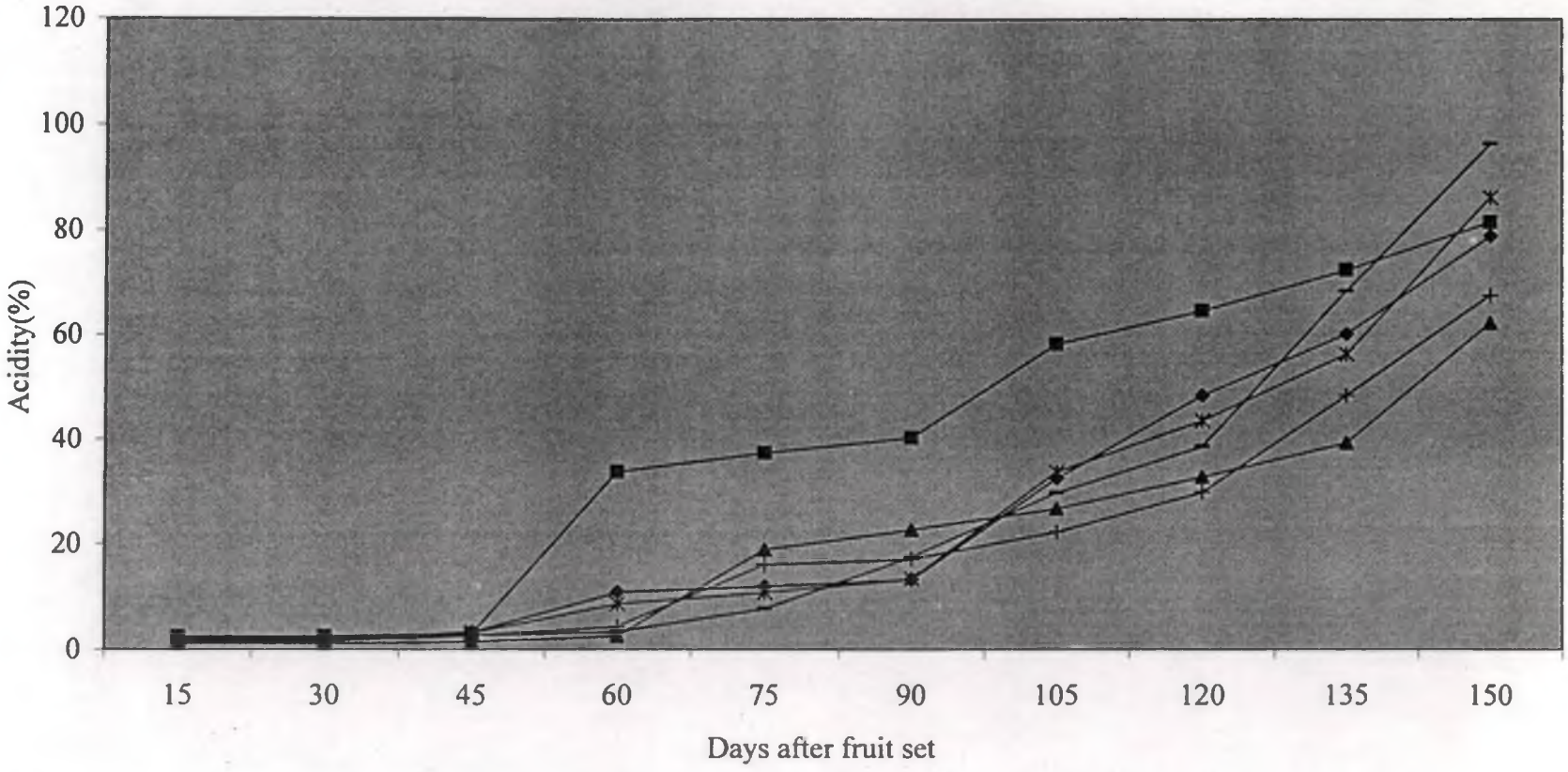



**Fig.9.Changes in acidity (%)during fruit development**

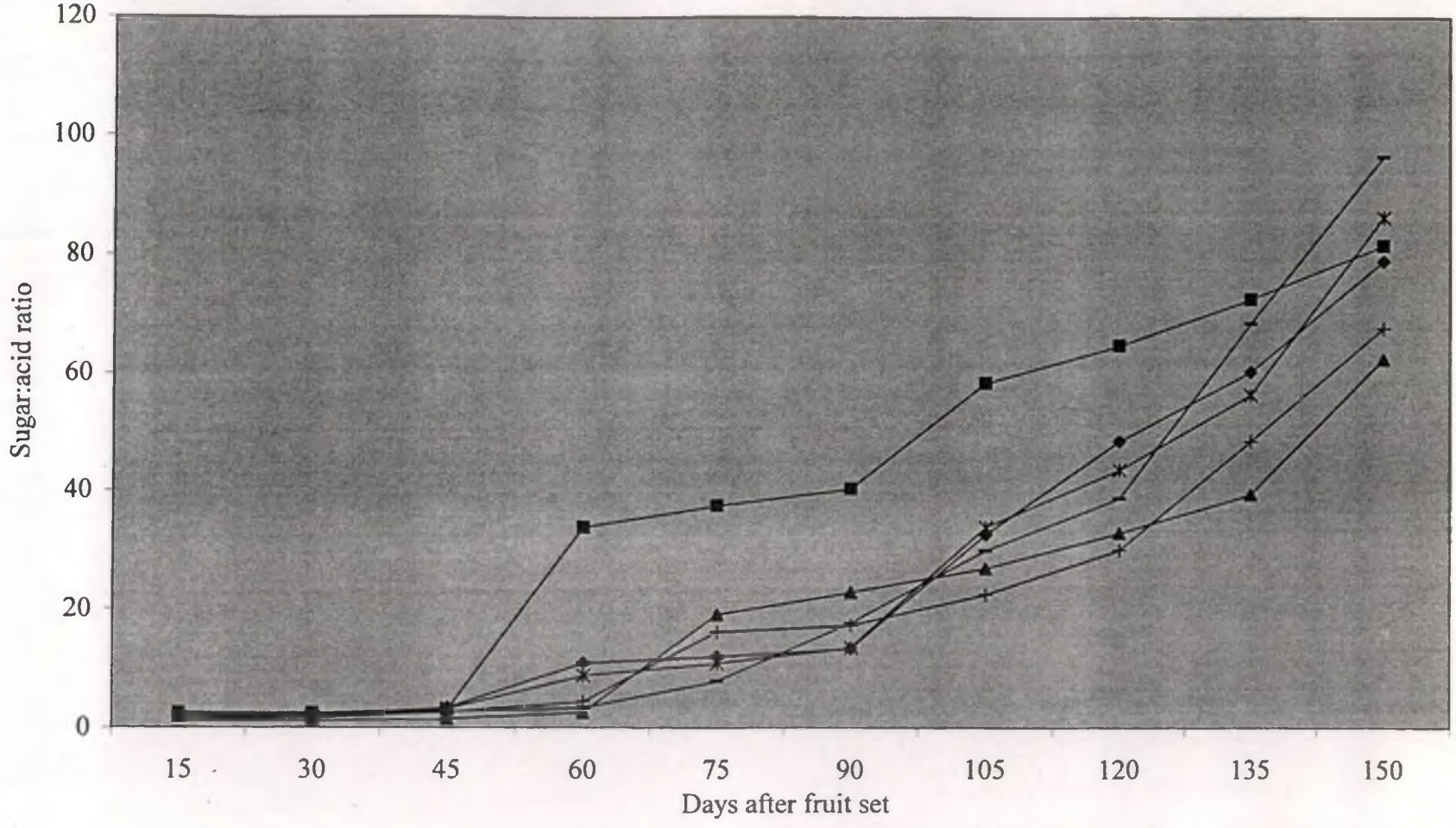



**Fig.10.Changes in sugar:acid ratio during fruit development**

**Table 16. Days taken for harvest maturity**

| Sl.No. | Variety | Season | | Thermal days (°C) | | |
|---|---|---|---|---|---|---|
| | | I (Oct-Nov) | II (Feb-Mar) | Season I | Season II | Mean |
| 1 | Co-2 | 167.6[a] | 150.2[b] | 16783.20 | 13147.50 | 14965.35[a] |
| 2 | Cricket Ball | 164.7[b] | 151.1[b] | 13447.50 | 13235.15 | 13341.33[b] |
| 3 | Oval | 164.8[b] | 154.9[a] | 13447.50 | 13585.75 | 13516.63[b] |
| 4 | Gavarayya | 159.4[c] | 146.5[c] | 13040.00 | 12884.55 | 12962.28[c] |
| 5 | PKM-1 | 151.5[d] | 134.8[d] | 12225.00 | 11832.75 | 12028.88[c] |
| 6 | Local | 150.4[e] | 138.5[d] | 12632.50 | 12095.70 | 12364.10[d] |

**Table 17. Fruit yield**

| Sl.No. | Variety | Season | | | |
|---|---|---|---|---|---|
| | | October-November | | February-March | |
| | | Fruit weight (kg) | Fruit number | Fruit weight(kg) | Fruit number |
| 1 | Co-2 | 13.80[c] | 120[c] | 33.50[c] | 250[b] |
| 2 | Cricket Ball | 26.25[a] | 150[b] | 39.60[b] | 220[c] |
| 3 | Oval | 14.25[c] | 95[cd] | 23.25[d] | 150[d] |
| 4 | Gavarayya | 20.65[b] | 165[b] | 32.25[c] | 250[b] |
| 5 | PKM-1 | 27.50[a] | 480[a] | 60.50[a] | 670[a] |
| 6 | Local | 4.95[d] | 110[c] | 11.75[c] | 250[b] |

Values with similar superscript letter did not differ significantly

## 4.11.YIELD

Fruit yield obtained in second harvesting period (February-March) was maximum when compared to first harvesting period (October – November)(Table 17). Total number of fruits was maximum in PKM-1 (670) in second crop, whereas it was 480 fruits in first crop. Total number of fruits was minimum in Oval (150) and Cricket Ball (220) varieties in second crop, whereas it was 95 and 150 fruits for Oval and Cricket Ball in first crop. Total fruit weight was maximum in PKM-1 (60.5kg) followed by Cricket Ball (39.9 kg) in second crop, whereas minimum fruit weight was recorded in Local (11.75 kg). In first season, total fruit weight was also maximum in PKM-1 (27.5 kg) and minimum in Local (14.95 kg).

## 4.12.COMPATIBILITY STUDIES

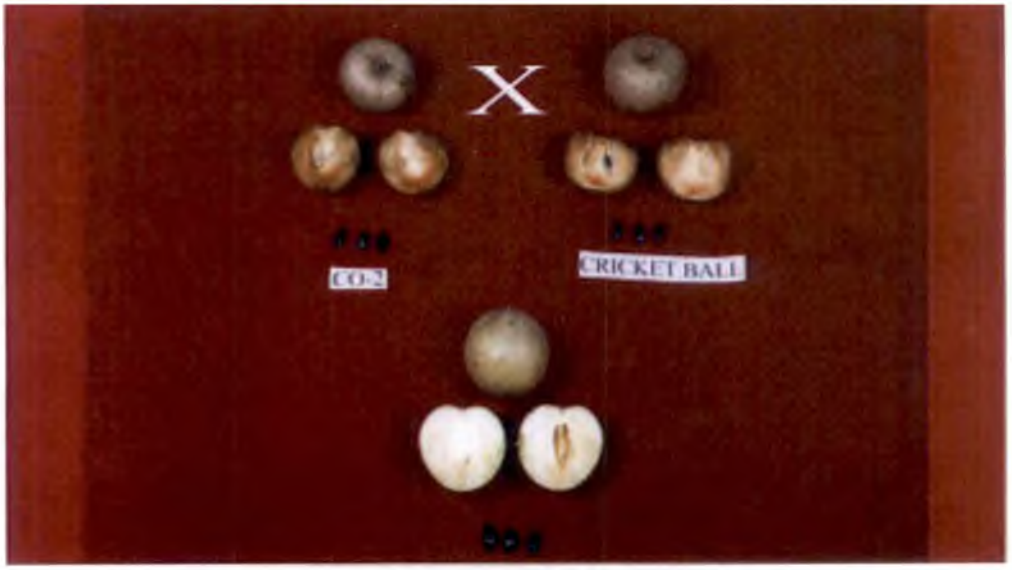
### 4.12.1.Compatibility within the varieties

Both self and cross compatibility studies were conducted in the six sapota varieties and results were presented in Table 18 and Plate 12 A-U.

Selfing the varieties resulted in only meager fruit set. There was no fruit set while selfing Oval, Cricket Ball and Local varieties. In cross-pollination among the varieties maximum fruit set (28.57%) was obtained in Co-2 X Gavarayya cross combinations followed by Cricket Ball X Co-2 (27.69%)cross combination. The entire cross combinations involving Gavarayya and PKM-1 as female parent set fruit. There was no fruit set in Co-2 X PKM-1, Co-2 X Local, Cricket Ball X PKM-1, Cricket Ball X Local, Oval X Cricket Ball, Oval X Local, Local X Co-2, Local X Cricket Ball, Local X Oval cross combinations. When Gavarayya was used as female parent maximum fruit set (26.66%) was obtained with Oval variety as pollen parent. Similarly, when PKM-1 was used as female parent, maximum fruit set was obtained with Local and Gavarayya varieties as pollen parents (21.67 % and 21.43% respectively).

**Table 18.Compatibility studies in sapota variety**

| Cross combinations | No. of flowers crossed | No. of fruit set | Fruit set (%) | Days taken from pollination to fruit set | No. of fruits dropped | Fruit drop (%) | Days For maturity |
|---|---|---|---|---|---|---|---|
| Co-2 X Co-2 | 65 | 1 | 1.54 | 8 | 1 | 100.00 | - |
| Cricket Ball X Cricket Ball | 70 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Oval X Oval | 60 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Gavarayya X Gavarayya | 70 | 2 | 2.85 | 9 | 2 | 100.00 | - |
| PKM-1 X PKM-1 | 75 | 2 | 2.85 | 8 | 2 | 100.00 | - |
| Local X Local | 70 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Co-2 X Cricket Ball | 80 | 18 | 22.50 | 8 | 8 | 44.44 | 167.20 |
| Co-2 X Oval | 70 | 7 | 10.0 | 7 | 3 | 42.86 | 166.00 |
| Co-2 X Gavarayya | 70 | 20 | 28.57 | 9 | 4 | 20.00 | 162.00 |
| Co-2 X PKM-1 | 80 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Co-2 X Local | 75 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Cricket Ball X Co-2 | 65 | 18 | 27.69 | 8 | 10 | 55.55 | 167.20 |
| Cricket Ball X Oval | 70 | 17 | 24.29 | 8 | 5 | 29.41 | 164.60 |
| Cricket Ball X Gavarayya | 70 | 14 | 20.00 | 7 | 6 | 42.86 | 158.90 |
| Cricket Ball X PKM-1 | 65 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Cricket Ball X Local | 60 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Oval X Co-2 | 60 | 5 | 8.33 | 8 | 0 | 0.00 | 164.50 |
| Oval X Cricket Ball | 65 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Oval X Gavarayya | 65 | 15 | 23.08 | 9 | 2 | 13.33 | 156.70 |
| Oval X PKM-1 | 70 | 9 | 12.86 | 8 | 1 | 11.11 | 153.50 |
| Oval X Local | 60 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Gavarayya X Co-2 | 65 | 13 | 20.00 | 8 | 6 | 46.15 | 161.86 |
| Gavarayya X Cricket Ball | 60 | 12 | 20.00 | 9 | 4 | 33.33 | 159.83 |
| Gavarayya X Oval | 60 | 16 | 26.66 | 7 | 3 | 18.75 | 162.60 |
| Gavarayya X PKM-1 | 70 | 11 | 15.71 | 8 | 1 | 9.09 | 152.00 |
| Gavarayya X Local | 60 | 7 | 11.67 | 8 | 1 | 14.29 | 154.80 |
| PKM-1 X Co-2 | 65 | 8 | 12.31 | 9 | 1 | 12.50 | 161.00 |
| PKM-1 X Cricket Ball | 60 | 9 | 15.00 | 9 | 2 | 22.20 | 158.80 |
| PKM-1 X Oval | 60 | 10 | 16.67 | 9 | 1 | 10.00 | 161.00 |
| PKM-1 X Gavarayya | 70 | 15 | 21.43 | 7 | 2 | 13.33 | 159.40 |
| PKM-1 X Local | 60 | 13 | 21.67 | 7 | 2 | 15.38 | - |
| Local X Co-2 | 60 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Local X Cricket Ball | 60 | 0 | 0.00 | 0 | 0 | 0.00 | - |
| Local X Oval | 60 | 0 | 0.00 | 0 | 0 | 0.00 | 154.60 |
| Local X Gavarayya | 60 | 16 | 26.67 | 7 | 7 | 43.75 | 154.00 |
| Local X PKM-1 | 60 | 8 | 13.33 | 7 | 2 | 25.00 | 149.00 |

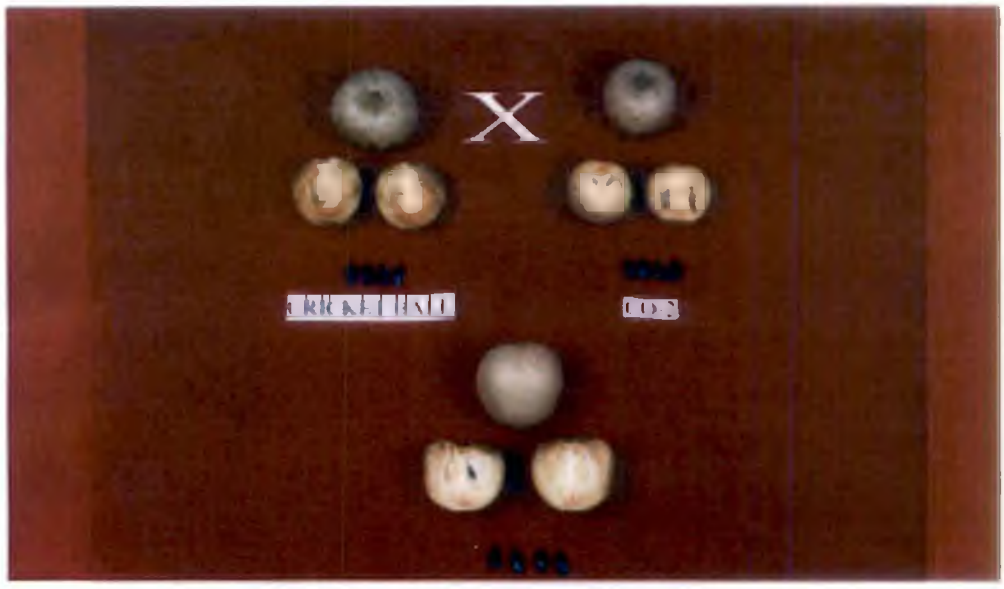



a. CO-2 x Cricket Ball

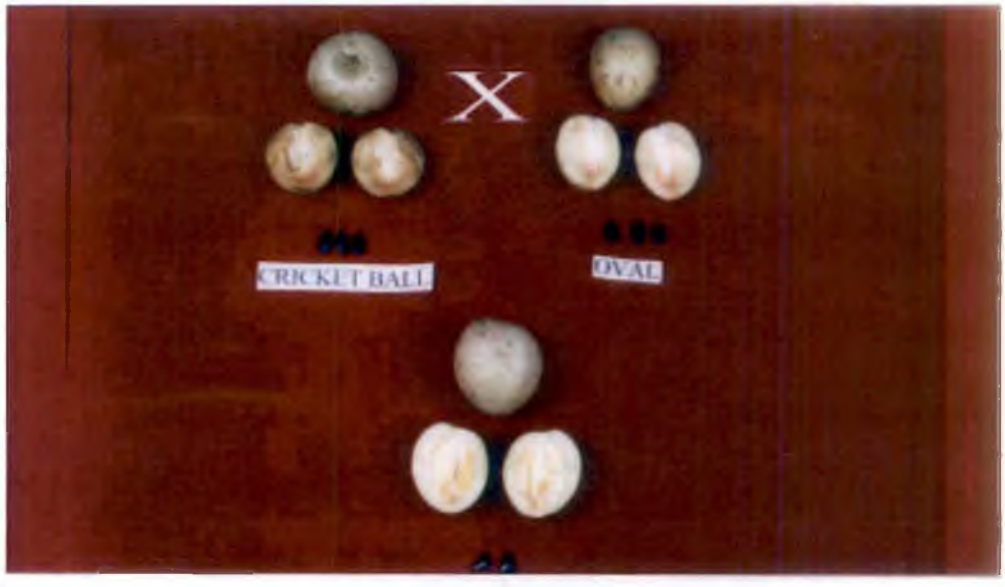

b. CO-2 x Oval


C. CO - 2 x Gavarayya

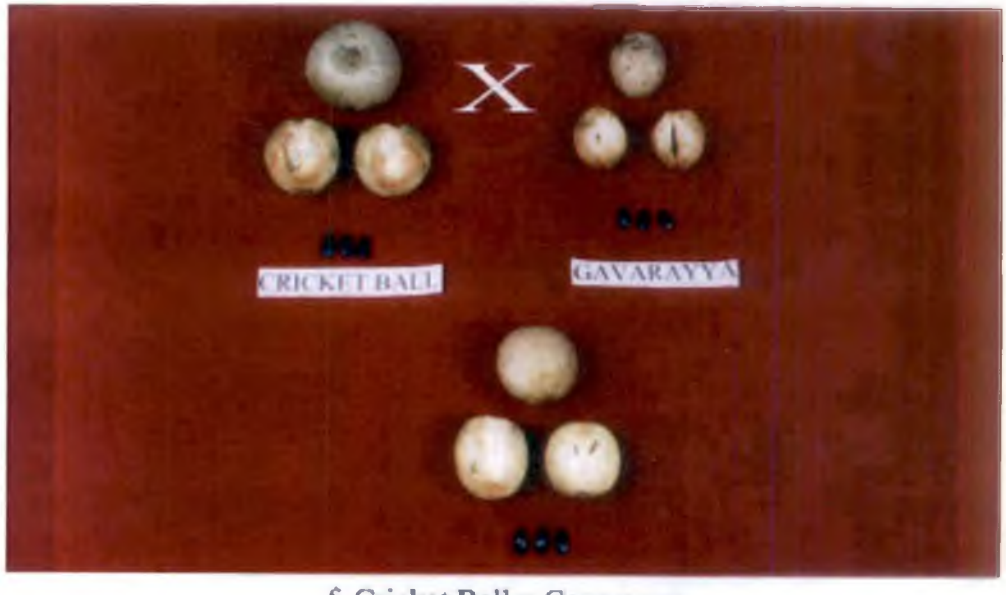
Plate : 12. Intervarietal compatibility between different sapota varieties




d. Cricket Ball x CO - 2

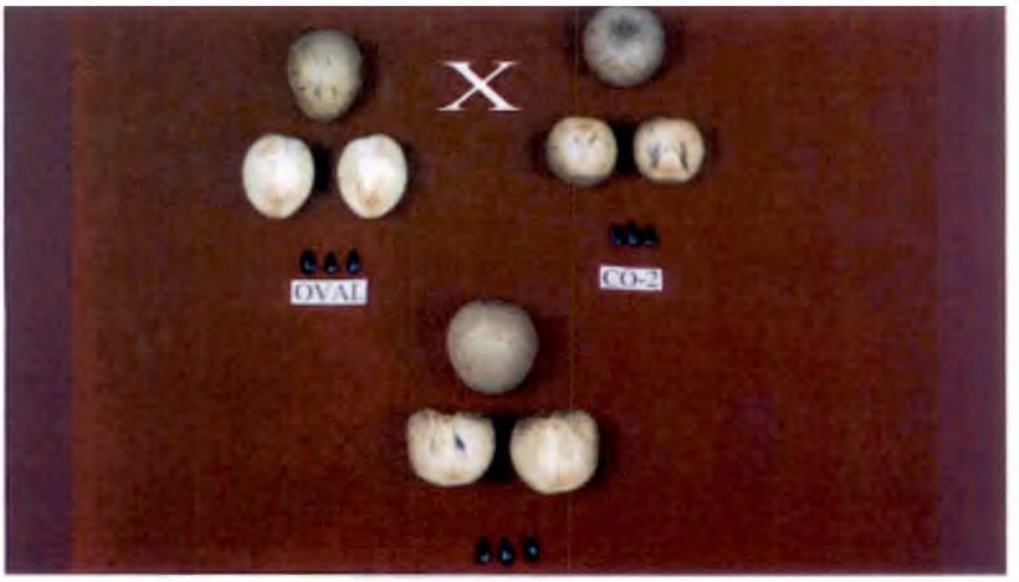



e. Cricket Ball x Oval




f. Cricket Ball x Gavarayya

Plate : 12. (Contd.) Intervarietal compatibility between different sapota varie



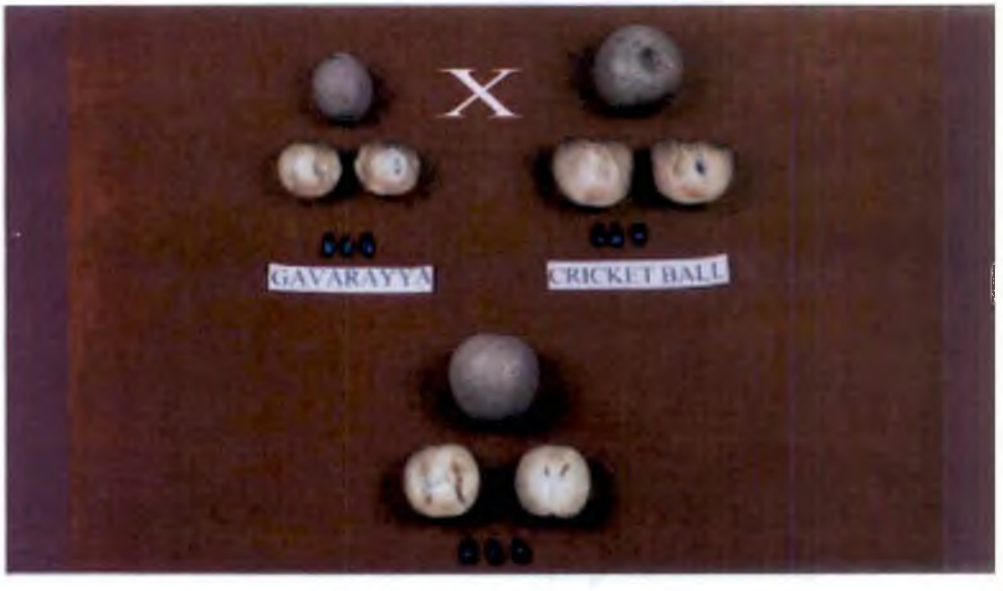

g. Oval x CO-2


h. Oval x Gavarayya

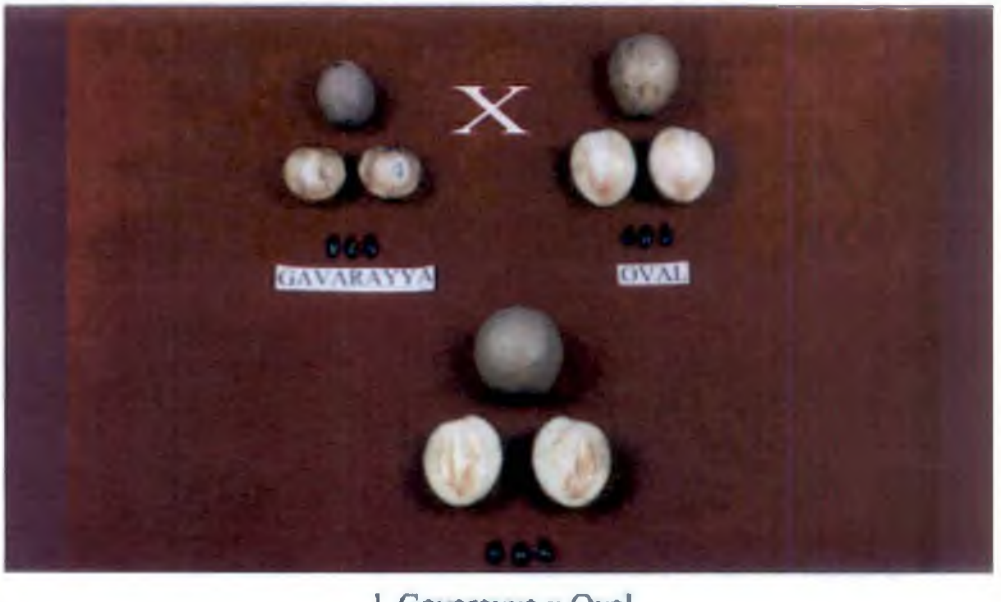

i. Oval x PKM-1

Plate : 12. (Contd.) Intervarietal compatibility between different sapota varietie


j. Gavarayya x CO-2

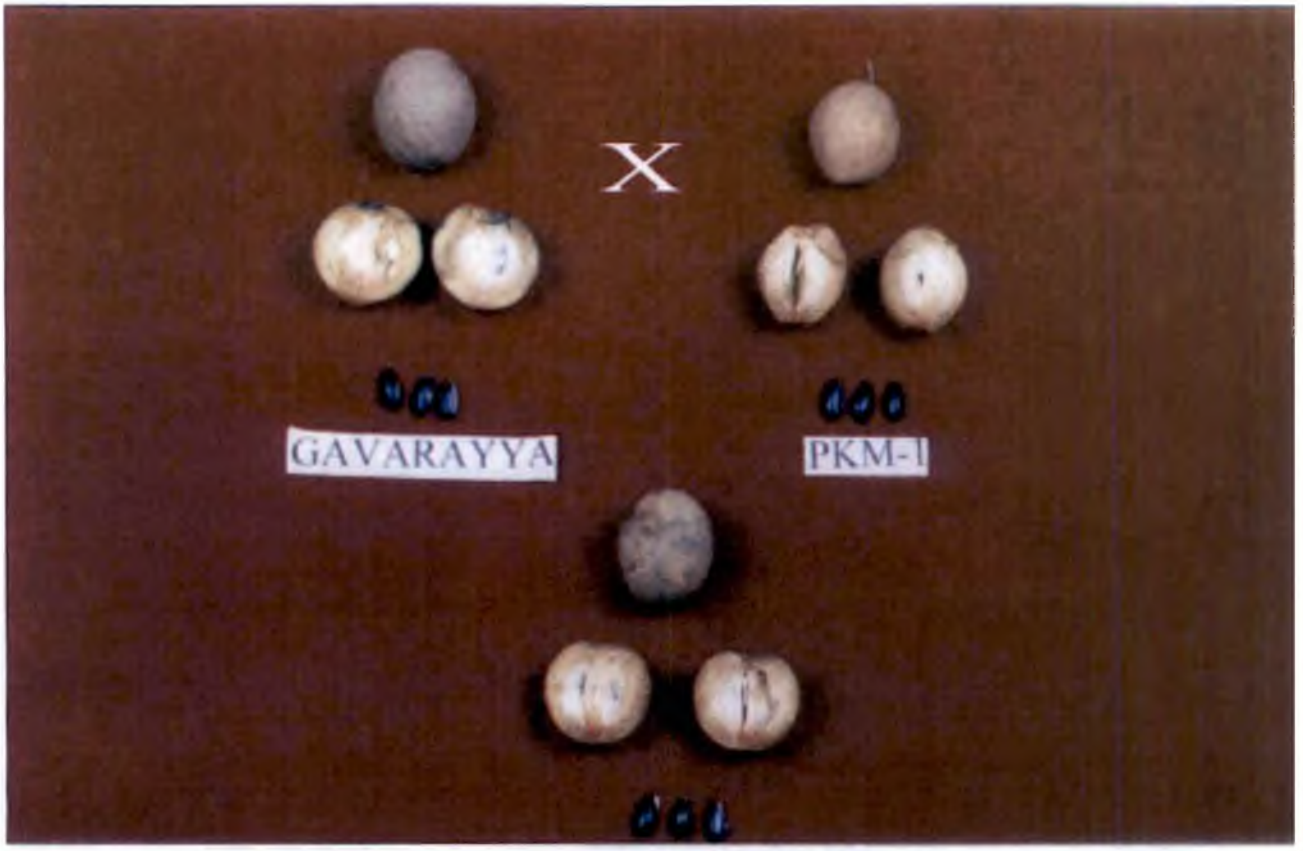



k. Gavarayya x Cricket Ball




l. Gavarayya x Oval

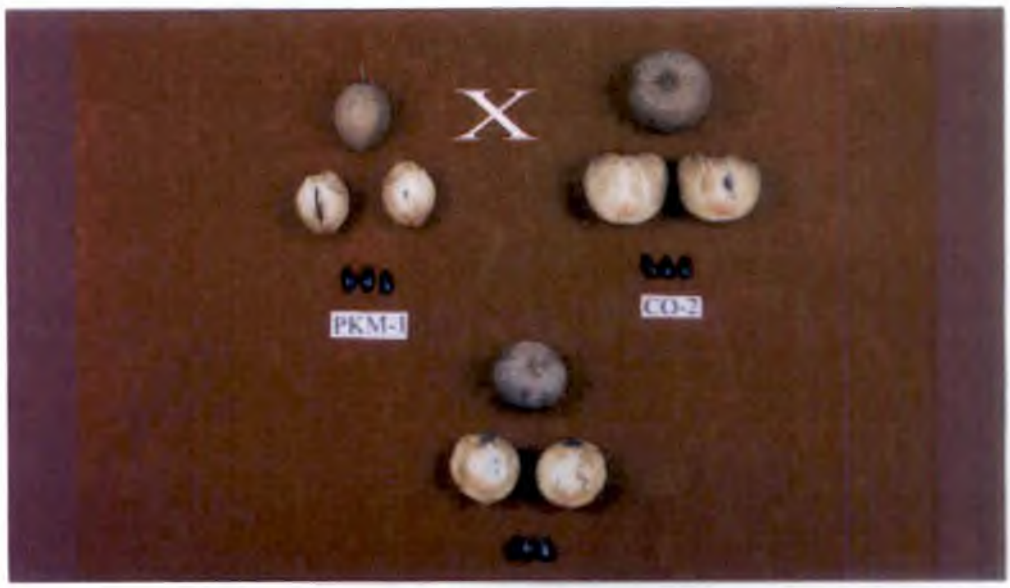
Plate : 12. (Contd.) Intervarietal compatibility between different sapota varieti



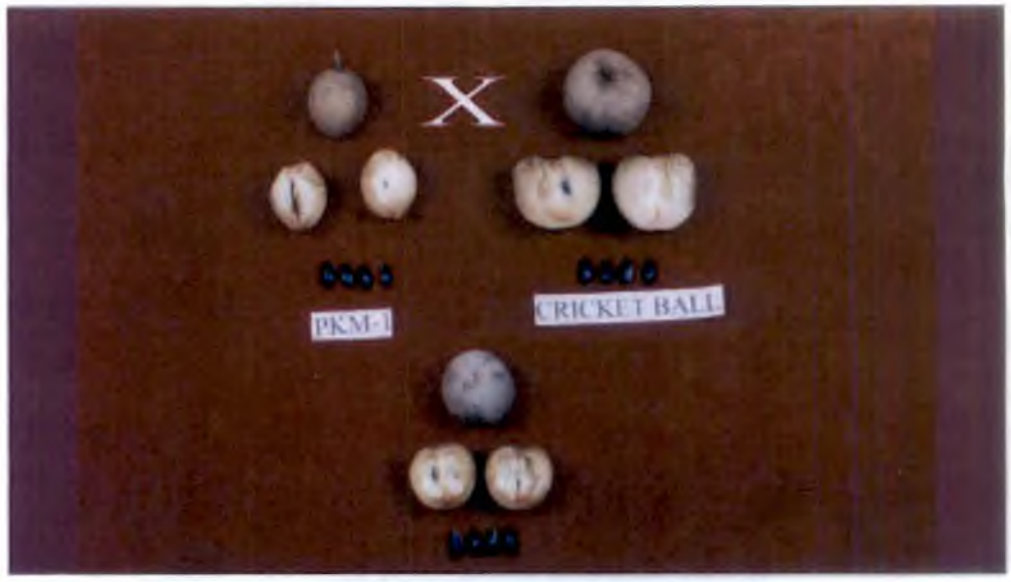

m. Gavarayya x PKM-1


n. Gavarayya x Local

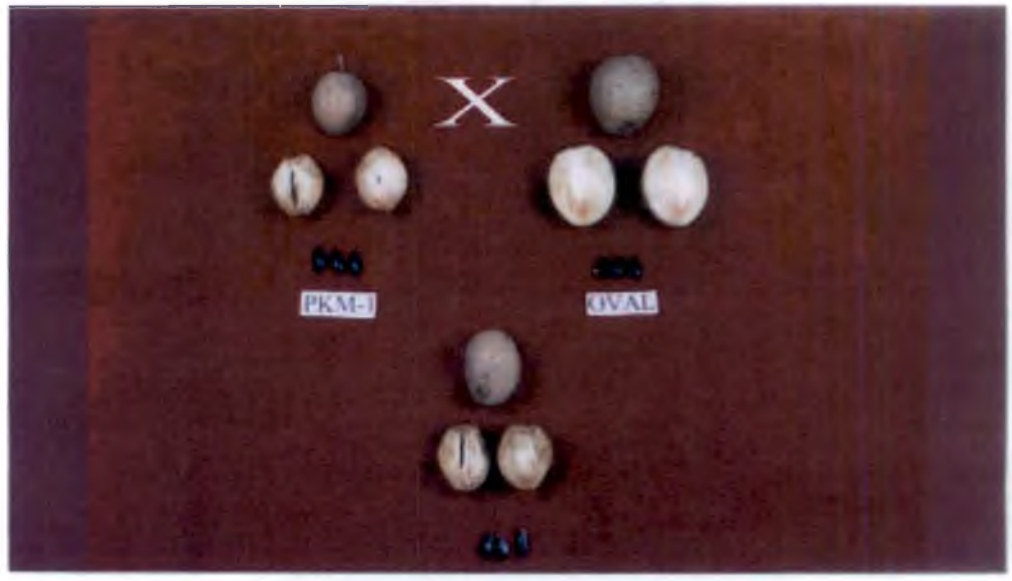
Plate : 12. (Contd.) Intervarietal compatibility between different sapota varieties




o. PKM-1 x CO-2

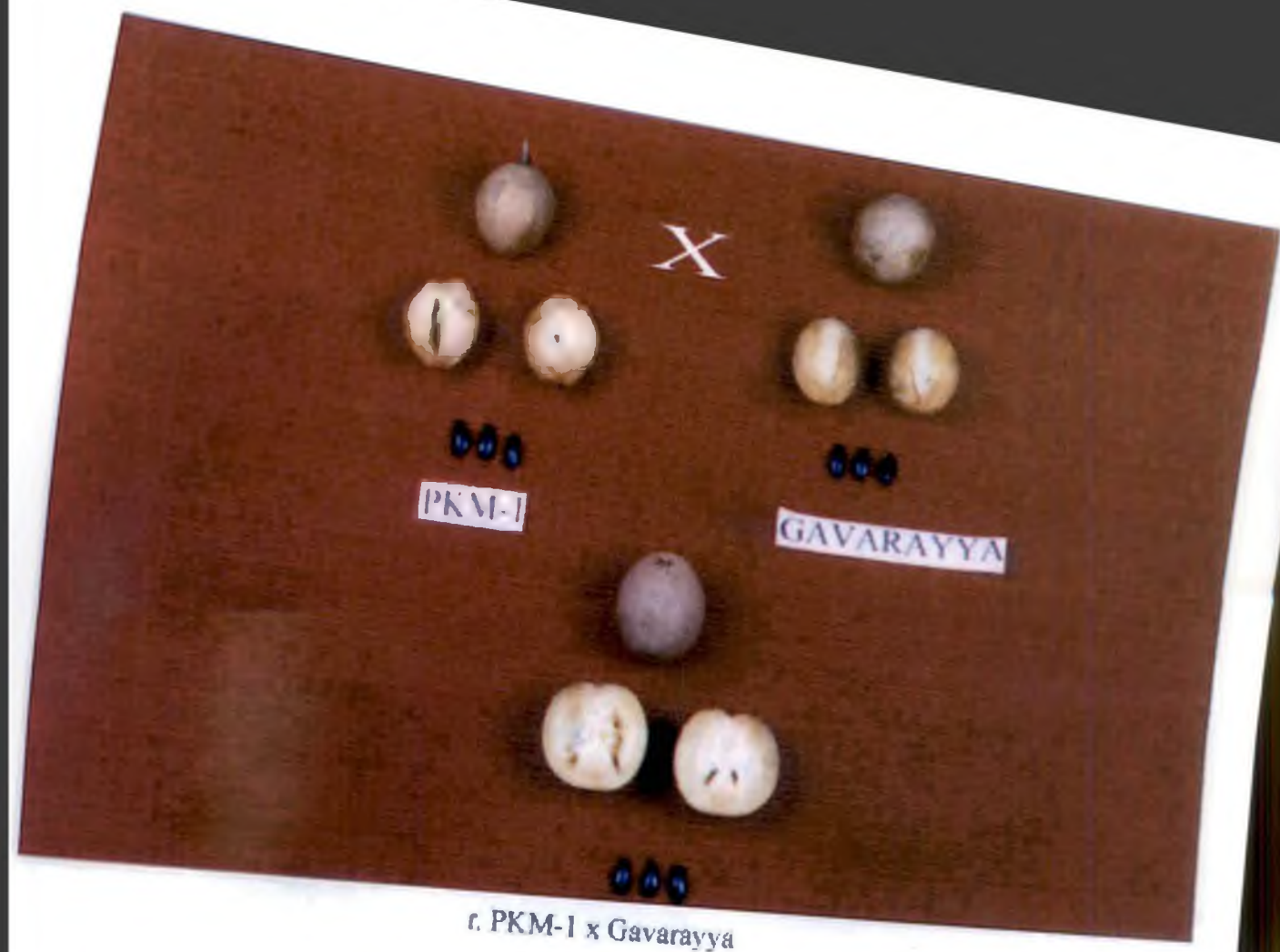



p. PKM-1 x Cricket Ball

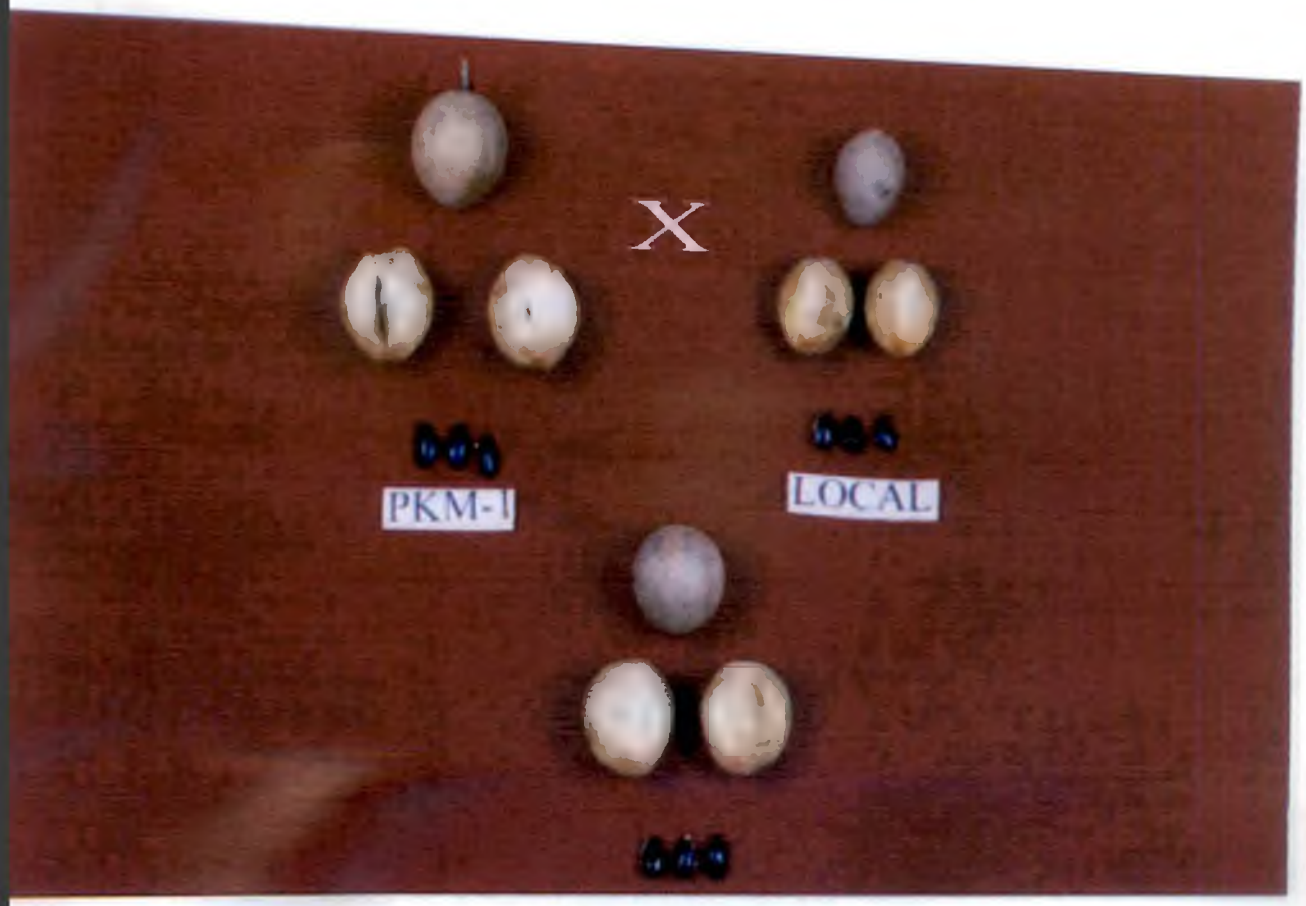



q. PKM-1 x Oval

Plate : 12. (Contd.) Intervarietal compatibility between different sapota varieties

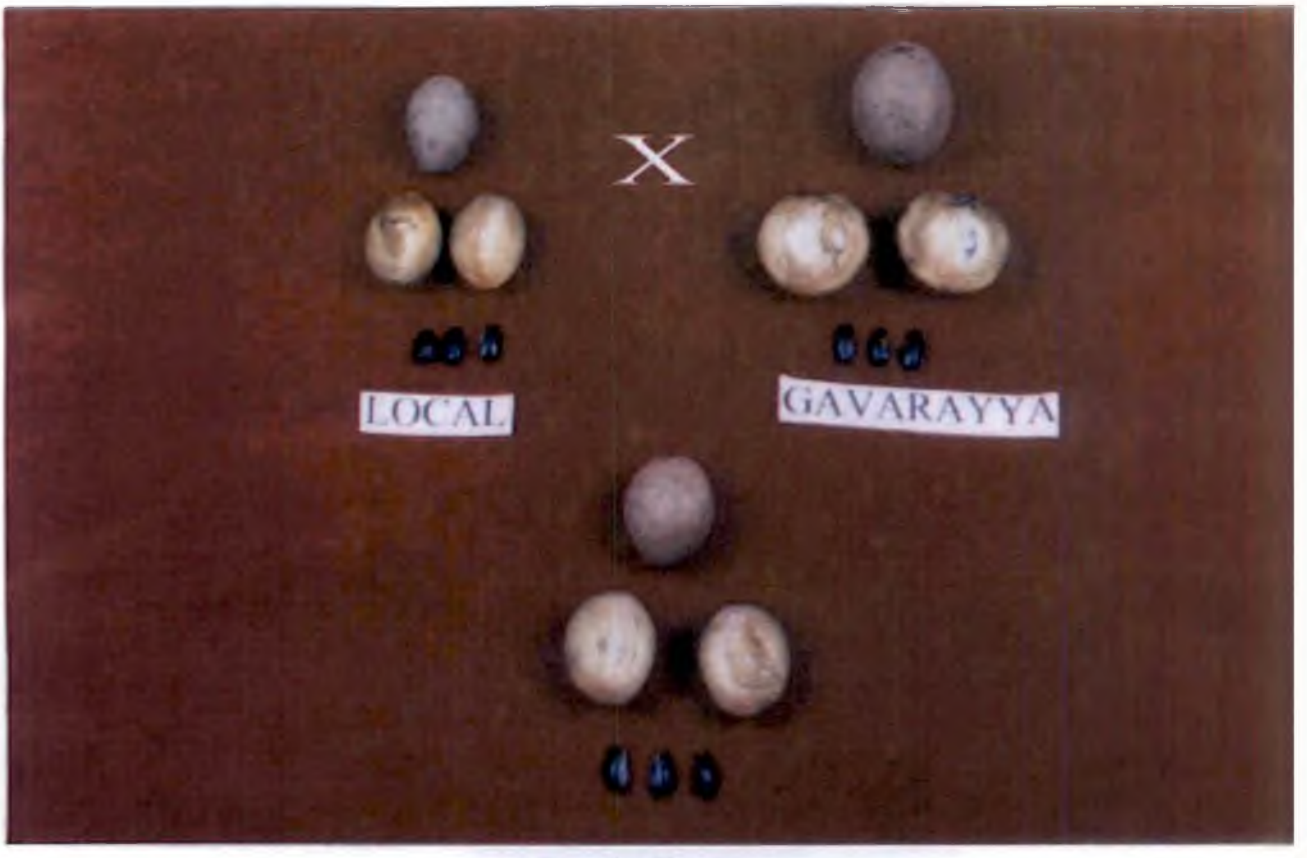



r. PKM-1 x Gavarayya

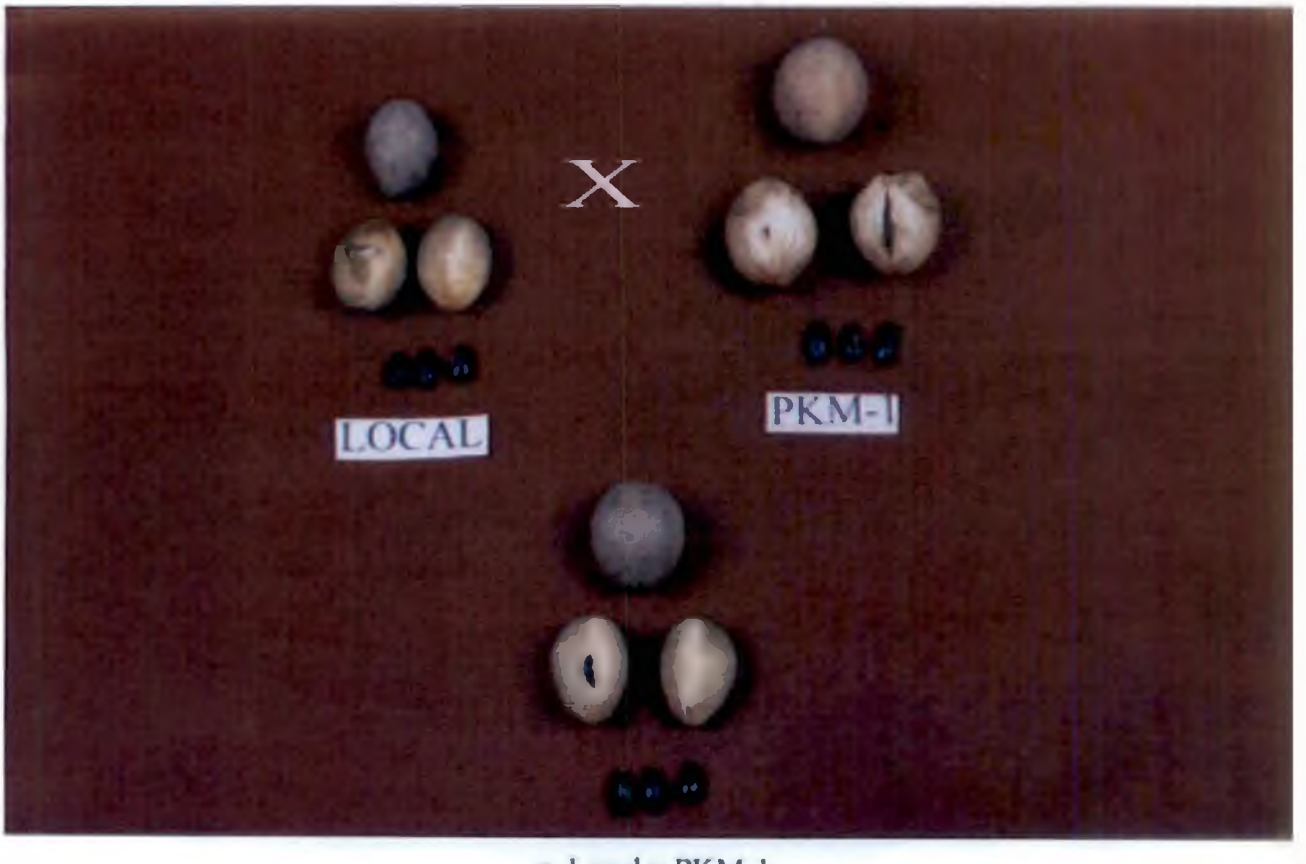



s. PKM-1 x Local

Plate : 12. (Contd.) Intervarietal compatibility between different sapota varieties




t. Local x Gavarayya




u. Local x PKM-1

Plate : 12. (Contd.) Intervarietal compatibility between different sapota varieties

### 4.12.2.Fruit drop in crossed fruits

The extent of fruit drop was maximum in the Cricket Ball X Co-2 cross combination (55.55%) followed by Gavarayya X Co-2 (46.15%). Fruit drop was minimum in Gavarayya X PKM-1 cross combination (9.09%). Cross combinations involving PKM-1 X Oval, Oval X PKM-1, PKM-1 X Co-2, Oval X Gavarayya and PKM-1 X Gavarayya recorded minimum fruit drop of 10.0%, 11.11 %, 12.5% and 13.33 % respectively.

### 4.12.3.Physical characters of crossed fruits

#### *4.12.3.1.Fruit weight*

The physical characters of the fruits obtained from different cross combinations were given in Table19.

Fruit weight was maximum in the Cricket Ball X Co-2 cross combination (180.80 g) followed by Cricket Ball X Oval (175.19 g). Minimum fruit weight was recorded in the cross combinations involving Local X Gavarayya (38.87 g) and Local X PKM-1 (40.27 g). In cross combination involving PKM-1 as the female parent, Cricket Ball gave the maximum fruit weight (77.34 g) when it was used as pollen parent. Minimum fruit weight was recorded when Local was used as pollen parent (103.86 g). In Gavarayya as female parent combination, use of Cricket Ball pollen resulted in maximum fruit weight (137.26 g) followed by Oval (130.56 g). The cross combinations involving Cricket Ball as female parent, use of Co-2 as pollen parent gave maximum fruit weight (180.80g) followed by Oval (175.19 g) and minimum fruit weight was recorded with Gavarayya as pollen parent (126.53 g). With Co-2 as female parent, use of Cricket Ball as pollen parent resulted in maximum fruit weight (173.81 g) and Gavarayya as pollen parent resulted in minimum fruit weight (117.33 g).

#### *4.12.3.2.Fruit length*

Maximum length of the fruit was recorded in cross Oval X Gavarayya (12.36 cm) followed by Gavarraya X Oval (11.40 cm) and minimum in the cross Co-2 X Cricket Ball (5.75 cm), Co-2 X Gavarayya (5.80 cm) and Local X PKM-1 (5.80 cm). Cricket Ball as

female parent use of Oval as pollen parent resulted in maximum fruit length (8.50 cm). With Gavarayya and PKM-1 as female parent, use of Oval as pollen parent resulted in greater fruit length (11.04 cm) and (8.25 cm) respectively.

***4.12.3.3.Fruit girth***

Fruit girth was maximum in the cross combinations Co-2 X Cricket Ball (17.6 cm), Cricket Ball X Gavarayya (17.5 cm), Cricket Ball X Co-2 (17.30 cm) and minimum in the cross Local X PKM-1 (5.00 cm) and Local X Gavarayya (5.20 cm). With Oval as female parent, use of Co-2 as pollen parent resulted in maximum fruit girth (16.15 cm). Use of Cricket Ball as pollen parent with Gavarayya resulted in maximum fruit girth (14.70 cm).

***4.12.3.4.Fruit volume***

Maximum fruit volume was recorded in the cross Cricket Ball X Co-2 (197.5 ml) followed by Cricket Ball X Oval (190.5 ml) and minimum fruit volume was recorded in the cross Local X PKM-1 (40.2 ml) and Local X Gavarayya (45.9 ml), use of Cricket Ball as pollen parent with PKM-1, Gavarayya and Co-2 resulted in maximum fruit volume (66.70 ml, 155.64 ml and 164.55 ml respectively).

***4.12.3.5.Specific gravity of fruit***

Specific gravity of fruit was maximum in the cross Cricket Ball X Co-2 (1.06) followed by Co-2 X Gavarayya (0.97) and Co-2 X Oval (0.96) and minimum in Local X PKM-1 (0.75) combinations.

***4.12.3.6.Pulp: seed ratio***

Pulp: seed ratio was maximum in the cross Oval X Co-2 (93.4) followed by Oval X Gavarayya (92.7) and minimum in Local X Gavarayya (23.2). Use of Oval as pollen parent with Co-2, Cricket Ball, Gavarayya and PKM-1 resulted in maximum pulp: seed ratio (74.6, 60.25 64.8 and 28.9 respectively).

**Table 19.Physical characters of the hybridized fruit**

| S.No | Cross combinations | Fruit weight (g) | Fruit length (cm) | Fruit girth (cm) | Fruit volume (ml) | Fruit specific gravity | Pulp: seed ratio | Shape |
|---|---|---|---|---|---|---|---|---|
| 1 | Co-2 X Cricket Ball | 173.81 | 5.75 | 17.60 | 164.55 | 1.06 | 64.25 | Round |
| 2 | Co-2 X Oval | 144.88 | 6.15 | 16.20 | 150.75 | 0.96 | 74.60 | Elongate |
| 3 | Co-2 X Gavarayya | 117.33 | 5.80 | 16.30 | 120.56 | 0.97 | 62.50 | Round |
| 4 | Cricket Ball X Co-2 | 180.80 | 6.74 | 17.30 | 197.50 | 0.92 | 59.50 | Flat bottom |
| 5 | Cricket Ball X Oval | 175.19 | 8.15 | 17.50 | 190.50 | 0.92 | 60.25 | Elongate |
| 6 | Cricket Ball X Gavarayya | 126.53 | 7.43 | 15.45 | 180.60 | 0.70 | 56.20 | Round Elongate |
| 7 | Oval X Co-2 | 140.40 | 11.10 | 16.15 | 165.20 | 0.85 | 93.40 | Stout oval |
| 8 | Oval X Gavarayya | 138.53 | 12.36 | 15.60 | 160.60 | 0.86 | 92.70 | Narrow |
| 9 | Oval X PKM-1 | 120.21 | 10.35 | 14.50 | 149.50 | 0.80 | 89.60 | oval |
| 10 | Gavarayya X Co-2 | 118.84 | 10.20 | 13.20 | 125.45 | 0.95 | 62.30 | Oval round |
| 11 | Gavarayya X Cricket Ball | 137.26 | 8.15 | 14.70 | 155.65 | 0.88 | 60.10 | Oblong round |
| 12 | Gavarayya X Oval | 130.56 | 11.40 | 14.00 | 145.33 | 0.89 | 64.80 | Elongate |
| 13 | Gavarayya X PKM-1 | 116.30 | 10.76 | 12.70 | 125.46 | 0.93 | 59.50 | Oval round |
| 14 | Gavarayya X Local | 103.86 | 10.35 | 11.75 | 120.23 | 0.86 | 60.20 | Elongate |
| 15 | PKM-1 X Co-2 | 58.31 | 7.50 | 12.40 | 65.40 | 0.89 | 27.50 | Stout round |
| 16 | PKM-1 X Cricket Ball | 77.34 | 7.43 | 13.70 | 66.70 | 0.84 | 26.40 | Stout round |
| 17 | PKM-1 X Oval | 70.24 | 8.25 | 13.40 | 65.45 | 0.85 | 28.90 | Narrow |
| 18 | PKM-1 X Gavarayya | 59.25 | 7.95 | 12.80 | 62.32 | 0.95 | 27.60 | oval |
| 19 | PKM-1 X Local | 51.68 | 7.28 | 10.10 | 55.70 | 0.93 | 26.80 | Oval round |
| 20 | Local X Gavarayya | 38.87 | 5.95 | 5.20 | 45.90 | 1.00 | 23.20 | Short oval |
| 21 | Local X PKM-1 | 40.27 | 5.80 | 5.00 | 40.20 | 0.75 | 24.20 | Egg shaped Narrow oval |

*4.12.3.7.Fruit shape*

In Cricket Ball X Co-2 cross combination, fruits were top and bottom compressed flat in nature whereas in Co-2 X Cricket Ball fruits with compressed round type were obtained, in Co-2 X Oval, fruits were compressed elongate while in Oval X Co-2, fruits were elongate and stout. In Oval X Gavarayya, fruits were bulged elongate, while in Gavarayya X Oval, fruits were elongated.

**4.12.4.Biochemical characters of crossed fruits**

*4.12.4.1.Total Soluble Solids*

TSS was maximum in the cross between PKM-1 X Gavarayya (26.20° Brix) followed by PKM-1 X Co-2 (25.20 ° Brix). Minimum TSS was recorded in the cross combinations of Co-2 X Gavarayya (20.35 ° Brix), Gavarayya X Cricket Ball and Co-2 X Oval (20.4 ° Brix each). TSS of the various crossed fruits was given in Table 20.

*4.12.4.2.Reducing sugars*

Reducing sugars was maximum in Gavarayya X Oval (12.90%) followed by Cricket Ball X Oval (12.80%) and minimum reducing sugar was recorded in Local X PKM-1 (9.55%). Use of Oval as pollen parent in Co-2 and PKM-1 crosses resulted in maximum fruit sugar (11.805 and 11.85% respectively)(Table 20).

*4.12.4.3.Non-reducing sugar*

Non-reducing sugar was maximum in Cricket Ball X Gavarayya (11.4%) followed by Cricket Ball X Oval (11.2%) and minimum non reducing sugar was recorded in Local x Gavarayya (5.5%). Use of Cricket Ball as pollen parent with Co-2 and PKM-1 resulted in maximum non-reducing sugar (9.5% and 7.6% respectively)(Table 20).

*4.12.4.4.Total sugars*

Total sugars were maximum in Cricket Ball X Oval (24.0%) followed by Cricket Ball X Gavarayya (23.6%) and minimum total sugar was recorded in Local X Gavarayya (15.1%). Total sugars of various crossed fruits were given in Table 20.

**Table 20. Biochemical characters of hybridized fruits**

| Cross combinations | TSS (°Brix) | Reducig sugars (%) | Non-reducing sugars (%) | Total sugars (%) | Acidity (%) | Sugar: acid ratio |
|---|---|---|---|---|---|---|
| Co-2 X Cricket Ball | 21.10 | 11.80 | 9.50 | 21.30 | 0.22 | 96.82 |
| Co-2 X Oval | 20.44 | 11.80 | 8.75 | 20.55 | 0.11 | 186.82 |
| Co-2 X Gavarayya | 20.35 | 11.40 | 8.80 | 19.20 | 0.10 | 192.00 |
| Cricket Ball X Co-2 | 21.30 | 12.70 | 10.60 | 23.30 | 0.12 | 194.17 |
| Cricket Ball X Oval | 23.50 | 12.80 | 11.20 | 24.0 | 0.11 | 218.18 |
| Cricket Ball X Gavarayya | 22.45 | 12.20 | 11.40 | 23.60 | 0.12 | 196.67 |
| Oval X Co-2 | 23.55 | 11.70 | 7.40 | 19.10 | 0.11 | 173.64 |
| Oval X Gavarayya | 23.40 | 12.10 | 6.80 | 18.90 | 0.12 | 171.82 |
| Oval X PKM-1 | 24.10 | 12.40 | 7.30 | 19.70 | 0.12 | 164.17 |
| Gavarayya X Co-2 | 23.80 | 12.40 | 8.60 | 21.0 | 0.22 | 149.17 |
| Gavarayya X Cricket Ball | 20.40 | 10.70 | 7.10 | 17.90 | 0.11 | 162.73 |
| Gavarayya X Oval | 22.90 | 12.90 | 6.40 | 19.30 | 0.13 | 148.46 |
| Gavarayya X PKM-1 | 23.40 | 11.80 | 6.20 | 18.00 | 0.11 | 163.64 |
| Gavarayya X Local | 23.10 | 11.10 | 6.30 | 19.40 | 0.10 | 194.00 |
| PKM-1 X Co-2 | 23.20. | 11.55 | 6.50 | 18.05 | 0.11 | 164.10 |
| PKM-1 X Cricket Ball | 22.30 | 11.75 | 7.60 | 19.40 | 0.11 | 176.36 |
| PKM-1 X Oval | 24.50 | 11.85 | 6.70 | 18.45 | 0.12 | 153.75 |
| PKM-1 X Gavarayya | 26.20 | 10.90 | 6.50 | 18.40 | 0.11 | 167.27 |
| PKM-1 X Local | 23.15 | 11.44 | 6.00 | 17.44 | 0.11 | 158.55 |
| Local X Gavarayya | 24.50 | 9.60 | 5.50 | 15.10 | 0.12 | 125.83 |
| Local X PKM-1 | 23.20 | 9.55 | 6.80 | 15.35 | 0.12 | 127.92 |

*4.12.4.5.Acidity*

Acidity was maximum in the cross Co-2 X Cricket Ball (0.22%) and Gavarayya X Co-2 (0.22%) combinations. Minimum acidity was recorded in Co-2 X Gavarayya (0.10%), Gavarayya X Local (0.10%)(Table 20).

*4.12.4.6.Sugar: acid ratio*

Sugar: acid ratio was maximum in Cricket Ball X Oval (218.18) followed by Cricket Ball X Gavarayya (196.67) and minimum sugar: acid ratio was recorded in Co-2 X Cricket Ball (96.82) cross combinations (Table 20).

**4.12.5.Seed characters**

*4.12.5.1.Number of seeds per fruit*

Maximum number of seeds per fruit was recorded in Cricket Ball X Oval (5.4), Cricket Ball X Gavarayya (5.3) and Cricket Ball X Co-2 (5.2) and minimum number of seeds per fruit was recorded in Local X Gavarayya (1.4) and Local X PKM-1 (1.5). Number of seeds per fruit recorded in different crossed fruits was given in Table 21.

*4.12.5.2.Length of seeds*

Length of seed was maximum in Cricket Ball X Co-2, Cricket Ball X Oval and Oval X Co-2 cross combinations (3.5 cm) (Table 22). Minimum length of seed was recorded in PKM-1 X Oval (2.5 cm), Local X Gavarayya (2.6 cm) and Local X PKM-1 crosses (2.6 cm).

*4.12.5.3.Breadth of seed*

Breadth of seed was maximum in Gavarayya X Local and Gavarayya X Cricket Ball (2.9 cm) each followed by Gavarayya X Co-2, Gavarayya X PKM-1 (2.8 cm each). Minimum breadth of seed was recorded in Cricket Ball X Gavarayya (1.7 cm) and Local X Gavarayya (1.7 cm).

*4.12.5.4.Seed weight per fruit*

Seed weight per fruit was maximum in the cross Cricket Ball X Gavarayya (4.60 g) followed by Cricket Ball X Oval (4.50 g) and Co-2 X Oval (4.15 g). Minimum seed weight per fruit was recorded in PKM-1 X Local (2.3 g) and PKM-1 X Oval (2.40 g). Seed weight per fruit recorded in different crossed fruits was given in Table 21.

*4.12.5.5.Seed shape*

A detailed account on the shape of seed of different crossed fruits was given in Table 21. The shape of seed in Co-2 X Cricket Ball is oval, stout with blunt tip, whereas in Cricket Ball X Co-2, the shape of the seed was elongated oval. In Co-2 X Oval, seed shape was elongated, slightly blunt at tip while in Oval X Co-2, shape of the seed was oval with blunt tip.

**4.12.6.Days taken for maturity**

Number of days taken for maturity was minimum in the cross Local X PKM-1 (149.0 days) followed by Gavarayya X Oval (152.0 days), Local X Gavarayya (154.0 days) and PKM-1 X Local (154.6 days). Maximum days taken for maturity were for the cross Co-2 X Cricket Ball (167.2 days), Cricket Ball X Co-2 (167.2 days), Co-2 X Oval (166.0 days). Use of Oval as pollen parent with Gavarayya and PKM-1 resulted in minimum number of days taken for maturity (162.6 days and 161.0 days respectively)(Table 16).

**4.12.7.Seed germination**

Seed germination per centage was maximum in the cross Oval x Co-2 (88.89 %) followed by Co-2 X Oval (66.67%) and Gavarayya X Co-2 (52.94%). Minimum germination per centage was recorded in Gavarayya X Oval (20.0%) followed by Gavarayya X Local (23.08%). Seed germination per centage of different crossed fruits was given in Table 22 and Plate 13.

Number of days taken for seed germination was minimum in the cross Local X PKM-1 (15.3 days) followed by Local X Gavarayya (16.2 days). Maximum number of

**Table 21. Seed characters of hybridized fruits**

| Cross combinations | Number of seed/fruit | Seed length (cm) | Seed breadth (cm) | Seed weigh fruit (g) | Shape of the seed |
|---|---|---|---|---|---|
| Co-2 X Cricket Ball | 3.2 | 3.3 | 2.0 | 3.20 | Oval, stout, blunt tip |
| Co-2 X Oval | 2.9 | 3.4 | 2.1 | 4.15 | Elongate, bent tip |
| Co-2 X Gavarayya | 2.8 | 3.2 | 1.9 | 3.10 | Oval, broad base |
| Cricket Ball X Co-2 | 5.2 | 3.5 | 2.1 | 3.30 | Elongate oval |
| Cricket Ball X Oval | 5.4 | 3.5 | 2.0 | 4.50 | Elongate, blunt end |
| Cricket Ball X Gavarayya | 5.3 | 3.3 | 1.7 | 4.60 | Oval |
| Oval X Co-2 | 3.6 | 3.5 | 2.2 | 4.10 | Oval, bent tip |
| Oval X Gavarayya | 3.4 | 3.0 | 2.1 | 3.90 | Elongate, stout,blunt |
| Oval X PKM-1 | 3.5 | 3.0 | 2.0 | 3.40 | Oval/elongated |
| Gavarayya X Co-2 | 2.2 | 3.0 | 2.8 | 3.10 | Oval |
| Gavarayya X Cricket Ball | 2.4 | 3.0 | 2.9 | 3.30 | Oval, blunt tip |
| Gavarayya X Oval | 2.3 | 3.1 | 2.7 | 3.26 | Oval/elongate |
| Gavarayya X PKM-1 | 2.2 | 3.0 | 2.8 | 2.87 | Short, oval, stout |
| Gavarayya X Local | 2.2 | 3.0 | 2.9 | 2.79 | Oval, thick |
| PKM-1 X Co-2 | 2.0 | 2.8 | 1.5 | 2.60 | Short, oval, stout |
| PKM-1 X Cricket Ball | 2.0 | 2.7 | 1.8 | 2.70 | Short, oval, stout |
| PKM-1 X Oval | 1.7 | 2.5 | 2.1 | 2.40 | Short, thick |
| PKM-1 X Gavarayya | 1.8 | 2.8 | 2.0 | 2.50 | Short, oval, stout |
| PKM-1 X Local | 1.6 | 2.7 | 1.9 | 2.30 | Short, stout |
| Local X Gavarayya | 1.4 | 2.6 | 1.7 | 2.60 | Short, oval, stout |
| Local X PKM-1 | 1.5 | 2.6 | 1.8 | 2.75 | Short, oval, stout |

**Table 22.Seed germination of hybridized fruits**

| Sl.No. | Cross combinations | Number of seeds sown | Number of seeds germinated | Germination percentage | Days taken for seedling emergence |
|---|---|---|---|---|---|
| 1 | Co-2 X Cricket Ball | 32 | 8 | 25.00 | 18.0 |
| 2 | Co-2 X Oval | 12 | 8 | 66.67 | 18.5 |
| 3 | Co-2 X Gavarayya | 45 | 11 | 24.44 | 19.3 |
| 4 | Cricket Ball X Co-2 | 42 | 15 | 35.71 | 17.5 |
| 5 | Cricket Ball X Oval | 64 | 18 | 28.13 | 16.4 |
| 6 | Cricket Ball X Gavarayya | 60 | 20 | 33.33 | 19.0 |
| 7 | Oval X Co-2 | 18 | 16 | 88.89 | 18.3 |
| 8 | Oval X Gavarayya | 40 | 15 | 37.50 | 17.5 |
| 9 | Oval X PKM-1 | 25 | 10 | 40.00 | 16.4 |
| 10 | Gavarayya X Co-2 | 17 | 9 | 52.94 | 19.2 |
| 11 | Gavarayya X Cricket Ball | 19 | 8 | 42.11 | 21.3 |
| 12 | Gavarayya X Oval | 30 | 6 | 20.00 | 16.7 |
| 13 | Gavarayya X PKM-1 | 26 | 7 | 35.00 | 18.3 |
| 14 | Gavarayya X Local | 13 | 3 | 23.08 | 19.2 |
| 15 | PKM-1 X Co-2 | 14 | 8 | 35.71 | 17.8 |
| 16 | PKM-1 X Cricket Ball | 14 | 7 | 50.00 | 16.9 |
| 17 | PKM-1 X Oval | 15 | 6 | 40.00 | 16.9 |
| 18 | PKM-1 X Gavarayya | 23 | 7 | 30.43 | 17.4 |
| 19 | PKM-1 X Local | 12 | 4 | 33.33 | 18.2 |
| 20 | Local X Gavarayya | 12 | 4 | 33.33 | 16.2 |
| 21 | Local X PKM-1 | 9 | 3 | 33.33 | 15.3 |

Plate : 13. Intervarietal seedling of sapota

days taken for seed germination was recorded in Gavarayya X Cricket Ball (21.3 days) followed by Co-2 X Gavarayya (19.3 days) and Gavarayya X Local (19.20 days) cross combinations (Table 22).

**4.12.8.Methods to overcome incompatibility barrier**

Pollination after removing the stigma and pollinating with *in vitro* basal medium, pollination with application of NAA 5.0 mg $l^{-1}$, 2,4-D-0.5 mg $l^{-1}$, pollination with gamma rays irradiated (40Gy, 50Gy and 75 Gy) pollen resulted in fruit set. But, the percentage of fruit set was very minimum and all the few fruits set were dropped within one week after fruit set (Table 23).

## 4.13.CORRELATION BETWEEN WEATHER PARAMETERS AND YIELD CHARACTERS

The studies revealed that number of flushes per unit area, number of inflorescence per metre square and fruit set was positively correlated with minimum temperature. Fruit weight, girth, volume, TSS, reducing sugars, total sugars and yield were positively correlated with maximum temperature. Sunshine hours were positively significant in correlation with reducing sugars; total sugars and yield while, rainfall had a negative correlation with the biochemical characters of fruits and total yield. Maximum temperature and wind are positively correlated with fruit drop. Correlation between weather parameters and yield characters were presented in Table 24(a, b).

## 4.14.VARIABILITY, COEFFICIENT OF VARIATION, HERITABILITY AND GENETIC ADVANCE

Among the characters, maximum variability was displayed for tree volume, number of flushes per metre square, flush length, number of inflorescence per metre square, fruitset percentage, fruit weight, girth, volume, number of fruits per tree. Phenotypic coefficient of variation ranged between 4.46 to 108.52 per cent and genotypic coefficient of variation ranged between 0.04 to 104.18 per cent (Table 25a and 25b). Tree volume, fruit weight, fruit volume, number of fruits per tree recorded high GCV and PCV

**Table 23.Methods to overcome incompatibility barrier**

| Sl.No. | Treatments | Number of flowers pollinated | Number of fruits set | Fruit set (%) | Fruit drop stage (days after fruit set) | Fruit drop (%) |
|---|---|---|---|---|---|---|
| 1 | Bud pollination | 15 | 0 | 0 | 0 | 0 |
| 2 | Pollination after cutting the stigma | 10 | 0 | 0 | 0 | 0 |
| 3 | Removal of stigma and pollination with basal medium | 15 | 0 | 0 | 0 | 100 |
| 4 | Removal of part of style and pollination with basal medium | 10 | 0 | 0 | 0 | 0 |
| 5 | Pollination with *in vitro* germinated pollen grains | 10 | 0 | 0 | 0 | 0 |
| 6 | End of season pollination | 15 | 0 | 0 | 0 | 0 |
| 7 | Pollination with NAA 5 mg $l^{-1}$ | 15 | 7 | 46.6 | 7 | 100 |
| 8 | Pollination with kinetin 5$mgl^{-1}$ | 15 | 0 | 0 | 0 | 0 |
| 9 | Pollination with 2,4-D0.5$mgl^{-1}$ | 15 | 5 | 33.3 | 3,6 | 100 |
| 10 | Pollination with 2,4-D1.0$mgl^{-1}$ | 10 | 0 | 0 | 0 | 0 |
| 11 | Double pollination | 15 | 0 | 0 | 0 | 0 |
| 12 | Removal of style and direct application of pollen on ovary | 15 | 0 | 0 | 0 | 0 |
| 13 | Pollination with gamma irradiated pollen@10Gy | 20 | 0 | 0 | 0 | 0 |
| 14 | Pollination with gamma irradiated pollen@20Gy | 25 | 0 | 0 | 0 | 0 |
| 15 | Pollination with gamma irradiated pollen@30Gy | 20 | 0 | 0 | 0 | 0 |
| 16 | Pollination with gamma irradiated pollen@40Gy | 25 | 3 | 12.0 | 2 | 100 |
| 17 | Pollination with gamma irradiated pollen@50Gy | 25 | 6 | 24.0 | 5 | 100 |
| 18 | Pollination with gamma irradiated pollen@75Gy | 25 | 2 | 8.0 | 7 | 100 |
| 19 | Pollination with gamma irradiated pollen@100Gy | 25 | 0 | 0 | 0 | 0 |

**Table 24. Correlation between weather parameters and yield and yield attributing characters**

| Weather parameters | No. of flushes/$m^2$ | No.inflorescence/$m^2$ | Fruit set | Fruit drop | Fruit weight | Fruit girth |
|---|---|---|---|---|---|---|
| Maximum temperature ($^o$ C) | 0.238 | 0.026 | -0.401 | 0.438* | 0.503* | 0.452* |
| Minimum temperature ($^o$ C) | 0.446* | 0.846** | 0.434* | -0.580** | -0.186 | -0.592** |
| Relative humidity-morning(%) | 0.307 | 0.683** | 0.207 | -0.435* | -0.492* | -0.806** |
| Relative humidity - evening(%) | 0.294 | 0.396 | 0.440* | -0.430 | -0.827** | -0.660** |
| Relative humidity-mean (%) | 0.687** | 0.497* | 0.442* | -0.445* | -0.773** | -0.718** |
| Rainfall (mm) | 0.447 | 0.551** | -0.157 | 0.280 | -0.572** | -0.698** |
| Sunshine (hours $day^{-1}$) | -0.216 | 0.398 | -0.390 | 0.336 | 0.631** | 0.602** |
| Wind speed (km/hr) | -0.664** | 0.259 | 0.418 | 0.471* | -0.594** | 0.651** |
| Soil temperature ($^o$C) | -0.715** | 0.349 | -0.027 | 0.435 | 0.565** | 0.088 |

* - indicates significance at 5% level
** - indicates significance at 1% level

**Table 24 (contd.). Correlation between weather parameters and yield and yield attributing characters**

| Weather parameters | Fruit volume (ml) | TSS (° Brix) | Reducing sugar (%) | Total sugar (%) | Acidity (%) | Yield (kg) |
|---|---|---|---|---|---|---|
| Maximum temperature (° C) | 0.434* | 0.444* | 0.459* | 0.462* | 0.421 | 0.434* |
| Minimum temperature (° C) | -0.583** | -0.260 | -0.492* | -0.296 | 0.441 | -0.306 |
| Relative humidity-morning (%) | -0.174 | -0.588** | -0.216 | -0.257 | 0.460* | -0.310 |
| Relative humidity -evening (%) | -0.186 | -0.321 | -0.089 | -0.270 | -0.390 | -0.208 |
| Relative humidity-mean (%) | -0.175 | -0.492* | -0.516* | -0.279 | -0.470* | -0.248 |
| Rainfall (mm) | -0.221 | 0.600** | -0.544* | -0.399 | -0.279 | 0.345 |
| Sunshine (hours $day^{-1}$) | 0.315 | 0.466* | 0.496* | 0.578** | 0.362 | 0.446* |
| Wind speed (km/hr) | 0.139 | 0.348 | 0.430 | 0.448* | 0.394 | -0.430 |
| Soil temperature (°C) | 0.239 | 0.434* | 0.457* | 0.470* | 0.346 | 0.254 |

* - indicates significance at 5% level
** - indicates significance at 1% level

(GCV ranged between 48.77 to 104.18 per cent while, PCV ranged between 48.72 to 108.52 per cent). Other characters like number of flowers per inflorescence, per cent flowering shoots, fruit drop, flush length and tree girth recorded low GCV and PCV (GCV ranged between 0.04 to 23.58 per cent and PCV ranged between 4.46 to 23.96 per cent). The phenotypic and genotypic coefficient of variation for number of seeds per fruit was 54.0 per cent and 56.8 per cent and for seed weight per fruit was found to be 54.17 per cent and 56.914 per cent respectively.

Characters like fruit girth, number of seeds per fruit, canopy spread and fruit weight (0.97), seed weight per fruit, tree girth recorded high heritability. Number of flushes per metre square, percentage flowering shoots, yield, number of flowers per inflorescence recorded low heritability.

Genetic advance recorded for the characters showed wide variation ranging between 0.21 to 119.04 per cent. Maximum genetic advance was observed for fruit weight (119.04) followed by fruit volume (118.92).

## 4.15.ANALYSIS OF GROWTH AND YIELD COMPONENTS

### 4.15.1.Correlation of morphological traits with yield.

The genotypic and phenotypic correlation of vegetative, flowering and fruit characters with yield were worked out.

The vegetative characters showing high positive correlation with fruit yield were tree height, tree girth while flowering characters were number of inflorescence per metre square, number of flowers per inflorescence and fruit characters were per cent fruit set, fruit weight, fruit girth and fruit volume. The genotypic correlations for these characters ranged from 0.556 to 0.654 while phenotypic correlation ranged from 0.450 to 0.581. The genotypic and phenotypic correlation recorded were the highest for number of flowers per inflorescence (rg = 1.113 and rp =0.681). Maximum negative correlation was observed for fruit drop (rg =-1.86 and rp =-0.247).

**Table 25.Genetic parameters of yield and yield attributing characters**

| Sl.No. | Characters | Range | Mean | GV | PV | GCV | PCV |
|---|---|---|---|---|---|---|---|
| 1 | Tree height (m) | 2.75-7.97 | 5.42 | -0.053 | 0.285 | 32.36 | 34.10 |
| 2 | Tree girth (m) | 0.32-2.65 | 0.48 | 0.025 | 0.439 | 23.58 | 23.96 |
| 3 | Canopy spread (m) | 3.08-7.60 | 4.68 | -0.121 | 0.470 | 35.20 | 35.58 |
| 4 | Tree volume ($m^3$) | 10.77-163.12 | 53.49 | -0.034 | 0.230 | 104.18 | 108.52 |
| 5 | No. of flushes /$m^2$ | 5.0-12.25 | 7.90 | -0.032 | 0.367 | 30.41 | 39.55 |
| 6 | Flush length (cm) | 6.82-13.82 | 10.87 | -0.124 | 0.639 | 23.48 | 24.82 |
| 7 | No. of leaves /flush | 7.0-15.75 | 10.88 | 0.105 | 0.267 | 34.58 | 36.50 |
| 8 | Shoot girth (cm) | 1.04-2.62 | 1.73 | -0.098 | 0.426 | 32.45 | 35.05 |
| 9 | Flowering shoots (%) | 81.25-87.25 | 84.25 | -0.003 | 0.142 | 0.73 | 4.46 |
| 10 | No. of inflorescence/ $m^2$ | 7.0-13.0 | 9.54 | 0.019 | 0.182 | 24.86 | 28.24 |
| 11 | No. of flowers per inflorescence | 4.5-6.5 | 5.59 | -0.087 | 0.474 | 11.26 | 17.50 |
| 12 | Fruit set (%) | 19.69-38.88 | 26.10 | -0.180 | 0.724 | 25.18 | 27.69 |
| 13 | Fruit drop (%) | 82.85-86.09 | 83.64 | -0.075 | 0.462 | 0.04 | 8.76 |
| 14 | Fruit weight (g) | 35.01-187.20 | 117.71 | -0.209 | 0.765 | 49.79 | 50.49 |
| 15 | Fruit girth (cm) | 4.59-17.62 | 13.05 | 0.132 | 0.603 | 38.25 | 38.29 |
| 16 | Fruit volume (ml) | 42.07-195.17 | 118.40 | -0.001 | 0.133 | 48.77 | 48.78 |
| 17 | No. of seeds per fruit | 1.38-5.64 | 2.88 | 0.204 | 0.353 | 54.00 | 54.17 |
| 18 | Seed weight per fruit (g) | 1.54-8.31 | 4.19 | -0.003 | 0.217 | 56.81 | 56.91 |
| 19 | No. of fruits per tree | 28.75-121.25 | 56.25 | 0.079 | 0.199 | 57.63 | 60.80 |
| 20 | Fruit yield (kg) | 1.71-6.85 | 5.27 | 0.009 | 0.131 | 36.43 | 42.02 |

Table 25(contd.). Genetic parameters of yield and yield attributing characters

| Sl.No | Characters | Heritability | Genetic advance | Genetic advance as percent of mean |
|---|---|---|---|---|
| 1 | Tree height (m) | 0.90 | 3.43 | 63.34 |
| 2 | Tree girth (m) | 0.97 | 0.23 | 48.02 |
| 3 | Canopy spread (m) | 0.98 | 3.35 | 71.66 |
| 4 | Tree volume ($m^3$) | 0.92 | 110.19 | 206.00 |
| 5 | No. of flushes /$m^2$ | 0.59 | 3.81 | 48.20 |
| 6 | Flush length (cm) | 0.89 | 4.97 | 45.73 |
| 7 | No. of leaves /flush | 0.89 | 7.34 | 67.49 |
| 8 | Shoot girth (cm) | 0.86 | 1.07 | 61.96 |
| 9 | Flowering shoots | 0.03 | 0.21 | 0.25 |
| 10 | No. of inflorescence/$m^2$ | 0.78 | 4.30 | 45.06 |
| 11 | No. of flowers per inflorescence | 0.41 | 0.83 | 14.84 |
| 12 | Fruit set (%) | 0.83 | 12.31 | 47.16 |
| 13 | Fruit drop (%) | 0.90 | 0.00 | 0.047 |
| 14 | Fruit weight (g) | 0.97 | 119.04 | 101.13 |
| 15 | Fruit girth (cm) | 1.99 | 10.28 | 78.76 |
| 16 | Fruit volume (ml) | 0.01 | 118.92 | 100.44 |
| 17 | No. of seeds per fruit | 0.99 | 3.19 | 110.92 |
| 18 | Seed weight per fruit | 0.99 | 4.90 | 116.92 |
| 19 | No. of fruits per tree | 0.89 | 63.71 | 113.26 |
| 20 | Fruit yield (kg) | 0.75 | 3.42 | 64.96 |

**4.15.2.Interrelation among characters**

The tree height recorded significantly negative correlation with fruit set and number of fruits per tree at both genotypic and phenotypic level (rg=-0.343 and rp=-0.39; rg=-0.326 and rp=-0.353). Trunk girth recorded positive correlation except fruit set and fruit drop at both genotypic and phenotypic level. Tree girth was highly negatively correlated with fruit set. Tree spread registered highest positive genotypic correlation with per cent flowering shoot and number of flushes per metre square while number of fruits per tree recorded the highest negative correlation (rg = -0.496 and rp= - 0.463). Similar trend was observed for tree volume.

The flushes per unit area were positively correlated with number of inflorescence per metre square (rg= 0.627). Maximum correlation of flushes per unit area was recorded with seed weight per fruit (rg= 1.066 and rp =0.819). Flush length recorded high positive correlation with fruit girth (rg= 0.989 and rp = 0.933) and highest negative correlation with fruit drop (rg = -17.30).

Number of leaves per flush was negatively associated with fruit set, fruit drop and number of fruits per tree and highest negative association was observed for fruit drop (rg= -21.208) and inflorescence per unit area registered high positive correlation with number of flowers per inflorescence (rg= 1.08) followed by yield (rg= 0.749 and rp=0.618). Similar correlation was observed between number of flowers per inflorescence and the characters under study.

Fruit set was positively correlated with number of flowers per inflorescence (rg= 0.566) and number of inflorescence per meter square (rg= 0.465). Maximum correlation was observed between fruit set and number of fruits per tree (rg=1.005) and hence the yield (rg = 0.463).

Fruit weight was highly positively correlated with per cent flowering shoots (rg =1.409) followed by number of flushes per unit area (rg =0.985). Maximum phenotypic correlation coefficient observed was between fruit weight and fruit volume (rp = 0.965) and fruit girth (rp = 0.932). Number of fruits per tree was highly correlated with fruit set (rg = 1.005) and rp = 0.902) followed by number of inflorescence per unit area (rg = 0.455 and rp = 0.423). All other characters had negative correlation with number of fruits per tree.

**Table 26. Genotypic correlations between yield and yield attributing characters**

| Characters | Tree girth (m) | Canopy spread (m) | Tree volume (m3) | No. of flushes /m2 | Flush length | No. of leaves /flush | Shoot girth | Shoots flowere | Inflorescence /m2 |
|---|---|---|---|---|---|---|---|---|---|
| Tree height (m) | 1.018** | 0.850** | 0.862** | 1.018** | 0.915** | 0.823** | 0.836** | 1.156** | 0.551* |
| Tree girth (m) | | 0.846** | 0.879** | 1.028** | 0.855** | 0.797** | 0.816** | 1.112** | 0.554* |
| Canopy spread (m) | | | 0.977** | 1.012** | 0.625** | 0.778** | 0.794** | 1.176** | 0.467* |
| Tree volume(m3) | | | | 1.017** | 0.591** | 0.778** | 0.861** | 1.017** | 0.627** |
| No. of flushes/m2 | | | | | 0.902** | 1.006** | 0.977** | 0.525* | 0.602** |
| Flush length | | | | | | 0.864** | 0.717** | 0.351 | 0.258 |
| No. of leaves/flush | | | | | | | 0.878** | 0.061 | 0.377 |
| Shoot girth | | | | | | | | -0.475* | 0.820** |
| Flowering shoots | | | | | | | | | 0.955** |

* -indicates significance at 5% level (r =0.444)

** -indicates significance at 1% level(r =0.561)

**Table 26(contd.) Genetic correlations between yield and yield attributing character**

| Characters | No. of flowers per inflores-cence | Fruit set (%) | Fruit drop (%) | Fruit weight (gm) | Fruit girth (cm) | Fruit volume (ml) | No. of seeds per fruit | Seed weight per fruit | No. of fruits per tree | Fruit yield (Kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Tree height (m) | 0.718** | -0.34 | 8.533** | 0.984** | 0.938** | 0.992** | 0.932** | 0.958** | -0.397 | 0.654** |
| Tree girth (m) | 0.735** | -0.38 | 12.87** | 0.941** | 0.890** | 0.981** | 0.944** | 0.961** | -0.406 | 0.626** |
| Canopy spread(m) | 0.676** | -0.39 | 8.617** | 0.848** | 0.716** | 0.822** | 0.935** | 0.890** | -0.496* | 0.473* |
| Tree volume($m^3$) | 0.693** | -0.35 | 17.85** | 0.795** | 0.678** | 0.824** | 0.966** | 0.946** | -0.413 | 0.482* |
| No. of flushes/$m^2$ | 0.574** | -0.41 | -5.02* | 0.985** | 0.938** | 0.997** | 1.045** | 1.066** | -0.500* | 0.497* |
| Flush length | 0.458* | -0.38 | -17.3** | 0.918** | 0.989** | 0.917** | 0.735** | 0.803** | -0.445* | 0.504* |
| No. of leaves/flush | 0.386 | -0.45 | -21.2** | 0.809** | 0.841** | 0.841** | 0.857** | 0.909** | -0.561* | 0.230 |
| Shoot girth | 0.900** | 0.006 | -5.40** | 0.695** | 0.781** | 0.740** | 0.808** | 0.919** | -0.090 | 0.601** |
| Flowering shoots | -0.060 | -0.04 | 2.02 | 1.409** | 0.488* | 1.321** | 1.178** | 0.554* | -1.544* | 0.515* |
| No. of inflorescence/m2 | 1.081** | 0.440 | 3.29** | 0.286 | 0.379 | 0.371 | 0.482* | 0.620** | 0.455* | 0.749** |
| No. of flowers per inflorescence | | 0.56* | -1.04** | 0.598** | 0.658** | 0.544* | 0.569** | 0.680** | 0.457* | 1.113** |
| Fruit set (%) | | | -1.087* | -0.488* | -0.261 | -0.524 | -0.533* | -0.375 | 1.005** | 0.463* |
| Fruit drop (%) | | | | -4.517* | -17.98* | 8.381** | 22.615** | 12.914** | 6.007** | -15.6** |
| Fruit weight (gm) | | | | | 0.945** | 0.978** | 0.883** | 0.874** | -0.555* | 0.556* |
| Fruit girth (cm) | | | | | | 0.914** | 0.765** | 0.831** | -0.353 | 0.637** |
| Fruit volume (ml) | | | | | | | 0.929** | 0.928** | -0.559* | 0.497* |
| No. of seeds per fruit | | | | | | | | 0.975** | -0.570* | 0.401 |
| Seed weight per fruit | | | | | | | | | -0.427 | 0.501* |
| No. of fruits per tree | | | | | | | | | | 0.494* |

*- significance at 5% level (r =0.444) **- significance at 1% level (r =0.561)

**Table 27. Phenotypic correlations between yield and yield attributing characters**

| Characters | Tree girth (m) | Canopy spread (m) | Tree volume (m3) | No. of flushes /m2 | Flush length | No. of leaves /flush | Shoot girth | Shoots Flowered | Inflorescence /m2 |
|---|---|---|---|---|---|---|---|---|---|
| Tree height (m) | 0.931** | 0.825** | 0.824** | 0.777** | 0.775** | 0.752** | 0.725** | 0.107 | 0.430 |
| Tree girth (m) | | 0.825** | 0.838** | 0.739** | 0.816** | 0.773** | 0.745** | 0.174 | 0.491* |
| Canopy spread (m) | | | 0.948** | 0.772** | 0.565** | 0.744** | 0.698** | 0.155 | 0.386 |
| Tree volume(m3) | | | | 0.790** | 0.533* | 0.765** | 0.762** | 0.052 | 0.524* |
| No. of flushes/m2 | | | | | 0.612** | 0.746** | 0.739** | 0.117 | 0.379 |
| Flush length | | | | | | 0.776** | 0.621** | 0.151 | 0.206 |
| No. of leaves/flush | | | | | | | 0.792** | -0.079 | 0.303 |
| Shoot girth | | | | | | | | -0.114 | 0.669** |
| Flowering shoots | | | | | | | | | 0.251 |

* -indicates significance at 5% level (r =0.444)

** -indicates significance at 1% level(r =0.561)

**Table 27(contd.)Phenotypic correlations between yield and yield attributing characters**

| Characters | No. of flowers per infloresc-ence | Fruit set (%) | Fruit drop (%) | Fruit weight (gm) | Fruit girth (cm) | Fruit volume (ml) | No. of seeds per fruit | Seed weight per fruit | No. of fruits per tree | Fruit yield (Kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Tree height (m) | 0.518* | -0.33 | 0.068 | 0.892** | 0.890** | 0.943** | 0.889** | 0.910** | -0.353 | 0.581 |
| Tree girth (m) | 0.426 | -0.341 | 0.131 | 0.931** | 0.875** | 0.967** | 0.924** | 0.941** | -0.373 | 0.538 |
| Canopy Spread(m) | 0.481* | -0.376 | 0.094 | 0.815** | 0.706** | 0.814** | 0.921** | 0.883** | -0.463* | 0.418 |
| Tree volume($m^3$) | 0.551* | -0.311 | 0.160 | 0.751** | 0.648** | 0.792** | 0.936** | 0.910** | -0.372 | 0.452 |
| No. of flushes/$m^2$ | 0.621** | -0.295 | 0.105 | 0.727** | 0.708** | 0.770** | 0.802** | 0.819** | -0.382 | 0.452 |
| Flush length | 0.257 | -0.344 | -0.125 | 0.874** | 0.933** | 0.865** | 0.696** | 0.752** | -0.435 | 0.334 |
| No. of leaves/flush | 0.271 | -0.387 | -0.010 | 0.760** | 0.795** | 0.797** | 0.813** | 0.855** | -0.488* | 0.215 |
| Shoot girth | 0.463* | 0.041 | -0.004 | 0.654** | 0.727** | 0.686** | 0.750** | 0.844** | -0.067 | 0.525 |
| Flowering shoots | -0.152 | -0.406 | -0.095 | 0.234 | 0.087 | 0.211 | 0.184 | 0.096 | -0.564* | 0.206 |
| No. of inflorescence/m2 | 0.488* | 0.433 | 0.003 | 0.252 | 0.330 | 0.325 | 0.437 | 0.537* | 0.423 | 0.618 |
| No. of flowers per inflorescence | | 0.262 | 0.199 | 0.342 | 0.409 | 0.353 | 0.375 | 0.446* | 0.262 | 0.681 |
| Fruit set (%) | | | -0.113 | -0.43 | -0.232 | -0.478* | -0.482* | -0.345 | 0.902* | 0.410 |
| Fruit drop (%) | | | | 0.043 | -0.084 | 0.053 | 0.076 | 0.066 | 0.039 | 0.247 |
| Fruit weight (gm) | | | | | 0.932** | 0.965** | 0.866** | 0.858** | -0.513* | 0.474 |
| Fruit girth (cm) | | | | | | 0.913** | 0.762** | 0.828** | -0.337 | 0.547 |
| Fruit volume (ml) | | | | | | | 0.925** | 0.926** | -0.526* | 0.437 |
| No. of seeds per fruit | | | | | | | | 0.969** | -0.545* | 0.339 |
| Seed weight per fruit | | | | | | | | | -0.405 | 0.431 |
| No. of fruits per tree | | | | | | | | | | 0.420 |

*- significance at 5% level (r =0.444) **- significance at 1% level (r =0.561)

DISCUSSION

# 5. DISCUSSION

A perusal on the experimental results indicates a number of observations, which are briefly discussed here under highlighting the various inferences. For any successful hybridization programme, knowledge about the compatible parents is a must. The present study was therefore taken up with a view to generate information on varietal characters, variability, heritability, genetic advance, correlation among characters, pollen and pollination studies and compatibility nature.

## 5.1.VEGETATIVE CHARACTERS

The relationship between vegetative growth and fruiting was studied in different tropical and subtropical tree crops like sapota, mango, guava, citrus, annona and nutmeg (Aravindakshan, 1960;Krishnamurthi *et al.*, 1960;Sundararajan, 1961; Randhawa and Singh, 1963;Singh and Ghose, 1965; Singh and Seghal, 1968;Singh, 1969;Reddy, 1983;Singh, 1986 and Aravindakshan, 1987). In this experiment height of the tree was maximum in the variety Cricket Ball (7.68m) followed by Oval (5.88m). The Local variety was the least short in stature (2.72m). Maximum girth of the tree was recorded in the variety Cricket Ball (0.63m) and the least girth in the Local variety. The variety Cricket Ball recorded the maximum canopy spread (7.40m) followed by Co-2 (5.16m). Volume of the tree was greatest in Cricket Ball (151.90 $m^3$). Varieties PKM-1 and Local recorded lower tree volume and they were on par with each other (13.65$m^3$ and 11.17 $m^3$ respectively). Number of flushes per square metre was maximum in the varieties Cricket Ball (15.11) and Co-2 (14.33). Maximum length of the flush was recorded in the varieties PKM-1 (13.10 cm), Gavarayya (12.68 cm) and Cricket Ball (12.13 cm). Maximum number of leaves which are considered as photosynthetically active young leaves per flush was recorded in the variety Cricket Ball (14.60cm). Girth of the shoot was maximum in the variety Cricket Ball (2.50 cm) followed by the variety Oval(1.79 cm). Total duration of flushing was maximum in the variety Oval (28.7 days) followed by Cricket Ball (27.6 days) and Gavarayya (27.2 days). The flushing span was lowest in the variety Local (18.0 days). Though periodical flushing in all the six sapota varieties under study occurred throughout the year, two seasons were observed as main seasons, viz., May –July

(first season) and September –November (second season). In the first season peak flushing period occurred between June 14th to July 8th in Co-2 and Cricket Ball, June 10th to June 20th in Oval, June 14th to June 20th in Gavarayya, June 7th to June 15th in PKM-1 and by June 21st to July12th in Local variety. Similarly, in second season, early flushing started in PKM-1 by September 7th,Gavarayya and Local varieties were late in flushing (September 14th and 15th respectively). Ponnuswamy and Irulappan (1989) reported that tree height in sapota ranged from 3.92m to 8.54m, the range being wide in Co-1 and Co-2 and narrow in Oval and PKM-1. Maximum canopy spread was observed in Cricket Ball. Tree volume ranged from 92.10$m^3$ to 623.11$m^3$, the range was wider in Kirtabarthi and Co-1. Tree girth was maximum in Cricket Ball, which was in accordance with the present study.

Continuous growth was observed in all the months, though it was negligible in summer months. Maximum mean monthly extension growth of shoots was recorded in June followed by October for all the varieties. A similar trend was also observed in percentage of shoots showing growth in all the six varieties under study. There was no shoot extension growth in March, April, August and December. Of the total extension growth of shoots, maximum percentage contribution to growth was recorded in June and October in all the six varieties. Maximum mean extension growth was recorded in the variety Oval (12.90 cm) followed by Co-2 (11.45 cm). Minimum mean extension growth of shoots was recorded in Gavarayya and PKM-1 (9.20cm, each). Singh and Khan (1939), Roy (1953), Singh (1959) and Reddy (1983) have reported different periods of primary and extension growth alternated with a period of quiescence in mango. 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.

The higher growth rate exhibited during June and October 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 reason 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 sapota in humid tropical conditions of Kerala. The moisture level of soil and the internal physiological conditions of the tree were also be the controlling factors as indicated by the scattered

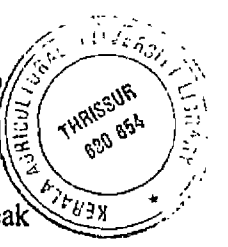
growth throughout the year. Sherly (1994) reported similar type of growth in *Garcinia cambogia*, where a main flushing season was followed by scattered flushing throughout the year. A similar condition was reported by Prasad (1998) in Lovi-lovi (*Flacourtia* spp.). Sundararajan (1961) reported that the growth in sapota commences with the onset of monsoon rains in June and ceases in early summer.

## 5.2.FLORAL CHARACTERS

In sapota, floral characters were studied by (Patil and Narwadkar, 1974;Nalawadi *et al.*, 1977). The tree produced flowers almost throughout the year with two distinct peak season and the peak flowering season were coped up simultaneously with flushing. Such a coincidence of shoot expansion and flowering was seen in Lovi-lovi (*Flacourtia cataphracta*)(Prasad, 1998). Occurrence of flower buds along with vegetative flush was reported in crops like nutmeg (Nazeem, 1979) and *Annona* sp. (Thakur and Singh, 1965). In sour lovi-lovi, the peak flowering season was coincided with a low mean temperature and relatively high humid climate (Prasad, 1998).

In this study, percentage of shoots flowered was maximum in the variety Cricket Ball (89.83 %) followed by Co-2 (89.17%) and minimum number of shoots flowered was recorded in PKM-1 (80.0%). The varieties like Co-2, Cricket Ball and Local variety started flowering by third week of May and extended up to last week of June in the first season. Varieties Oval and PKM-1 started flowering by first week of June and extended only up to June last week whereas Gavarayya started flowering by first week of June, it ceased by first week of July. But, in second season, flowering started by second week of September and ceased by October last week in Co-2, Oval, Gavarayya and PKM-1.In Cricket Ball and Local varieties, flowering in second season started by third week of September and extended up to last week of October.

Nalawadi *et al.* (1977) studied the floral biology of sapota at the Agricultural College, Dharwad, Karnataka, in Kalipatti, Cricket Ball, Calcutta Round and Oval cultivars. Three seasons of flowering were recorded with maximum in June, while in October and March the flowering was less. Dhaliwal *et al.* (1990) reported that there were two main seasons in sapota, viz., June and November and the duration of full




bloom ranged from 16 days to 19 days. Lenka *et al.* (1996) reported two distinct peak flowering periods in sapota cultivars (February-April and October –November). The crop requires 55 days to 60 days from flower bud initiation to anthesis under Bhubaneshwar conditions. The per centage of flower buds, which developed into flowers, ranged from 50.00 in Cricket Ball to 72.72 in Kalipatti. The gap between flowering and fruit set was 50.0 days to 54.5 days. Gunaki *et al.* (1999) reported that in sapota the highest flowering was observed during November – January, followed by July – August, the lowest flowering was observed in March. Paulas (1964) studied the growth and flowering of different classes of shoot in a number of mango varieties and observed that flowering occurs 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.

Maximum per cent of shoots flowered in all the six varieties were observed in the shoots oriented in the North followed by South. In northern side, Co-2 recorded maximum number of shoots flowered (95%) followed by Cricket Ball (94%). In southern side, maximum per cent of shoots flowered were observed in Co-2 and Cricket Ball (90%, each). This is in conformity with Shirsath *et al.* (1998). Minimum per cent of shoots flowered were in East - West orientation. The well exposure orientation of shoots in northern direction to sunlight might be the possible reason for more number of flowering shoots. Maximum number of inflorescence per square metre was recorded in the variety PKM-1 (12.5) and Cricket Ball (11.8) and these varieties were on par with each other and minimum was recorded in the Local variety (6.5). Maximum number of flowers was observed in Cricket Ball (6.1), Co-2 (5.9), Gavarayya (5.7) and PKM-1 (5.6) and all these varieties differed significantly. Minimum number of days taken for complete opening of an inflorescence was recorded in Oval (5.6). The varieties Co-2 (7.1) and Cricket Ball (7.3) took more number of days for complete opening of an inflorescence. Minimum number of flowers per inflorescence was recorded in Local (4.4) and Oval (4.6) varieties. Dhaliwal *et al.* (1990) reported that there were two main seasons in sapota, viz., June and November and the duration of full bloom ranged from 16 days to 19 days.

The stages of sapota flower bud development were divided into seven. In stage 1 and 2, there were no significant difference in length and girth of the bud. But from

the stage 3 onwards, the length and girth of flower bud was significantly maximum in the variety Oval. Maximum length and girth of Oval flower bud at stage 7 was 2.1cm and 2.5 cm respectively. Minimum length and girth of the flower bud at stage 7 was observed in the variety Local followed by PKM-1 (1.2 cm and 1.8 cm respectively).

**5.2.1.Floral biology**

In sapota, anthesis period occurred between 7.00 a.m. and 8.00 a.m. in all the six varieties under study. But the peak anthesis period occurred between 7.00 a.m. and 7.30 a.m. Nalawadi *et al.* (1977) observed peak period of anthesis in sapota by 04.00 a.m. Lenka *et al.* (1996) reported that peak period of anthesis in sapota was at 04.00 hour and continued up to 08.00 hour. Peak anthesis was observed between 6.00 a.m. and 7.30 a.m. in guava (Singh and Sehgal, 1968).

The period of anther dehiscence occurred at one day before the anthesis. It suggests that it was protandry in nature. There was no anther dehiscence during the day of opening and one day after anthesis. Minhas and Sandhu (1985) in his experiment with three cultivars of sapota stated that anther dehiscence started before anthesis, suggesting protandry and maximum dehiscence occurred between 08.00 a.m. and 11.00 a.m.

Maximum receptivity of stigma in all the six varieties was found at the time of anthesis. The receptivity of stigma gradually decline even after on the same day of anthesis .The receptivity of stigma ascertained by the per cent fruit set was absent by 8.00 hours to 10.00 hours after anthesis. Stigma receptivity was maximum from a day before anthesis to a day after anthesis in sapota (Minhas and Sandhu, 1985). Stigma receptivity was maximum on the day of anthesis in *Garcinia indica* (Karnik and Gunjate, 1984). In *G.cambogia* stigmatic receptivity was found to be maximum 12 hours before anthesis (Sherly, 1994).

**5.2.2.Pollen studies**

Maximum pollen production per anther was recorded in the variety Cricket Ball (2871.60) and Co-2 (2655.90) and the minimum were recorded in the variety Local (1261.60). Anthers produce 250-650 pollen grains with a mean of 450 grains per anther in mango (Popenoe, 1917,and 1920; Spencer and Kennard, 1955). Pollen

production studies had been reported in fruit crops like, sapota and papaya by Rao and Khader (1960), guava (Nair *et al.*, 1964) in varikka and koozha types of jack by Joseph (1983) and Pomegranate (Sampathkumar and Jallikop, 1990)

In the present study, pollen fertility percentage ascertained by acetocarmine staining test was not significantly differed among the varieties. Maximum pollen fertility (96 %) was observed in the varieties Cricket Ball and PKM-1.The diameter of the viable pollen grain was maximum (94.75 micron) in Gavarayya and minimum in Local variety. The maximum and minimum diameter of non-viable pollen was recorded in Gavarayya (53.68 micron) and PKM-1 (53.18 micron).

Rao and Khader (1960) made investigations on pollen morphology of six fruit crops namely, sapota, guava, papaya, jack, pomegranate and grapes. Nair and Mehra (1961) had described the pollen grains of citrus species. Singh and Mishra (1979) studied the characteristic of the pollen of three species of *Zizyphus*. In mango, pollen grains are oblong, when dry and more spherical when hydrated (Mukherjee, 1949; Singh, 1954; Randhawa and Damodaran, 1961and DeWet and Robertse, 1986). Singh (1961) observed that mean length of pollen grains of 50 Indian mango cultivars ranged from 23.5-micron metre to 28.3-micron metre.

Maximum germination (90.5%) of sapota pollen was observed in the media containing sucrose (15%) in combination with agar 0.5 per cent, boric acid 100 mg $l^{-1}$ and calcium nitrate 0.03 per cent. Pollen germination occurred at sucrose 5.0 per cent and gradually increased up to 15 per cent concentration but thereafter germination per cent showed a declining trend. Maximum tube length (197.6 micron) was recorded in the basal medium supplemented with agar 0.5 per cent +boric acid 100mg $l^{-1}$ + calcium nitrate 0.03per cent Maximum pollen germination percentage was recorded in the variety Co-2 (85.40%) followed by Oval (84.25%). In Local variety minimum pollen germination percentage (75.50%) was recorded. Mean maximum pollen tube length was recorded in Cricket Ball (196.7 micron) followed by Gavarayya (193.8 micron) and Co-2 (193.4 micron). Longest pollen tube length was recorded in Co-2 (215.6 micron) and the smallest in the variety Local (188.3 micron).

Viability of pollen in all the storage conditions showed gradual declining trend. Pollen viability was maximum (76.30%) when pollen grains were stored in refrigerator at 4°C followed by pollen storage at calcium chloride in desiccator

(60.70%) at 5 days after storage. Pollen viability was minimum in keeping pollen grains over calcium chloride in desiccator under refrigerator at 4 °C followed by control. According to Stanley and Liskens (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 as it ensures protection against desiccation. Schumaker (1935), Munzer (1960) and Rao and Khader (1960) reported that the presence of boric acid would have stimulated pollen germination and pollen tube growth. Germination of mango pollen on various artificial medium has been reported (Popenoe, 1917;Spencer and Kennard, 1955;Young, 1958;Randhawa and Damodaran, 1961;Singh, 1961;Robbertse *et al.*, 1988 and De Wet *et al.*, 1989). Mango pollen is most viable soon after anther dehiscence and rapidly degrades within a few hours (Sen *et al.*, 1946;Spencer and Kennard, 1955;Malik, 1957;Singh, 1963).

Pollen grains started to germinate 4 hours after incubation and gradually increased. Both germination percentage and pollen tube length were reached a peak at 9 hours after incubation and thereafter remains constant upto 12 hours after incubation. Flower bud drop occurred at regular interval at each stages of flower bud development. Maximum flower bud drop occurred at stage 4 followed by stage 5. Maximum flower bud drop occurred in the variety Oval (24.0%) followed by Cricket Ball and Gavarayya (22.0%, each). Minimum flower bud drop was recorded in Local (16.0 %). Gunaki *et al.* (1999) reported that highest flower drop was noticed in Cricket Ball and lowest flower drop in DHS-1 for all the flushes.

## 5.3.FRUIT SET

In the present study it was observed that the flowers situated at the base of inflorescence opened and set earlier. Fruit set was maximum in the variety PKM-1 (41.25%) followed by Local variety (31.75%). Oval recorded minimum number of fruit set (19.50%). Maximum number of fruit set occurred in northern direction of tree due to more perception of sunlight. In the northern side of the tree, maximum fruit set of 70 per cent was recorded in the variety PKM-1 followed by Co-2 (40.0%). Number of days taken from pollination to fruit set was minimum in the variety Oval. The variety Cricket Ball took more number of days from pollination to fruit set.

Gunaki *et al.* (1999) reported that in sapota highest percentage of fruit set occurred in July-August flush; fruit set was lower in the March flush. Fruit set was highest in DHS-1 when compared to DHS-2, Kalipatti and Cricket Ball at Dharward. Problems of shedding and low fertility in sapota were reported by Cheema *et al.* (1954) and Hayes (1957). In cultivar Kalipatti, 22 per cent natural fruit set was observed and the maximum fruit drop occurred immediately after fruit setting (Patil and Narwadkar, 1974). Pollen size and viability are quite variable between cultivars, possibly causing the varied results in fruit set (Minhas and Sandhu, 1985). Much like avocado, sapodilla produces many flowers than developed fruits. The great variability in fruit set may be due to differences in flower abortion and flower drop, although differences in this phenomenon between cultivars has not been specifically examined in sapodilla. The major period of fruit drop occurs in the first five weeks following fruit set and as little as 1.6 per cent of the flowers produced by a tree may develop into fruit (Relekar *et al.*1991). Gonzalez and Feliciano (1953) suggested that tree vigour might be related to flower production and fruit set. Mulla and Desle (1990) reported that fruit set was maximum in variety kalippatti. Dhaliwal and Ajmer (1990) reported that highest fruit set by open pollination (2.37%) and hand –selfing (1.01%) was obtained in Kalipatti variety. Relekar *et al.* (1991) reported highest per cent fruit set (28%) was obtained with open pollination in February.

## 5.4.FRUIT DROP

Among the six varieties observed maximum percentage of fruit drop occurred in Cricket Ball (86.07%) followed by Gavarayya (85.51%) and Local (84.6%) varieties. Minimum fruit drop was recorded in Co-2 (79.73%). Maximum fruits retained were observed in the variety PKM-1 (22.98%) followed by Co-2 (20.66%). Fruit retention percentage was minimum in Cricket Ball (13.93%). Maximum fruit drop percentage occurred in first and second fortnight after fruit set in all the six varieties under study.

Mone *et al.* (1991) reported that major fruit drop in sapota occurred in the first five weeks after fruit set .Of the total 171 fruits set on 150 shoots, only 9.36 per cent were retained to maturity. Gunaki *et al.* (1999) reported that highest fruit drop was

noticed in Cricket Ball, and lowest fruit drop in DHS-1 for all flushes. Since the fruit drop was confined mainly to the early periods of development, the probable reason for the drop may be lack of fertilization or improper fertilization. Chadha and Singh (1963) attributed the competition between young developing fruits as the main cause of fruit drop, especially in the early stages in mango. The production of large number of flowers might lead to competition among the young developing fruits resulting in shedding of the fruits. The fruit drop may be the result of an abscission mechanism as reported by Addicot and Lynch (1955), Chadha and Singh (1963), Randhawa (1971) and Davis and Addicot (1972) in different crops. However, Baradwaj (1975) suggested the imbalance between various plant growth regulators as the possible reason for fruit drop. According to him, the auxin and gibberellin produced in the seed and the abscission zone located at the base of the pedicel. If auxin and gibberellin were not available in significant amounts to metabolize the effect of abscission, the flower or fruit shed. The pattern of abscission of initially set fruitlets is asymptotic with the greatest losses occurring during the first week following the completion of anthesis in mango (Nunez-Elisa and Davenport, 1983;Prakash and Ram, 1984;Searle *et al.*, 1995). Generally, more fruits set on the distal portion of panicles in mango (Chadha and Singh, 1963;Nunez-Elisea and Davenport, 1983). Fruit drop has several causes and has often been associated with embryo abortion, resulting in blackened or shrivelled embryos, in early phase of fruit set in mango (Singh, 1954; Singh, 1961;Singh, 1964;Sharma and Singh, 1972;Ram *et al.*, 1976).

## 5.5.FRUIT DEVELOPMENT

### 5.5.1.Physical characters of fruit

Weight of the fruit gradually increased in all the six varieties from fruit set up to 75 days after fruit set. There was a sudden increase in fruit weight of the varieties Gavarayya, PKM-1 and Local from 90 days after fruit set. Whereas, in varieties Cricket Ball, Co-2 and Oval the sudden increase in fruit weight occurred at 105 days after fruit set. Fruit length was gradually increased from fruit set to harvest maturity in all the six varieties under study. Varieties Oval and Gavarayya recorded a sudden increase in length after 135 days after fruit set. Ponnuswami *et al.* (1992) reported that fruit length showed only a moderate growth in Co-1, but to lower magnitude in PKM-

1 and Kirthabarthi. Girth of the fruit increased gradually from fruit set to maturity. Fruit girth exhibited a phenomenal and continuous increase in variety Co-1 and in PKM-1, after an initial increase there was a plateau between 45 and 75 days. Fruit girth increased steadily in Kirthabarthi (Ponnuswamy *et al.*, 1992). Volume of the fruit had sudden increase from 90 days after fruit set. Specific gravity of fruit increased gradually with an increase at 90 –105 days after fruit set.

Fruit development followed a sigmoid pattern (Sulladmath *et al.*, 1979; Karim *et al.*, 1987) in sapota. The initial growth phase is due to cell division and involves maturation of the embryo within the fruit. A phase of greatly reduced growth follows, until a second rapid growth phase occurs, during which time growth is due to cell enlargement. This second growth phase is the time when maximum growth occurs between 5 and 7.5 months from fruit set (Lakshminarayana and Subramanyam, 1966). The fruits are suitable for harvesting after the second growth phase, when they attained maximum size. Rao *et al.* (1995) reported that sapota fruits experienced a protracted period of growth, which was not commensurate with the rate of mature fruit weight gain as in other species. This protracted period could be partly attributable to the lag phase. Advani (1998) developed a double logistic model for the cultivar Kalipatti by monitoring the changes in fruit weight fortnightly. The rate of fruit development was initially rapid, after which it became almost standstill and then increased gradually (Sundararajan and Rao, 1967). Chacko *et al.* (1970) reported that in mango the period of rapid growth was associated with the period of maximum activity of auxin and gibberellin like substances in the seed. Singh *et al.* (1990) reported that size of the seed also contribute to the size of the fruit. This rapid development of fruit may be due to rapid development of seed. The increase in weight during the maturity of guava was attributed to an increase in both cell size and volume of intercellular space in flesh, which enabled maximum possible accumulation of food substances (Singh *et al.*, 1990).

Maximum fruit weight was recorded in Cricket Ball (188.80 g) followed by Oval (155.85 g) and minimum fruit weight was recorded in Local variety (35.40 g). Sundararajan and Rao (1967) and Ingle *et al.* (1982) observed that mean weight of the fruits varied from 30.8g to 140 g. In general the round fruited varieties recorded more weight than the oval and elliptic ones. According to Lakshminarayana (1980) the

fruits generally weighed about 75g to 200g but in exceptional case fruits even upto 1 kg was also recorded. Maximum fruit length was recorded in the variety Oval (12.50 cm) followed by Gavarayya (10.50 cm) and minimum in Co-2 (5.25 cm) and Local variety (5.4 cm). Lakshminarayana and Rivera (1979) found that length of the fruit ranged from 5.2cm to 9.2 cm, while diameter ranged from 4.8cm to 9.3 cm. Maximum fruit girth was recorded in the variety Cricket Ball (17.4 cm) followed by Oval (16.50 cm) and Co-2 (16.42 cm) and minimum in the variety Local (4.85 cm). Maximum volume of the fruit was recorded in the variety Cricket Ball (195.25 ml) followed by Oval (162.5 ml) and minimum in the Local variety (42.20 ml). The mean volume of mature fruits of Cricket Ball, Co-1 and Oval were 305ml, 115ml and 62 ml respectively (Shanmugavelu and Srinivasan, 1973). Specific gravity of the fruit was maximum in Cricket Ball (0.99) followed by Oval (0.96) and minimum in the variety Local (0.83). The specific gravity of the mature graded sapota varied from 1.016 to 1.086 (Sawant, 1989). At maturity Guthi and Oval recorded 0.95 and 1.06 respectively (Durairaj *et al.*, 1991) while in Kalipatti it varied between 1.025 and 1.057 (Shende, 1993).

Scruffness was high in variety Cricket Ball whereas Local variety and PKM-1 has less scruffness. In Co-2, Oval and Gavarayya moderate level of scruffness was observed. Skin thickness is thin in PKM-1 and Local variety, whereas it is thick in Cricket Ball and Gavarayya. Flesh colour of Oval is reddish brown while other varieties possess light brown. Texture of flesh in Cricket Ball was highly gritty. Oval has slightly granular texture whereas, soft buttery, delicious texture was observed in PKM-1 and Local variety. Co-2 and PKM-1 are very sweeter in taste.

**5.5.2.Seed characters**

Maximum number of seeds per fruit was recorded in Cricket Ball (5.4) followed by Oval (3.6) and minimum in Local variety (1.5) and PKM-1 (1.8). Maximum seed weight per fruit was recorded in Cricket Ball (8.26 g) followed by Oval (5.04 g) and minimum in Local variety (1.79 g). Pulp: seed ratio gradually increased with a sudden increase from 120 days after fruit set. Maximum pulp:seed ratio was recorded in Oval (94.53) followed by Co-2 (66.23) and minimum in Local variety (22.54).

Maximum seed length was recorded in Cricket Ball (3.5 cm) followed by Oval (3.3 cm). Seed length was minimum in the variety Local (2.2 cm) and PKM-1 (2.5 cm). Maximum seed breadth was recorded in Oval (2.4 cm) followed by Cricket Ball (2.0 cm) and Gavarayya (2.0 cm). Minimum seed breadth was observed in Local variety (1.60 cm). Seeds of Co-2 and Gavarayya were Oval; PKM-1 has short stout, oval seeds. Seeds of Cricket Ball were elongated with blunt end whereas seeds of Oval has slight curve at tip.

**5.5.3.Biochemical characters of fruit**

In all the six varieties, TSS increased drastically from 30 days after fruit set and thereafter increased gradually till maturity. Shende (1993) observed that the TSS of cultivar Kalipatti at maturity and at the ripe stage ranged between 21.50 °Brix and 22.44 to 23.80 to 24.16 °Brix, respectively. TSS increased from fruit set to maturity from 13 to 21.6 °Brix in Kalipatti (Paralkar *et al.*, 1987). Reducing sugar increased sharply after 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1 and thereafter increased gradually whereas the sharp increase in reducing sugar occurred after 45 days from fruit set in Co-2, Oval and Local varieties and thereafter increased gradually. The increase in non-reducing sugar followed the similar pattern like that the changes in reducing sugar. Total sugars increased gradually with a sharp increase after 45 days from fruit set in Co-2, Oval and Local varieties, whereas the sudden increase in total sugar occurred at 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1. Lakshminarayana and Subramanyam (1967) observed that the reducing and total sugars were 10.3 and 21.0 per cent respectively at the mature stage, which increased to 16.7 and 26.0 per cent respectively at the eating-ripe stage, in cv. Calcutta Round. Selvaraj and Pal (1984) observed that alcohol- insoluble solids and starch contents decreased until the ripe stage in the varieties Cricket Ball and Oblong. Glucose and fructose contents increased during development and reached a maximum in the ripe fruit. The flesh of Kalipatti fruits was mellow and very sweet containing 12 to 14 per cent sugars, which were noticed from third month of fruit set. Similarly reducing sugars were also increased from 0.38 per cent to 8.92 per cent at maturity (Paralkar *et al.*, 1987). During ripening of the fruit, sucrose showed maximum increase followed by glucose and fructose (Lakshminarayana and Subramanyam,

1966). There was a gradual decline in acidity in all the six varieties during the fruit development. Lakshminarayana and Subramanyam (1967) reported 0.22 per cent acidity in mature Calcutta Round sapota, which decreased to 0.11 per cent at ripe stage. The total titratable acidity was high in the early developmental stages (0.48-1.36%), which declined steadily and reached a minimum (0.11-0.41%) in ripe fruits. Suryanarayana and Goud (1984) observed 0.38 per cent acidity in mature sapota fruits at harvest, which decreased to 0.18 per cent at ripe stage in cv. Oval. Sugar: acid ratio increased progressively during their development period with a sudden increase in after 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1, whereas in varieties Local, Co-2 and Oval the sudden increase in sugar: acid ratio occurred at 45 days after fruit set. Maximum TSS was recorded in the variety PKM-1 (22.6° Brix) followed by Oval (20.56° Brix), Cricket Ball and Gavarayya (20.5° Brix each).

## 5.6.HARVEST MATURITY

Purseglove (1968) reported that the maturity at harvest in sapota plays a significant role in the post harvest behaviour of the fruits. Fruits of different stages are available all through the year leading to practical difficulties in harvesting of fruits of definite maturity. Sapota matures 8-10 months after fruit set depending upon the cultivar and available heat units. Fruits harvested earlier than physiological maturity take too long to soften and have poor quality while those harvested later soften quickly resulting in fast spoilage during handling and transport. The time taken from fruit set to maturity was an important factor with respect to harvesting and maturity. It varied from 120 days to 245 days to mature after anthesis depending on the cultivar, agro climatic location and available heat units (Purseglove, 1968; Sulladmath, 1975).

The maturity of the sapota fruit could be judged on the basis of several external signs, viz., peel developed a dull orange or potato colour with a yellowish tinge, a yellow streak rather than a green one was seen on light scratching of the skin, the brown scaly material disappeared from the fruit surface, milky latex content dropped to almost zero and dried spine like stigma fell from the tip of the fruit (Sulladmath and Reddy, 1990). Kariyanna *et al.*(1990) reported that sapota fruits harvested at 245 days possessed excellent chemical and sensory qualities.

In the first season, maximum number of days taken for maturity was Co-2 (167.6 days) followed by Cricket Ball and Gavarayya (164.8 days,each). Varieties Local (150.4 days) and PKM-1 (151.5 days) took lesser number of days for maturity. In second season Oval recorded maximum number of days for maturity (154.8 days) followed by Cricket Ball (151.1 days). PKM-1 recorded minimum number of days for maturity (135.8 days) followed by Local variety (138.5 days). In the first season, maximum number of days taken for maturity was Co-2 (167.6 days) followed by Cricket Ball and Gavarayya (164.8 days). Varieties Local (150.4 days) and PKM-1 (151.5 days) took lesser number of days for maturity. In second season Oval recorded maximum number of days for maturity (154.8 days) followed by Cricket Ball (151.1 days). PKM-1 recorded minimum number of days for maturity (135.8 days) followed by Local variety (138.5 days).

Sapota took nearly 10 months (29 weeks) from fruit set to reach harvest maturity at Nagpur (Singh, 1951). At Coimbatore, Sundararajan and Rao (1967) reported that the fruit attained full maturity after 7 months from fruit set. Flow of sap from the cut fruit stalk of mango slows down if the harvest is done after maturity (Mann *et al.*, 1975;Campbell *et al.*, 1987). Lakshminarayana (1980) reported, on maturity, the fruit attains a thin rusty brown scurfy skin and yellowish brown or red pulp with pleasant aroma. Physiologically mature fruits shed off the brown scaly external material and become practically smooth with yellowish tinge intermitted with a corky brown colour.

The TSS, total and reducing sugar content, acidity, pH and tannins which showed distinct trends during fruit growth and development could be considered as chemical indices of maturity (Paralkar *et al.*, 1987). Fruit development follows a sigoidal pattern (Sulladmath *et al.*, 1979; Karim *et al.*, 1987). The initial growth phase is due to cell division and involves maturation of the embryo within the fruit. A phase of greatly reduced growth follows, until a second rapid growth phase occurs, during which time growth is due to cell enlargement. This second growth phase is the time when maximum growth occurs, between 5 and 7.5 months from fruit set (Lakshminarayana and Subramanyam, 1966). The fruits are suitable for harvesting after the first growth phase, although higher quality fruits are obtained if they are harvested following the second growth phase, when there is a dramatic increase in

sugar content of the fruit. Sundararajan and Rao (1967) suggest using total soluble solids as a measure of maturity in sapota. George (1982) reported that remnants of the flower style until maturity was also a good indicator.Karim *et al.*, (1987) found that fruit length and width were better indicators of maturity than weight and volume or firmness. Heat unit requirement was maximum for the variety Co-2 followed by Cricket Ball and Oval. Heat unit requirement was minimum for the variety PKM-1 and Local. Number of days for maturity and heat unit requirement were maximum for the first season of harvest and minimum for second crop. The heat unit requirement for litchi cv. Shahi was 813°C (Ray *et al.*, 1985), 1980-2236°F, 2236-2566°F and 2516-2920 °F for Gola, Kaithili and Umran cultivars of Ber (Pareek and Gupta, 1988).

## 5.7.YIELD

Fruit yield obtained in second harvesting period (February-March) was maximum when compared to first harvesting period (October – November). Total number of fruits was highest in PKM-1 (670) in second crop, whereas it was 480 fruits in first crop. Total number of fruits was lowest in Oval (150) followed by Cricket Ball (220) varieties in second crop, whereas it was 95 and 150 fruits for Oval and Cricket Ball, respectively in first crop. Total fruit weight was maximum in PKM-1 (60.5kg) followed by Cricket Ball (39.9 kg) in second crop, whereas minimum fruit weight was recorded in Local (11.75 kg). In first season, total fruit weight was also maximum in PKM-1 (27.5 kg) and minimum in Local (14.95 kg). Gunaki *et al.* (1999) reported that DHS-1 recorded the highest yield per tree (104.97 kg) and Kalipatti recorded the lowest yield per tree (38.64 kg). Sapota tree bear crops 3 to 5 years following planting, with mature trees bearing crops of 125 to 200 kg. Kalipatti is the most planted cultivar in the Gujarat region of India, accounting for about 99 per cent of the acreage. It also appears to be the highest yielding cultivar of those tested in India (Chundawat and Bhuva, 1982). Ponnuswamy and Irulappan (1989) reported that the number of fruits per tree exhibited a wider range from 730 to 2976 among the sapota varieties, the range was wider for PKM-1 and Guthi, whereas Cricket Ball, Kirtabarthi showed a narrow range. The highest yield in PKM-1 as reported by Ponnuswamy and Irulappan (1989) was similar to the result of the present study.

Chaudhary *et al.* (1995) reported that Kalipatti produced the highest fruit yield (78.80 kg/tree) and good quality fruits.

## 5.8.COMPATIBILITY STUDIES IN SAPOTA

Cooper (1938) studied the various aspects of fruit set in apple and reported that all the varieties studied are self- incompatible. He also reported that the system available in this crop was due to the presence of certain inhibitory substances of the pistil that considerably retarded the growth of pollen tube. Seth (1962) reported varietal cross- incompatibility in guava since neither fruit nor seed set was obtained when crosses were made between Behat coconut and Lucknow-49, Behat coconut and Apple colour. Self- incompatibility in loquat was of gametophytic nature. In self incompatible varieties, pollen tubes penetrated the stylar canal up to one fourth to one third of its length and did not go further even after 72 hours of pollination (Singh and Rajput, 1962). Self- incompatibility has been reported in pummelo, sweet lime and lemon. Nauriyal (1962) reported better fruit set by cross-pollination than by self or open pollination in pummelos indicating self – incompatibility. In sweet lime, maximum fruit set was recorded with the pollen of Duncan grapefruit (Shinde and Dhuria, 1960; Kumar *et al.*, 1976). Seedless lemon is self- incompatible and the fruits develop parthenocarpically (Diware *et al.*, 1970; Chakrawar and Warke, 1983). Rao and Khader (1961) observed inter-varietal specificity for pollen in sapota. Picatos and Knight (1975) found sapodilla to be self –incompatible, indicating that cross-pollination might be necessary. While production of some cultivars such as 'Prolific' is high, fruit yield among cultivars is variable, a characteristic which may be due to self – incompatibility. Gonzalez and Feliciano (1953) examined flowering and fruit set in 'Ponderosa' sapodilla and found that the trees could not be self-pollinated, either naturally or artificially. Similar results were observed in 'Kalipatti' sapodilla by Relekar *et al.* (1991). Mulla and Desle (1990) found that the highest per cent fruit set was observed in trees cross-pollinated with pollen of the same cultivar and ranged from 20 to 34 per cent.

**5.8.1.Fruit set and fruit drop**

Selfing the varieties resulted in only meager fruit set. There was no fruit set while selfing Oval, PKM-1 and Local varieties. In cross-pollination among the varieties maximum fruit set (28.57%) was obtained in Co-2 X Gavarayya cross combinations followed by Cricket Ball X Co-2 (27.69%). The entire cross combinations involving Gavarayya and PKM-1 as female parent set fruit. There was no fruit set in Co-2 X PKM-1, Co-2 X Local, Cricket Ball X PKM-1, Cricket Ball X Local, Oval X Cricket Ball, Oval X Local, Local X Co-2, Local X Cricket Ball, and Local X Oval. Minimum fruit set was obtained in the Oval X Co-2 cross combination (8.33 %) followed by Co-2 X Oval (10.0%). When Gavarayya was used as female parent more fruit (26.66%) set was obtained with Oval as the pollen parent. Similarly, PKM-1 as female parent, maximum fruit set was obtained when varieties Local and Gavarayya was used as pollen parent (21.67% and 21.43% respectively). Rao (1976) reported that hand pollination gave 6.4 per cent fruit set in Kalipatti, 27.5 per cent in Cricket Ball.19.0 per cent in Calcutta Round and 10 per cent in Oval. In cross-pollination studies, Kalipatti set 77.7 and 50.0 per cent fruits with pollen Oval and Cricket Ball as male parent respectively. Cultivar Cricket Ball set 72,67.4 and 15 per cent fruits with pollen of Oval, Kalipatti and Cricket Ball respectively. Similar differences in the fruit set were also observed, as Kalipatti did not set any fruit with the pollen of Calcutta Round, whereas in reciprocal combination, it gave 65 per cent fruit set.

Thakur and Singh (1965) reported that in *Annona*, interspecific cross fertility was observed when *A.cherimola* was pollen parent and *A. reticulata* and *A.squamosa* were female parents. With *A.cherimola* as pollen parent, there was a high per cent of fruit set, viz., 48.8 per cent in *A.squamosa* (green), 52.5per cent in *A.squamosa* (red) and 37.5 per cent in *A.reticulata*. Godara (1981) found that cultivars Banarsi, Karaka,Mundi Murhara,Reshmi,Umran,Illaichi and Kakrola Gola were self-incompatible and Umran was found to be the best pollen recipient as well as pollen donor. Vashistha and Pareek(1983) found that in reciprocal crosses among Seb,Gola,Sanaur-2,Katha and Umran cultivars, mature fruits were harvested only in SebXGola,SebXKatha,SebXUmran and UmranXSeb,while in others the fruits dropped prematurely. Josan *et al.* (1981) observed cross-incompatibility in some of

the combinations. Nauriyal (1962) reported better fruit set by cross than by self or open pollination in pummelos indicating self-incompatibility. In sweet lime, maximum set was recorded with the pollen of Duncan grapefruit (Singh and Dhuria, 1960;Kumar *et al.*, 1976). The cultivars Italian and Pant Oblong were found most promising pollinizers for PantLemon-1 giving a final fruit retention of 55.50 per cent and 56.92 per cent respectively (Venkateswaralu and Lavania, 1985). Studies of Ram *et al.* (1976) indicated self-unfruitfulness in cultivars Dashehari, Langra and Chausa. Dasehari was found to be cross unfruitful with Chausa and Safeda Malihabad but cross-fruitful with Langra, Rataul and Bombay Green (Singh *et al.*, 1962;Robbertse *et al.*, 1993). Inter and intra specific cross combinations among six species of annona revealed the effectiveness of *Annona squamosa* as pollen parent on *A. atemoya* and *A.cherimola*. *A.squamosa* was not an effective female parent with *A.atemoya* but *A.cherimola* was compatible with both *A.squamosa* and *A.cherimola*. *A.atemoya* can be crossed freely with *A.reticulata*, *A.glabra* and *A.cherimola* (Sampath kumar and Jalikop, 2000). Ram *et al.*, (1976) reported cross incompatibility among certain cultivars of mango.

The extent of fruit drop was maximum in the Cricket Ball X Co-2 cross combination (55.55%) followed by Gavarayya X Co-2 (46.15%). Fruit drop was minimum in Gavarayya X PKM-1 cross combination (9.01%). Cross combinations involving Oval X PKM-1, Oval X Gavarayya, PKM-1 X Oval recorded minimum fruit drop of 11.11 per cent, 13.33 per cent, and 10.0 per cent respectively. Self-incompatibility was reported in Dashehari, Langra, Chausa and Bombay Green cultivars of mango (Mukherjee *et al.*, 1918;Sharma and Singh, 1970). Embryological studies have shown that although fertilization takes place after self-pollination, degeneration of endosperm occurs 15 days after pollination involving self-incompatible parents (Mukherjee *et al.*, 1968). The pattern of abscission of initially set fruitlets is asymptotic with the greatest losses occurring during the first week following the completion of anthesis in mango (Nunez-Elisa and Davenport, 1983;Prakash and Ram, 1984;Searle *et al.*, 1995). Generally, most fruit are set on the distal portion of panicles in mango (Chadha and Singh, 1963;Nunez-Elisea and Davenport, 1983). Fruit drop has several causes and has often been associated with embryo abortion, resulting in blackened or shrivelled embryos, in early phase of fruit

set in mango (Singh, 1954;Chandler, 1958;Singh, 1961;Singh, 1964;Sharma and Singh, 1972;Ram *et al.*, 1976).

**5.8.2.Physical characters**

Fruit weight was maximum in the Cricket Ball X Co-2 cross combination (180.80 g) followed by Cricket Ball X Oval (175.19 g). Minimum fruit weight was recorded in the cross combination involving Local X Gavarayya (38.87 g) and Local X PKM-1 (40.27 g). In cross combination involving PKM-1 as the female parent, Cricket Ball gave the maximum fruit weight (77.34 g) when it was used as pollen parent. Minimum fruit weight was recorded when Local was used as pollen parent (103.86 g). In Gavarayya as female parent combination also, use of Cricket Ball pollen resulted in maximum fruit weight (137.26 g) followed by Oval (130.56 g). In cross combinations involving Cricket Ball as female parent, use of Co-2 as pollen parent gave maximum fruit weight (180.80g) followed by Oval (175.19 g) and minimum fruit weight was recorded when pollen parent used was Gavarayya (126.53 g). With Co-2 as female parent use of Cricket Ball as pollen parent resulted in maximum fruit weight (173.81 g) and minimum fruit weight was recorded when Gavarayya was used as pollen parent (117.33 g). Shinde and Patil (1979) observed satisfactory fruit set in Anab-e-Shahi grapes with its own pollen (63.8 berries per bunch) but the maximum number of berries was observed by pollination with Cheema Sahebi (80.6 berries per bunch) pollen. Maximum length of the fruit was recorded in the cross Oval X Gavarayya (12.36 cm) followed by Oval X Co-2 (11.05 cm) and minimum in the cross Co-2 X Cricket Ball (5.75 cm), Co-2 X Gavarayya (5.80 cm) and Local X PKM-1 (5.80 cm). Cricket Ball as female parent and Oval as pollen parent resulted in maximum fruit length (8.50 cm). With Gavarayya and PKM-1 as female parent, use of Oval as pollen parent resulted in greater fruit length (11.04 cm and 8.25 cm respectively).

Fruit girth was maximum in the crossess Co-2 X Cricket Ball (17.6 cm), Cricket Ball X Gavarayya (17.50 cm), Cricket Ball X Co-2 (17.35cm) and minimum in the cross Local X PKM-1 (5.80 cm) and Local X Gavarayya (5.95 cm). With Oval as female parent and Co-2 as pollen parent resulted in maximum fruit girth (16.15 cm). Use of Cricket Ball as pollen parent with Gavarayya resulted in maximum fruit

girth (14.70 cm). Maximum fruit volume was recorded in the cross Cricket Ball X Co-2 (197.5 ml) followed by Cricket Ball X Oval (190.5 ml) and minimum fruit volume was recorded in the crossess Local X PKM-1 (40.2 ml) and Local X Gavarayya (45.9 ml), use of Cricket Ball as pollen parent for PKM-1, Gavarayya and Co-2 female parent maximum fruit volume was recorded (66.70 ml, 155.64 ml and 164.55 ml respectively). Specific gravity of fruit was maximum in the cross Cricket Ball X Co-2 (1.06) followed by Co-2 X Gavarayya (0.97) and Co-2 X Oval (0.96) and minimum specific gravity was recorded in Local X Gavarayya (0.75).

Pulp: seed ratio was maximum in the cross Oval X Co-2 (93.4) followed by Oval X Gavarayya (92.7) and minimum in Local X Gavarayya (23.2). Use of Oval as pollen parent with Co-2, Cricket Ball, Gavarayya and PKM-1 resulted in maximum pulp: seed ratio (74.6, 60.25 64.8 and 28.9 respectively). In Cricket Ball X Co-2 cross combination, fruits were top and bottom compressed, flat in nature whereas in Co-2 X Cricket Ball fruits with compressed round type were obtained .The Co-2 X Oval fruits were compressed elongate while in Oval X Co-2, fruits were elongate, stout. In Oval X Gavarayya cross, fruits were buldged and elongated, while in Gavarayya X Oval, fruits were elongated.

**5.8.3.Biochemical characters**

TSS was maximum in the cross PKM-1 X Gavarayya (26.20 ° Brix) followed by PKM-1 X Co-2 (25.20 ° Brix). Minimum TSS was recorded in the cross Co-2 X Gavarayya (20.35 ° Brix), Gavarayya X Cricket Ball and Co-2 X Oval (20.4 ° Brix each). Reducing sugars was maximum in Gavarayya X Oval (12.90%) followed by Cricket Ball X Oval (12.80%) and minimum reducing sugar was recorded in Local X PKM-1 (9.55%). Use of Oval as pollen parent with Co-2 and PKM-1 resulted in maximum fruit sugar (11.81% and 11.85%, respectively).

Non-reducing sugar was maximum in Cricket Ball X Gavarayya (11.4%) followed by Cricket Ball X Oval (11.2%) and minimum non- reducing sugar was recorded in Local x Gavarayya (5.5%). Use of Cricket Ball as pollen parent with Co-2 and PKM-1 resulted in maximum non-reducing sugar (9.5% and 7.6%, respectively). Total sugars were maximum in Cricket Ball X Oval (24.0%) followed by Cricket Ball X Gavarayya (23.6%) and minimum total sugar was recorded in Local X Gavarayya

crosses (15.1%). Shinde and Patil (1979) reported that sugar level in berries was the highest under artificial self pollination (17.9%) in Anab-e-Shahi and it was lowest (14.6%) when pollination was carried out with pollen of Bhokri cultivar. Acidity was maximum in the cross Co-2 X Cricket Ball (0.22%) followed by Gavarayya X Co-2 (0.22%). Minimum acidity was recorded in Co-2 X Gavarayya (0.10%), Gavarayya X Local (0.10%). Sugar: acid ratio was maximum in Cricket Ball X Oval (218.18) followed by Cricket Ball X Gavarayya (196.67) and minimum sugar: acid ratio was recorded in Co-2 X Cricket Ball (96.82).

**5.8.4.Seed characters**

The shape of seed in Co-2 X Cricket Ball is oval, stout with blunt tip, whereas in Cricket Ball X Co-2, the shape of the seed was elongated oval. In Co-2 X Oval, seed shape was elongated, slightly blunt at tip while in Oval X Co-2, shape of the seed was oval with blunt tip. Seed weight per fruit was maximum in the cross Cricket Ball X Gavarayya (4.60 g) and the minimum in PKM-1 X Local (2.3 g). Maximum number of seeds per fruit was recorded in Cricket Ball X Oval (5.4), Cricket Ball x Gavarayya (5.3) and Cricket Ball X Co-2 (5.2) and minimum number of seeds per fruit was recorded in Local X Gavarayya (1.4) and Local X PKM-1 (1.5). Length of seed was maximum in Cricket Ball X Co-2 (3.5 cm), Cricket Ball X Oval (3.5 cm) and Oval X Co-2 (3.5 cm). Minimum length of seed was recorded in PKM-1 X Oval (2.5 cm), Local X Gavarayya (2.6 cm) and Local X PKM-1 (2.6 cm). Breadth of seed was maximum in Gavarayya X Local (2.9 cm) and Gavarayya X Cricket Ball (2.9 cm) and minimum in Cricket Ball X Gavarayya (1.7 cm) and Local X Gavarayya (1.7 cm) combinations.

Seed germination percentage was maximum in the cross Oval x Co-2 (88.89 %) followed by Co-2 (66.67%) and Gavarayya X Co-2 (52.94%). Minimum germination percentage was recorded in Gavarayya X Oval (20.0%). Number of days taken for seed germination was minimum in the cross Local X PKM-1 (15.3 days) followed by Local X Gavarayya (16.2 days). Maximum number of days taken for seed germination was recorded in Co-2 X Gavarayya (19.3 days) followed by Gavarayya X Local (19.2 days). Purohit (1987) observed that in pomegranate when a hard seeded cultivar was pollinated by a soft seeded one, the hardness of the seeds

slightly decreased in the resultant fruits and when a soft seeded cultivar was pollinated either by a soft or hard seeded cultivar, the lignification of seed testa and hardness of seeds increased making the fruits medium hard seeded.

**5.8.5.Days for maturity**

Number of days taken for maturity was minimum in the cross Local X PKM-1 (150.0 days) followed by Gavarayya X Oval (152.0 days), Local X Gavarayya (154.0 days) and PKM-1 X Local (154.6 days). Maximum days taken for maturity were for the cross Co-2 X Cricket Ball (167.2 days), Cricket Ball X Co-2 (167.2 days), Co-2 X Oval (166.0 days). Use of Oval as pollen parent with Gavarayya and PKM-1 resulted in minimum number of days taken for maturity (162.6 days and 161.0 days respectively).

## 5.9. POLLEN PISTIL INTERACTION

The pollen pistil interaction in sapota was studied by the fluorescent technique, 24 hr after pollination under selfing and crossing. In selfed flowers, it was observed that pollen germinate on the stigma but the pollen tube gets distorted in the style. In the cross-compatible combinations normal pollen tube growth occurred, which entered into the ovary (Plate 14-15).According to Sears (1937), there are three sites of incompatibility, stigma, style and ovary. Self-incompatibility studies in sweet potato revealed that the inhibition of pollen grains was at the stigma level (Venkateswaralu, 1980). Ram *et al.* (1992) reported that stigma is the site of action of the self-incompatibility alleles in coffee. Han (1994) reported that in *Hibiscus syriacus* L. pollen tube growth of the incompatible pollinations was inhibited in the style, two third of the way from the stigma to the base. Brunn *et al.* (1995) studied the self-incompatibility reaction in *Beta vulgaris* and reported that self-incompatibility response was observed at the border between stigma and style. Gupta *et al.* (1998) observed that pollen grains germinated on the stigma, but pollen tubes failed to grow beyond the proximal one third of the style in *Commiphora wrightii.*

Plate : 14.. Pollen pistil interaction showing pollen tube distortion in incompatible sapota varieties (x 400 X)

Plate : 15. Pollen pistil interaction showing pollen tube entering ovary in cross - compatible sapota varieties

## 5.10.METHODS TO OVERCOME INCOMPATIBILITY BETWEEN VARIETIES

A number of methods have been tried by various workers to induce fertility by breaking the incompatibility barrier in crop plants. They include surgical techniques, bud pollination, hormonal treatment, polyploidy, irradiation etc. The effect of various methods tried for breaking the self-incompatibility barriers are discussed as follows.

In the present study, bud pollination was found to be quite ineffective in breaking the self-incompatibility barrier. Lack of stigma receptivity during the bud stage can be considered as the cause for the failure of this method. This is in line with the reports made by Togeri and Kawahara (1942) and Kumar (1983). Gradziel and Robinson (1989) reported that self-incompatibility could be broken down in *Lycopersicon peruvianum* by supplying pollen-germinating medium followed by bud pollination.

The method of cutting the stigma and part of style were quite ineffective to overcome the incompatibility barrier. Large reduction in pollen germination and pollen tube growth may be the reasons for absence of fruit set. Stigmatic exudate is necessary for pollen germination and the exudates get removed by cutting the stigma. These results are supported by Davis (1957) and Kumar (1983) in sweet potato. Latex exudation observed while cutting the stigma and style coagulate on the cut position, which also might have prevented pollen germination.

Kashyap and Gupta (1989) reported that self incompatibility can be partially overcome *in vitro* by treating pollen and / or stigma with gibberellic acid ($GA_3$) in *Ipomoea cairica, Brassica campestris* and *Raphanus sativus* which was due to callose deposition in the stigmatic papillae and hence total inhibition of pollen germination. Illieva and Alipieva (1996) reported that self – incompatibility can be broken in certain lines of cabbage by means of pollen irradiation treatment.

Inhibition of pollen tube growth or its abnormally slow development inside the stylar column was reported to be one cause of incompatibility in angiosperms by Sears (1937). The preliminary studies conducted by Miller (1938) in sweet potato revealed that lack of fertility might be due to the style being deficient in an unknown

substance which might initiate pollen germination or it may contain some substances which act as inhibitor of pollen germination.

In the present study pollen germinated in *in vitro* basal medium showed that despite normal pollen germination, frequency of distorted pollen tube elongation or branched pollen tube and bursted at tip of pollen tube were high. This could be the possible reason for lower fruit set and inter varietal pollen specificity (incompatibility) nature in sapota. Hogenboon (1972) reported abnormally slow growth of *Lycopersicon esculentum* pollen in styles of self-incompatible *L. peruvianum* and the hybrids of such crosses showed embryo abortion. Nettencourt (1973) studied the ultra structural aspects of self – incompatible mechanism in *L. peruvianum* and reported that the incompatible pollen tubes were not only slow in their growth through the style, but were destroyed in the inner wall and lysis of the pollen tube occurred. Rugkhla *et al.* (1997) observed that on selfing, growth of pollen tubes was arrested in the style, ovary and around the embryo sac, a few penetrated the embryo sac in *Santalum album*. Damri *et al.* (1998) observed swelling and bursting of pollen tubes into the stigma in selfed flowers of lemon. Sucrose was found to be a favourable medium for pollen germination in many crop plants as reported by Kiss (1970) and Radhakrishnan (1976). In the present study, it was found that application of sucrose solution on the cut surface of the style was not at all favourable for pollen germination and seed set. Generally, stigmatic excretion is essential for pollen germination and it could be assumed that in addition to sugar, some other growth promoting substances may be present in stigmatic secretion, which is essential for pollen germination. According to Addicott (1943), pollen tube requires inorganic salts ($Ca^{++}$) apart from sugar for its growth. Pollination using *in vitro* germinated pollen also did not set fruits. The result indicates that lack of pollen germination is not the barrier in fruit setting, but there might be some abnormalities in the later stages of pollen tube growth or some inhibitory substances, which controls the incompatibility reaction. In sweet potato, Kumar (1983) reported that the inhibitory substances are situated on the stigma. According to Moneur *et al.* (1991) inhibitory substance are located in the ovary in *Acacia mearnsii*.

Pollination with NAA 5.0 mgl $^{-1}$ and 2,4- D – 0.5mg l $^{-1}$ resulted in fruit set which revealed that insufficient amount of auxin like substances in the pollen for the

normal growth and elongation of pollen tube. Application of 2,4-D and NAA showed positive response to fruit set. Charles *et al.* (1974) reported the suppression of floral abscission by the application of 2,4-D, which resulted in successful seed set in *Ipomoea trichocarpa*. They reasoned that the application of 2,4-D gave adequate time for the pollen tube to penetrate the incompatible style and enhanced normal pollen tube growth without distortion and resulted in fertilization and seed set. According to Kumar (1983), self-incompatibility can be broken down by 2,4-D treatment in some varieties of sweet potato. Pollinating with gamma-irradiated pollen (40Gy, 50Gy and 75Gy) also resulted in fruit set. This could be due to some possible usual cellular and molecular changes that will regulate the pollen tube elongation through style. Pollination with irradiated pollen (low dose of 10Gy, 20Gy or with high dose of 100 Gy) did not resulted in fruit set as the low dose may not so effective in bringing out the changes while higher dose of radiation may cause lethal injury resulted in loss of pollen viability, which was in accordance with dose- effect relationship. Other methods tried did not resulted in fruit set. Pollination after removing the style and direct application of pollen on ovary did not resulted in fruit set as it may cause tissue injury and high fungal growth. Pollination with *in vitro* germinated pollen grains also did not result in any fruit set which showed that pollen that could be germinate under laboratory condition did not perform well under open field condition.

## 5.11.CORRELATION BETWEEN WEATHER PARAMETERS AND YIELD CHARACTERS

Under humid tropical conditions of Kerala, number of flushes per unit area, number of inflorescence per metre square and fruit set was positively correlated with minimum temperature. Fruit weight, girth, volume, TSS, reducing sugars, total sugars and yield were positively correlated with maximum temperature. Sunshine hours were positively significant in correlation with reducing sugars, total sugars and yield while, rainfall had a negative correlation with the biochemical characters of fruits and total yield. Maximum temperature and wind are positively correlated with fruit drop.

Maximum temperature was positively correlated with fruit set while minimum temperature was negatively correlated with fruit drop and fruit girth, reducing sugars

and total sugars. Mean relative humidity was positively correlated with number of flushes per unit area, number of inflorescence per metre square, fruit set but negatively correlated with fruit weight. Fruit girth, TSS, reducing sugars and total sugars. Rainfall was negatively correlated with fruit set, which could be due to washing out of pollen from anthers and insufficient pollen transfer. Rainfall was also negatively correlated with biochemical characters like reducing sugars, total sugars as it favours the slow metabolic conversion of polysaccharides into simple sugars. A high temperature above 41° C during summer causes drying up of stigmatic fluid, flower drop and fruit scorching. In severe cases, leaves and fruits undergo scorching. Dry and strong winds also cause damage to flowers, leaves and fruits (Gopalaswamiengar, 1970). Shirsath *et al.* (1998) examined data on average temperature, relative humidity, rainfall, soil temperature, sunshine hours and evapotranspiration in relation to yields of sapota cultivar Kalipatti at Rahuri. Maximum and minimum temperature had a negative correlation with yield while relative humidity; rainfall and sunshine hours were positively correlated with yield under Rahuri condition. Mango trees develop vegetative shoots when shoot initiation occurs in warm temperature, whereas inflorescences develop when shoots initiated growth in cool temperature (Whiley *et al.*, 1989;Nunez-Elisa and Davenport, 1991 and 1995;Nunez-Elisea *et al.*, 1993 and 1996).

## 5.12.VARIABILITY, COEFFICIENT OF VARIATION, HERITABILITY AND GENETIC ADVANCE

Studies were carried out to determine the extent of variability and degree of association of quantitative characters with yield and flowering in sapota. Wide variability in terms of range and coefficient of variation existed in the population with respect to many of the vegetative, flowering and yield characters. Wide variability in terms of range and coefficient of variation existed in the population with respect to many of the vegetative, flowering, nut and yield characters. Parameswaran *et al.* (1984) and Reddy *et al.* (1996) reported high variability for different parameters of cashew.

Among the vegetative characters, maximum variability was displayed for tree volume (10.77 $m^3$ – 163.12 $m^3$), number of flushes (5.0 -12.25), number of leaves per flush (7.0 – 15.75). This variability observed is of considerable importance since high and medium yielder had more number of flushes per metre square and tree volume.

The variability for tree height among the population ranged from 2.75m – 7.97m with a mean of 5.42m. The genotypic and phenotypic coefficient variation was of medium magnitude for this character (32.36 and 34.10 per cent) indicating moderate variability among this clonal population. Variabilty for tree girth and flush length was low among the vegetative characters.

When flowering characters were subjected to variability analysis, number of inflorescence per metre square and fruit set percentage were observed to vary much among the varieties studied. The broad spectrum of variability observed for these characters was also of considerable importance since high yielder was found to possess more number of fruit set percentage. Since fruit set is directly related to the yield necessity for its exploitation for realizing higher yield is evident from this study.

Variability for fruit weight was observed at a range of 35.0 to 187.20 in the present study and for number of fruits per tree (28.75 – 121.25). The high variability with respect to this character observed may be due to the inclusion of some varieties like PKM-1, Local having cluster bearing habit resulting in more number of fruits per tree. Here again the association of this character with yield was in the same pattern as observed for the fruit set percentage and this can be utilized in the yield improvement programme.

The low variability observed in the present study for the percentage of flowering shoots is a matter of concern as this is an important character deciding yield. But the low variability observed for number of flowers per inflorescence is not a matter of concern as only one or two flowers (usually at base of an inflorescence) set fruit.

Maximum variability was observed for number of fruits per tree and fruit weight. This indicated a higher contribution of these traits towards the total genetic divergence. The high variability with respect to yield of the varieties tested provides ample scope for selection and further improvement in this character. This also

emphasis the need for incorporating high fruit weight character with many of the high yielder like PKM-1. Since the main perspective of breeding programme in sapota is for evolving varieties having more fruit weight and more number of fruits per tree, the varieties identified in the present study with high fruit weight (Cricket Ball) and more number of fruits per tree (PKM-1) are valuable in breeding programmes.

Subramanyan and Iyer (1981) reported a wide variability in terms of number of fruits per plant, seed weight, number of seeds per fruit, pulp weight, fruit weight and peel weight in papaya (*Carica papaya*). Ponnuswamy and Irulappan (1989) observed a wider variability in terms of tree height, canopy spread, tree volume and girth, number of fruits per tree and quality characters like TSS, sugars and acidity in sapota.

Ponnuswamy and Irulappan (1989) reported a wide range of tree height in Co-1 and Co-2 while it was narrow in Oval and PKM-1 of sapota and the range of tree volume were wider in Kirtabarthi and Co-1 but narrower in Guthi and Dwarapudi. Kumar and Singh (1993) noted a wide variability in fruit characters like fruit weight, number of seeds per fruit and biochemical characters like moisture, TSS, acidity, ascorbic acid, reducing sugar, non-reducing sugar, total sugar, anthocyanin pigment, total carotenoids, iron content in karonda (*Carissa carandas* L.). Ray and Sharma (1988) reported the high GCV associated with high heritability for peel weight followed by seed weight, aril weight and fruit weight in litchi. Ghanta *et al.* (1994) observed a wide variability for peel weight, seed weight, aril weight and fruit weight in litchi.

Ranpise and Desai (1994) reported that higher values of GCV and PCV for yield per plant, number of fruits per plant, flowers per twig and tree volume of acid lime. The PCV was higher than corresponding GCV for all the characters studied in papaya, which might be due to the modifying effect of environment at the phenotypic level. The highest PCV (35.50) as well as GCV (32.50) were recorded for seed weight, followed by number of seeds per fruit and number of fruits per plant (Dwivedi *et al.* (1995).

Estimates of heritability are useful to the plant breeder as they provide basis for selection based on phenotypic performance. In the present study fruit volume recorded the highest magnitude (100%) of heritability followed by fruit girth

(118.92%) and fruit weight (110.19%) and all the characters studied registered moderate to high heritability. High heritability can aid in effective selection based on phenotypic performance. The other character with high heritability was tree girth and canopy spread, which is also directly related to yield. The moderate heritability observed for yield indicates that improvement for yield could be offered through hybridization followed by selection. Subramanyan and Iyer (1981) observed high heritability estimates along with genetic advance for seed weight, number of fruits per plant, number of seeds per fruit, pulp weight, fruit weight and peel weight in papaya suggesting that further selection for improvement in number of fruits per plant, pulp weight and fruit weight would be effective. Genetical studies conducted in guava indicated that seed pulp colour is dominated to white and that this character is governed monogenically (Subramanyam and Iyer, 1982). Bold seeds in guava were found to be dominant over soft seeds and this was also found to be dominant monogenically. Sharma (1987) considered that additive gene action might be involved in the inheritance of flesh colour in mango. Ghanta *et al.* (1994) reported high heritability and genetic advance for peel weight, aril weight and seed weight in litchi. Attri *et al.* (1999) observed remarkable variability in qualitative character in mango collections of South Andaman. All the qualitative characters showed higher estimates of broad sense heritability, whereas genetic advance recorded was very high in carotenoids, fruit weight, fruit volume and ascorbic acid.

In the present study the genetic advance for all the characters were moderate to low except for fruit weight which express a high genetic advance of (119.04) followed by fruit volume (118.92). High heritability coupled with high magnitude of genetic advance indicated the role of additive genes and suggest a very good scope for faster improvement through selection (fruit weight and fruit volume). Those characters which expressed low/medium genetic advance and high /moderate heritability like percentage of fruit set, number of fruits per tree and yield can be improved through hybridization.

## 5.13.MORPHOLOGICAL CHARACTERS ASSOCIATED WITH YIELD

### 5.13.1.Correlation of the specific traits with yield

Economic characters are generally complex in nature and influenced by many plant characters through different physiochemical mechanism. Knowledge on the association of character is essential to identify the character, which could influence the economic traits. Since variability is contributed both by genotype and environment, the correlation observed between two characters in a genetically variable population is phenotypic in nature. Phenotypic correlation is the net result of genotypic and environmental correlation and hence its magnitude is intermediate. In the present study phenotypic correlation coefficient (Table 27a &b) was found to be less than genotypic correlation coefficient (Table 26a&b). Negative association was observed for certain vegetative characters with yield and maximum negative correlation were observed with fruit drop and flush length. This emphasis that shorter flush length and higher yield are highly correlated and a direct selection can be done on this basis. The intensity of correlation observed for the plant yield with shoot girth and tree volume was of high magnitude. In cashew the intensity of correlation observed for the plant yield with tree spread and number of flush was of high magnitude (Nayar *et al.*, 1981;Nawale, 1983;Parameswaran *et al.*, 1984;Manoj *et al.*, 1994 and Reddy *et al.*, 1996).

In contrast to the feeble association of most of the vegetative characters studied with yield, almost all flowering characters had positive correlation. Number of flowers per inflorescence and number of inflorescence per metre square were the most prominent. Since lengthy flushes had shown negative correlation and production of more number of flowers per inflorescence and inflorescence per metre square had positive correlation with yield, methods to control vegetative growth and induce maximum flowering will be a better preposition to improve yield in sapota. Association of more flowers per inflorescence and more inflorescence per metre square with yield may be due to the aforesaid reason of short flushes resulting in better partition of metabolites for reproductive phase occurring in the high yielding varieties. Thus these characters serve as a criterion for direct selection of high yielding varieties.

All the fruit characters exhibited positive correlation with yield. Among the fruit characters, girth of the fruit has maximum correlation coefficient with yield followed by fruit weight and volume and number of fruits per tree. In sapota, a correlation was worked out between the shape index and seed number per fruit and also between fruit weight and seed number. A positive correlation was present between number of seed per fruit and fruit weight. Round fruits were heavier (101g) than oval fruits (69.7g) (Tendolkar, 1978).

A positive association between peel weight and seed weight and aril size was estimated in litchi by Huang and Qiu (1987). Ray and Sharma (1988) reported a negative correlation between fruit weight and yield in litchi. Bandyopadhyaya *et al.* (1990) and Sarkar *et al.* (1991) reported strong association between aril weight and all other quantitative traits associated with fruit quality in litchi (*Litchi sinensis* Sonn.). Dwivedi *et al.* (1994) observed a high positive correlation between aril weight and fruit weight and fruit diameter, high coheritability for aril weight and fruit weight and aril weight and fruit diameter. Ranpise and Desai (1994) reported that growth parameters (plant height, tree volume and stem girth) were positively correlated with each other in kagzhi lime (*Citrus aurantifolia*). They were also positively correlated with number of fruits per plant and yield and had favourable association with most of the fruit quality parameters. The fruits per plant and yield had also favourable association with fruit quality attributes.

Number of seeds per fruit and seed weight per fruit had a weak positive correlation with yield since number and weight of seed simply contribute to fruit weight and hence the weak positive association of these characters with yield is justifiable. A best example is the variety Cricket Ball that possesses more number of seeds and seed weight per fruit but it is not a high yielder. A variety having more fruit weight alone cannot be considered as high yielder if they failed to lead more number of fruits to maturity. In the present study, both number of fruits per tree and fruit weight recorded a positive correlation with yield. Since fruit drop is highly negatively associated with fruit weight and fruit girth, higher fruit weight may cause greater competition among the fruits elevating the intensity of fruit drop. Varieties with high number of flowers per inflorescence, number of inflorescence per metre square, more fruit weight and more number of fruits per tree are to be screened and further

providing better management practices could exploit the yield potential of desirable varieties in full.

Based on this study, the varieties showing desirable expression of various characters are furnished below so that it can be made use of in future hybridization programmes.

**Table No.28. Varieties selected for desirable characters**

| Sl.No. | Character | Desirable varieties |
|---|---|---|
| 1 | Tree height (Short statured and low canopy spread suited for high density planting) | Local, PKM-1 |
| 2 | Max.number of flushes per metre square | Cricket Ball, Oval |
| 3 | Max.number of inflorescence per metre square | PKM-1, Cricket Ball |
| 4 | Minimum flower drop | Local, PKM-1 |
| 5 | Maximum fruit set | PKM-1, Local |
| 6 | Minimum fruit drop | Co-2 |
| 7 | More fruit retention to maturity | Gavarayya |
| 8 | Maximum fruit weight, girth and volume | Cricket Ball |
| 9 | Maximum fruit length | Oval |
| 10 | Minimum seed weight per fruit | Local, PKM-1 |
| 11 | Minimum seeds per fruit | Local, PKM-1 |
| 12 | Minimum fruit skin scruffness | PKM-1, Local |
| 13 | Maximum TSS | PKM-1, Co-2 |
| 14 | Maximum fruit reducing sugar | Co-2, Oval |
| 15 | Maximum fruit non reducing sugar | Local |
| 16 | Maximum total fruit sugar | Co-2, PKM-1 |
| 17 | Minimum days for maturity | Local, PKM-1 |
| 18 | Minimum heat unit requirement | PKM-1, Local |
| 19 | Maximum number of fruits per tree | PKM-1 |
| 20 | Maximum yield per tree | PKM-1 |


SUMMARY

## 6. SUMMARY

Present studies were undertaken on six sapota varieties namely, Cricket Ball, Oval, Co-2, Gavarayya, PKM-1 and Local grown in the orchard, Department of Pomology and Floriculture, College of Horticulture during the period April 2001-March 2002. The objectives of study were to understand

1. The pattern of growth, flowering and floral biology
2. Fruit set, fruit development, fruit drop and quality analysis
3. Self and cross compatibility nature.

The following conclusions were made based on the investigations.

Height of the tree was maximum in the variety Cricket Ball (7.68 m) followed by Oval (8.88 m) and minimum height was recorded in the variety Local (2.72 m). Maximum girth of the tree was recorded in the variety Cricket Ball (0.63 m) followed by Oval (0.54 m). The variety Cricket Ball recorded the maximum canopy spread (7.40 m) followed by Co-2 (5.16 m). Canopy spread was minimum in the variety PKM-1 (2.99 m). Volume of the tree was greatest in Cricket Ball (151.90 $m^3$). Varieties PKM-1 and Local recorded lower tree volume and they were on par with each other (13.65 $m^3$ and 11.7 $m^3$ respectively). Number of primary branches was highest in Cricket Ball (3.0) followed by Co-2 and Oval varieties (2.50, each).

Number of flushes per meter square was maximum in Cricket Ball (11.90). Maximum length of the flush was recorded in the varieties Oval (13.10 cm), Cricket Ball (12.68 cm) and Co-2 (12.13 cm). Number of leaves per flush was highest in Cricket Ball (14.60 cm). Girth of the shoot was maximum in the variety Cricket Ball (2.50 cm) followed by the variety Oval (1.79 cm). Total duration of flushing was maximum in the variety Oval (28.7 days) followed by Cricket Ball (27.6 days) and Gavarayya (27.2 days). Two seasons of flushing were observed as main seasons, viz., May-July and September-November. In first season early flushing occurred in PKM-1, Co-2 and Cricket Ball. Similarly, in second season, early flushing started in PKM-1 by September 7$^{th}$, Gavarayya and Local were late in flushing (September 14$^{th}$ and 15$^{th}$ respectively). Maximum mean monthly extension growth of shoots was recorded in June followed by

October for all the varieties. A similar trend was also observed in the percentage of shoots showing growth in all the six varieties under study. There was no shoot extension growth in March, April, August and December. Percentage of shoots flowered was maximum in the variety Cricket Ball (89.83%) followed by Co-2 (89.17%) and minimum number of shoots flowered was recorded in PKM-1 (80.0%). Maximum per cent of shoots flowered was recorded in all the six varieties were observed in the shoots oriented in the North followed by South. In northern side, Co-2 recorded maximum number of shoots flowered (95%) followed by Cricket Ball (94%). Minimum per cent of shoots flowered were in East-West orientation of the tree.

Maximum number of inflorescence per square metre was recorded in the variety PKM-1 (12.50) and maximum number of flowers was observed in Cricket Ball (6.10). Number of days taken for bud emergence to bud opening was maximum for the variety Cricket Ball (28 days) followed by Oval (24 days). Minimum number of days taken for complete opening of an inflorescence was recorded in Oval (5.6 days). The varieties Co-2 (7.1 days) and Cricket Ball (7.3 days) took number of days for complete opening of an inflorescence. The stages of sapota flower bud development were divided into seven stages. Maximum length and girth of Oval flower bud at stage 7 was 2.1 cm and 2.5 cm respectively. Minimum length and girth of the flower bud at stage 7 was observed in the variety Local followed by PKM-1 (1.2 cm and 1.8 cm, respectively). Anthesis occurred at 7.00 a.m. to 8.00 a.m. with peak anthesis from 7.00 a.m. to 7.30 a.m. The period of anther dehiscence occurred at one day before the anthesis. It suggests the protandrous nature of flowers. There was no anther dehiscence during the day of opening and one day after anthesis. Maximum receptivity of stigma in all the six varieties was found at the time of anthesis. The receptivity of stigma gradually decline on the same day of anthesis since the per cent fruit set was absent by 8.00 hours to 1.000 hours after anthesis.

Maximum pollen fertility (96%) was observed in the varieties Cricket Ball and PKM-1. The diameter of the viable pollen grain was maximum (94.75 micron) in Gavarayya and minimum in Local variety. The maximum and minimum diameter of non-viable pollen was recorded in Cricket Ball (58.65 micron) and PKM-1 (53.18 micron

respectively). Maximum germination (90.5%) and pollen tube length (197.6 micron) of sapota pollen was observed in the medium having sucrose 15 per cent combined with agar 0.5 per cent, boric acid 100 mg $l^{-1}$ and calcium nitrate 0.03 per cent. Maximum pollen germination percentage was recorded in the variety Co-2 (85.46%) followed by Oval (84.25%). Maximum pollen tube length was recorded in Cricket Ball (196.7 micron) followed by Gavarayya (193.8 micron) and Co-2 (193.4 micron). Longest pollen tube length was recorded in Co-2 (215.6 micron). Maximum pollen production per anther was recorded in the variety Cricket Ball (2871.60) followed by Co-2 (2655.90). Pollen viability was maximum (76.30%) when pollen grains were stored in refrigerator at 4°C followed by pollen storage at calcium chloride in desiccator (60.70 per cent) at 5 days after storage. Pollen grains stated to germinate 4 hours after incubation. Both germination percentage and pollen tube length were reached a peak at 9 hours after incubation and thereafter remains constant.

Maximum flower bud drop occurred at stage 4 followed by stage 5 and it was maximum in the variety Oval (24.0%) and minimum in Local variety (16.0%). Fruit set was maximum in the variety PKM-1 (41.25%) and minimum in the variety Oval (19.50%). Maximum number of fruit set occurred in the northern direction of tree. In the northern side of the tree, maximum fruit set of 70 per cent was recorded in the variety PKM-1 followed by Co-2 (40.0%). Number of days taken from pollination to fruit set was minimum in the variety PKM-1 followed by Local variety and Co-2 variety. Maximum percentage of fruit drop occurred in the Cricket Ball (86.1%) and minimum in Co-2 (79.4%) variety. Maximum fruit drop percentage occurred during first and second fortnight after fruit set in all the six varieties under study.

There was sudden increase in fruit weight of the varieties Gavarayya, PKM-1 and Local from 90 days after fruit set. Whereas, in varieties Cricket Ball, Co-2 and Oval the sudden increase in fruit weight occurred at 105 days after fruit set. Maximum fruit weight was recorded in Cricket Ball (188.80 g) followed by Oval (155.85 g). Varieties Oval and Gavarayya recorded a sudden increase in length after 135 days after fruit set. Maximum fruit length was recorded in variety Oval (12.5 cm) followed by Gavarayya (10.5 cm). Girth of the fruit increased gradually from fruit set to maturity. Maximum fruit

girth was recorded in Cricket ball (17.4 cm) and minimum in Local (4.85 cm) variety. Volume of the fruit had sudden increase from 90 days after fruit set. Maximum volume of the fruit was recorded in the variety Cricket Ball (195.25 ml) and minimum in Local variety (42.20 ml). Specific gravity of the fruit was maximum in Cricket Ball (0.99) minimum in the variety Local (0.83).

Maximum number of seeds per fruit was recorded in Cricket Ball (5.4) and minimum in Local (1.50) variety. Maximum seed weight per fruit was recorded in Cricket Ball (8.26 g). Pulp: seed ratio was recorded in Oval (94.53) followed by Co-2 (66.23). Seed weight per fruit was minimum in Local (1.79 g). Maximum seed length and breadth was recorded in Cricket Ball and minimum in the variety Local. Seeds of Co-2 and Gavarayya were oval; PKM-1 has short stout, oval seeds. Seeds of Cricket Ball were elongated with blunt end whereas seeds of Oval have slight curve a tip.

TSS was very low upto 30 days after fruit set thereafter increased gradually till maturity. Maximum TSS was recorded in the variety PKM-1 (22.6°Brix) followed by Co-2 (21.25°Brix). Reducing sugar increased sharply after 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1 and thereafter increased gradually whereas the sharp increase in reducing sugar occurred after 45 days from fruit set in Co-2, Oval and Local varieties and thereafter increase gradually. Reducing sugar was maximum in the variety Co-2 (15.8%) followed by Oval (14.5%). The increases in non-reducing sugar followed the similar pattern like that of the changes in reducing sugar. Non-reducing sugar was more in PKM-1 (6.5%) followed by Local (5.2%). Total sugars recorded were highest in Co-2 (20.55%). There was a gradual decline in acidity in all the six varieties during the span of fruit development. Maximum acidity was present in Cricket Ball (0.28%) followed by Co-2 (0.26%). Sugar: acid ratio increased progressively during the development period with a sudden increase after 60 days from fruit set in Cricket Ball, Gavarayya and PKM-1, whereas in Local, Co-2 and Oval the sudden increase in sugar: acid ratio occurred at 45 days after fruit set. Maximum sugar: acid was recorded in PKM-1 (96.50%0 followed by Oval (86.36%).

In the first season, maximum number of days taken for maturity was in Co-2 (167.6 days). Local (150.4 days) and PKM-1 (151.5 days) took lesser number of days for

maturity. In second season, Oval recorded maximum number of days for maturity (154.9 days) and PKM-1 recorded minimum number of days (135.8 days). Heat unit requirement was maximum for the variety Co-2 (followed by Cricket Ball and Oval.

Fruit yield in second harvesting period (February-March) was maximum when compared to first harvesting period (October-November). Total number of fruits was maximum in PKM-1 (670) in second crop, whereas it was 480 fruits in first crop. Total number of fruits was minimum in Oval (150) and Cricket Ball (220) fruits in second crop. Total fruit weight was maximum in PKM-1 (60.5 kg) in second crop; whereas minimum fruit weight was recorded in Local (11.75 kg).

Selfing the varieties resulted in only meagre fruit set. There was no fruit set while selfing Oval, Cricket Ball and Local varieties. In cross-pollintion among the varieties maximum fruit set (28.57%) was obtained in Co-2 x Gavarayya cross combinations followed by Cricket Ball x Co-2 (27.69%). The entire cross combinations involving Gavarayya and PKM-1 as female parent set fruit. There was no fruit set in Co-2 x PKM-1, Co-2 x Local, Cricket Ball x PKM-1, Cricket Ball x Local, Oval x Cricket Ball, Oval x Local, Local x Co-2, Local x Cricket Ball and Local x Oval. Minimum fruit set was obtained in the Oval x Co-2 cross combination (8.33%) followed by Co-2 x Oval (10.0%). The extent of fruit drop was maximum in the Cricket Ball x Co-2 cross combination (55.55%) followed by Gavarayya x Co-2 (46.15%). Fruit drop was minimum in Gavarayya x PKM-1 cross combination (9.01%).

Fruit weight was maximum in the Cricket Ball x Co-2 cross combination (180.80 g) and minimum in the cross combination involving Local x Gavarayya (38.87 g). Maximum length of the fruit was recorded in cross Oval x Gavarayya (12.36 cm) and minimum in the cross Co-2 x Cricket Ball (5.75 cm), Co-2 x Gavarayya (5.80 cm) and Local x PKM-1 (5.80 cm). Fruit girth was maximum in the cross Co-2 x Cricket Ball (17.6 cm) and Cricket Ball x Gavarayya (17.5 cm) and minimum in the cross Local x PKM-1 (5.80 cm) and Local x Gavarayya (5.95 cm). Maximum fruit volume was recorded in the cross Cricket Ball x Co-2 (197.5 ml) and minimum in the cross Local x PKM-1 (4.02 ml). Specific gravity of fruit was maximum in the cross Cricket Ball x Co-2 (1.06) and minimum specific gravity was recorded in Local x Gavarayya (0.75).

Pulp: seed ratio was maximum in the cross Oval x Co-2 (93.4) and minimum in Local x Gavarayya (23.2).

TSS was highest in the cross PKM-1 x Gavarayya (26.20° Brix) and lowest TSS was recorded in the cross Co-2 x Gavarayya (20.35° Brix). Reducing sugars was maximum in Gavarayya x Oval (12.90%) and minimum in Local x PKM-1 (9.5%) while non-reducing sugar was maximum in Cricket Ball x Gavarayya (11.4%) and minimum in Local x Gavarayya (5.5%). Total sugars were maximum in Cricket Ball x Oval (24.0%) followed by Cricket Ball x Gavarayya (23.6%) and minimum in Local x Gavarayya (15.1%). Acidity was maximum in the cross Co-2 x Cricket Ball (0.22%) and minimum in Co-2 x Gavarayya (0.10%) and Gavarayya x Local (0.10%). Sugar: acid ratio was maximum in Cricket Ball x Oval (218.18) followed by Cricket Ball x Gavarayya (196.67) and minimum in Co-2 x Cricket Ball (96.82).

Seed weight per fruit was maximum in the cross Cricket Ball x Gavarayya (4.60 g) and minimum in PKM-1 x Local (2.3 g) and PKM-1 x Oval (2.40 g). Maximum number of seeds per fruit was recorded in Cricket Ball x Oval (5.4) and minimum in Local x Gavarayya (1.4) crosses. Length of the seed was maximum in Cricket Ball x Co-2 (3.5 cm) and minimum in PKM-1 x Oval (2.5 cm), while the breadth of the seed was maximum in Gavarayya x Local (2.9 cm), Gavarayya x Cricket Ball (2.9 cm) and minimum in Cricket Ball x Gavarayya (1.7 cm) and Local x Gavarayya (1.7 cm). Seed germination percentage was maximum in cross Oval x Co-2 (88.89%) followed by Co-2 x Oval (66.67%) and Gavarayya x Co-2 (52.94%). Minimum germination percentage was recorded in Gavarayya x Oval (20.0%) followed by Gavarayya x Local (23.08%). Number of days taken for seed germination was minimum in the cross Local x PKM-1 (15.3 days) followed by Local x Gavarayya (16.2 days). Maximum number of days taken for seed germination was recorded in Gavarayya x Cricket Ball (21.3 days).

Number of days taken for maturity was minimum in the cross Local x PKM-1 (150.0 days) followed by Gavarayya x Oval (152.0 days), Local x Gavarayya (154.0 days) and PKM-1 x Local (154.6 days). Maximum days taken for maturity were for the crosses Co-2 x Cricket Ball (167.2 days) and Cricket Ball x Co-2 (167.2 days).

Pollination with the application of NAA 5.0 mg $l^{-1}$, 2,4-D 0.5 mg $l^{-1}$, pollination with gamma rays irradiated (40 Gy, 50 Gy and 75 Gy) pollen resulted in fruit set in incompatible varieties.

Number of flushes per unit area, number of inflorescence per metre square and fruit set was positively correlated with minimum temperature. Fruit weight, girth, volume, TSS, reducing sugars and yield were positively correlated with maximum temperature. Sunshine hours were positively significant in correlation with reducing sugars, total sugars and yield while, rainfall had a negative correlation with the biochemical characters of fruits and total yield.

Tree volume, fruit weight, fruit volume, number of fruits per tree recorded high GCV and PCV (GCV ranged between 48.77 and 104.18 per cent while, PCV ranged between 48.72 and 108.52 per cent). The phenotypic and genotypic coefficient of variation for number of seed per fruit was 54.0 per cent and 56.8 per cent and for seed weight per fruit was found to be 54.17 per cent and 56.91 per cent respectively. Characters like fruit volume, fruit girth, weight, seed weight per fruit, tree girth recorded high heritability. Genetic advance recorded for the characters showed wide variation ranging between 0.23 and 119.04 per cent. Maximum genetic advance was observed for fruit weight followed by fruit volume. The vegetative characters showing high positive correlation with fruit yield were tree height, tree girth while flowering characters were number of inflorescence per metre square, number of flowers per inflorescence and fruit characters were fruit set percentage, fruit weight, fruit girth and fruit volume. The geotypic correlations for these characters ranged between 0.556 to 0.654 while phenotypic correlation ranged between 0.450 to 0.581. The flushes per unit area were positively correlated with number of inflorescence per metre square (rg = 0.627). Fruit set was positively correlated with number of flowers per inflorescence (rg = 0.566) and number of inflorescence per square metre (rg = 0.465). Maximum correlation was observed between fruit set and number of fruits per tree (rg = 1.005) and hence the maximum positive correlation with yield (rg = 0.463). Number of fruits per tree was highly correlated with fruit set (rg = 1.005) and (rp = 0.902) followed by number of inflorescences per unit area (rg = 0.455 and rp = 0.423).

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APPENDIX

**Appendix-I**
**Weather parameters from January 2001-July2002**

| Month | Temperature (°C) (Max.) | Temperature (°C) (Min.) | R.H. (%) morning | R.H. (%) evening | Mean R.H. (%) |
|---|---|---|---|---|---|
| **2001** | | | | | |
| January | 32.6 | 23.2 | 71 | 41 | 56 |
| February | 34.5 | 22.9 | 86 | 48 | 67 |
| March | 34.9 | 24.0 | 84 | 54 | 69 |
| April | 34.2 | 24.7 | 88 | 63 | 75 |
| May | 32.3 | 24.5 | 89 | 73 | 81 |
| June | 28.4 | 23.1 | 94 | 79 | 87 |
| July | 29.0 | 22.7 | 93 | 77 | 85 |
| August | 29.1 | 23.1 | 94 | 76 | 87 |
| September | 30.7 | 23.2 | 91 | 67 | 79 |
| October | 30.7 | 23.0 | 91 | 71 | 81 |
| November | 33.3 | 23.1 | 77 | 60 | 72 |
| December | 30.4 | 22.2 | 70 | 48 | 60 |
| **2002** | | | | | |
| January | 32.8 | 22.7 | 79 | 45 | 62 |
| February | 34.3 | 22.4 | 71 | 28 | 50 |
| March | 36.2 | 24.1 | 85 | 40 | 63 |
| April | 35.0 | 24.8 | 86 | 55 | 71 |
| May | 32.6 | 24.5 | 88 | 67 | 87 |
| June | 30.0 | 23.3 | 93 | 78 | 86 |
| July | 29.8 | 23.1 | 94 | 74 | 84 |

Appendix-I (Contd.) Weather parameters from January 2001 to July 2002

| Month | Rainfall (mm) | Sunshine (hrs) | Wind speed (Km/hr) | Soil temperature (°C) -10cm depth |
|---|---|---|---|---|
| **2001** | | | | |
| January | 0.0 | 249.4 | 8.0 | 35.6 |
| February | 12.2 | 223.4 | 4.2 | 37.8 |
| March | 14.4 | 252.8 | 4.1 | 40.7 |
| April | 243.1 | 193.7 | 3.5 | 38.9 |
| May | 192.6 | 198.4 | 3.3 | 35.7 |
| June | 676.2 | 57.0 | 3.4 | 30.5 |
| July | 477.7 | 73.5 | 3.5 | 32.5 |
| August | 253.2 | 112.3 | 3.6 | 31.8 |
| September | 200.9 | 160.3 | 3.2 | 33.2 |
| October | 215.8 | 145.5 | 4.7 | 32.7 |
| November | 115.8 | 184.9 | 4.9 | 34.4 |
| December | 0.0 | 252.4 | 10.0 | 32.9 |
| **2002** | | | | |
| January | 0.0 | 249.9 | 8.0 | 36.6 |
| February | 0.0 | 233.3 | 7.8 | 37.6 |
| March | 16.2 | 255.0 | 4.8 | 41.5 |
| April | 50.8 | 234.4 | 4.1 | 40.7 |
| May | 308.4 | 178.4 | 4.1 | 35.9 |
| June | 533.5 | 81.0 | 4.0 | 31.4 |
| July | 354.2 | 105.7 | 3.8 | 31.2 |

# VARIETAL EVALUATION AND COMPATIBILITY STUDIES IN SAPOTA

## (*Manilkara achras* [Mill]. Fosberg)

By

**P. RAJASEKAR**

## ABSTRACT OF THE THESIS

**Submitted in partial fulfilment of the requirement for the degree of**

## Master of Science in Horticulture

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# ABSTRACT

The experiment on varietal evaluation and compatibility studies in sapota (*Manilkara achras* (Mill.) Fosberg) was carried out in the trees maintained in the orchard, Department of Pomology and Floriculture, College of Horticulture, Vellanikkara.Height of the tree was maximum in Cricket Ball and minimum in Local. Maximum girth, canopy spread, volume of the tree was recorded in Cricket Ball. Number of flushes per metre square, number of leaves per flush, girth of the shoot was maximum in Cricket Ball. Length of the flush was maximum in Oval. Total duration of flushing was maximum in Oval and Cricket Ball. There were two main seasons of flushing May- July and September – October. PKM-1, Co-2 and Cricket Ball were early in flushing. Mean monthly extension of growth of the shoots and percentage of shoots flowered was maximum in June followed by October for all the varieties. Percentage of shoots flowered was maximum in Cricket Ball. Oval and PKM-1 were early flowering in nature, maximum percentage of shoots flowered were in north orientation of tree. Maximum number of inflorescence per metre square was recorde in PKM-1 and Cricket Ball. Number of flowers per inflorescence was maximum in Cr et Ball. Minimum number of days taken for complete opening of an inflorescence was r rded in Oval.

Peak anthesis period occurred between 7.00 a. to 7.30 a.m and anthe dehiscence was on the day before anthesis. Maximum na receptivity was found a time of anthesis. Maximum pollen fertility was reco in Cricket Ball and PKM-1. Diameter of viable pollen was maximum in Gavara Maximum pollen germination and pollen tube length was recorded in sucrose 15 pe +agar 0.5 per cent +boric acid 100 ml $^{-1}$+ calcium nitrate 0.03 per cent med Maximum pollen germination percentage and longest pollen tube length was re in Co-2 and maximum polle tube elongation was recorded in Cricket Ball. Max ollen production per anther was in Cricket Ball. Maximum pollen germination a n tube elongation occurred at 9 hours after incubation. Flower bud drop was m in Oval. Maximum fruit set percentage and minimum number of days take llination to fruit set recorded in the variety PKM-1. Maximum percentage of occurred in Cricket Ball in one

month after fruit set. Maximum fruits were retained in PKM-1. Maximum fruit weight, girth, volume, specific gravity, number of seeds per fruit, seed weight per fruit, seed length were recorded in Cricket Ball. Fruit length, pulp: seed ratio, seed breadth was maximum in Oval. TSS, non-reducing sugars, total sugars, and sugar: acid ratio were maximum in PKM-1, while reducing sugar, acidity was maximum in Co-2. Number of days taken for maturity depends on the season and heat unit requirement. Co-2 required more number of days for maturity while PKM-1 recorded minimum number of days for maturity. Heat unit requirement was maximum for the variety Co-2 followed by Cricket Ball and Oval. Maximum fruit yield was obtained in second season crop. PKM-1 recorded high yield in terms of number of fruits and fruit weight.

Selfing the varieties resulted very poor fruit set, while intervarietal cross pollinations resulted in maximum fruit set in Co-2 X Gavarayya and Cricket Ball X Co-2. Maximum fruit drop occurred in Cricket Ball X Co-2. Fruit weight, volume and specific gravity were maximum in Cricket Ball X Co-2, fruit length in Oval X Gavarayya, fruit girth in Co-2 X Cricket Ball, pulp: seed ratio in Oval X Co-2. TSS was maximum in PKM-1 X Gavarayya, reducing sugar in Gavarayya X Oval, non reducing sugar in Cricket Ball X Gavarayya, total sugar and sugar: acid ratio in Cricket Ball X Oval, acidity in Co-2 X Cricket Ball cross combinations. Number of days taken for maturity was minimum in Local x PKM-1 and maximum in Co-2 X Cricket Ball and Cricket Ball X Co-2. Maximum seed weight per fruit was recorded in Cricket Ball X Gavarayya, number of seeds per fruit in Cricket ball X Oval, length of seed in Cricket Ball X Co-2, Cricket Ball X Oval, breadth of seed in Gavarayya X Local and Gavarayya X Cricket Ball. Seed germination percentage was maximum in Oval x Co-2 and number of days taken for seed germination was minimum in Local X PKM-1. Co-2 X PKM-1, Co-2 X Local, Cricket Ball X PKM-1, Cricket Ball X Local, Oval X Cricket Ball, Oval X Local, Local X Co-2, Local X Cricket Ball, Local X Oval were found to be cross incompatible combinations. Pollination after removing the stigma and pollinating with *in vitro* basal medium, pollination with application of NAA 5 mg $l^{-1}$, 2,4-D-0.5 mg l, pollination with gamma rays irradiated (40Gy, 50Gy and 75 Gy) pollen resulted in fruit set in incompatible varieties.

Tree volume, fruit weight, fruit volume, number of fruits per tree recorded high GCV and PCV (GCV ranged between 48.77 to 104.18 per cent while, PCV ranged between 48.72 to 108.52 per cent). Characters like fruit volume, fruit girth, weight, seed weight per fruit, tree girth recorded high heritability. Genetic advance recorded for the characters showed wide variation ranging between 0.23 to 119.04 per cent. Maximum genetic advance was observed for fruit weight followed by fruit volume. The vegetative characters showing high positive correlation with fruit yield were tree height, tree girth while flowering characters were number of inflorescence per metre square, number of flowers per inflorescence and fruit characters were fruit set percentage, fruit weight and fruit girth and fruit volume. Maximum correlation was observed between fruit set and number of fruits per tree (rg=1.005) and hence the yield (rg = 0.463). Number of fruits per tree was highly correlated with fruit set (rg = 1.005) and rp = 0.902) followed by number of inflorescence per unit area (rg = 0.455 and rp = 0.423).