# BIODIVERSITY ANALYSIS OF TRADITIONAL MANGO TYPES OF KERALA AND STUDIES ON THE REPRODUCTIVE BIOLOGY OF SELECTED POPULAR TYPES

By

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**THESIS**

*submitted in partial fulfillment of the*

*requirement for the degree of*

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# DECLARATION

I hereby declare that the thesis entitled **"Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types"** is a record of research work done independently by **Miss.Mannambeth Renisha Jayarajan (2009-12-104)**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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## SHORT FORMS USED

**ADB**- Asian Development Bank

**Bioversity** – Bioversity International

**CBM**- Community Biodiversity Management

**FCA**- Four Cell Analysis

**FCR**- Flurochromatic Reaction

**FGD**- Focal Group Discussion

**GP**- Gramapanchayath

**IBPGR**- Indian Bureau for Plant Genetic Resource

**IK**- Indigenous Knowledge

**IPGRI**- International Plant Genetic Research Institute

**ITK**- Indigenous Traditional Knowledge

**PPB**- Participatory Plant Breeding

**TFT**- Tropical Fruit Trees

**VBR**- Village Biodiversity Register

# *Introduction*

# 1. INTRODUCTION

Plant genetic resources play a vital role in enhancing adaptations and resilience of agricultural production systems. The term 'genetic conservation' was reported to be first used by Erna Bennett in 1965 (Frankel, 1986). It evolved from the realization of the imminent threat to the crop types of traditional agriculture, which were recognized as the "store houses of genetic diversity" or "the plant breeder's treasury" (Frankel, 1967). Green revolution and such other rapid strides in crop production, which took place during 60's, resulted in paving way to highly productive, uniform modern cultivars in place of the "primitive cultivars" or landraces of different crops. It was much rampant in the developed parts of the world causing the extinction of many useful local types. Such a whole scale devastation of local types of crops did not take place in the lesser developed regions of Asia, Africa and Latin America and especially in the centers of genetic diversity identified by Vavilov during 20's and 30's. The value of what came to be known as "genetic resources" (Frankel and Bennett, 1970) had been widely recognized ever since and a concerted attempt to conserve these resources was made in the years that followed.

Collection, characterization and conservation of the diversity in germplasm banks were given high priority initially and the efforts resulted in a worldwide network of *ex situ* gene banks of different crops including tropical fruit trees. Nevertheless it was not able to accommodate the full range of useful diversity of many local types of different crops. Proper documentation of the acquired traditional knowledge of farming community in crop and varietal selection and the management aspects inherent in the development and evolution of such unique types were also left out during the process.

In the last two decades, a shift in biodiversity conservation strategies has taken place all over the world in which 'on farm/ *in situ* conservation' methods are gaining more attention than before. Use of farmer participatory tools for biodiversity

assessment and documenting the ITK from the villages gained more prominence during the period.

The village homesteads in many of the South-East Asian countries are rich repositories of tropical fruit tree (TFT) biodiversity. Kerala, on the southwest coast of Indian peninsula, is such a location where most of the villages in central and northern region are still having many primitive TFT cultivars or local types in the traditional homesteads. The biodiversity status of these types and the potential for utilizing the material in crop improvement are yet to be assessed systematically. Any attempt in this direction will also help in working out ways and means for conserving the 'rare' types from extinction.

Such a TFT biodiversity in the villages of Kerala is unique with the presence of many traditional mango types in the homesteads. Many of them belong to the poly-embryonic group and well adapted to the humid tropics. They are hardy and resistant to the common diseases affecting the popular types from other states when brought and cultivated here. A research project on "Hybridization of mango varieties of Kerala" was initiated in this background at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Thrissur during 2009. It broadly comprises of assessing the biodiversity status of mango types in the villages of Thrissur and adjoining districts, and undertaking hybridization among the promising ones and popular types to evolve varieties with excellent fruit quality. The present project entitled "Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types" was taken up as a prelude to this and implemented during 2009-2011 period.

Assessment of local mango biodiversity by applying farmer participatory tools in selected villages of Thrissur and Palakkad districts were taken up as the first component of this project. Bioversity International, Wageningen, under the DGIS-Wageningen UR partnership programme of the global CBM studies, awarded a

student fellowship for undertaking the above aspect and provided technical and financial support for implementation.

Basic studies on reproductive biology of selected popular mango types involved in the original hybridization programme was taken up as the second component utilizing the trees in the varietal collection maintained in the department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Thrissur.

# *Review of Literature*

# 2. REVIEW OF LITERATURE

## 2.1 Biodiversity analysis

### 2.1.1 Fruit diversity-Asian scenario

Asia is blessed with a rich fruit crop diversity having about 500 different species distributed in its varied ecosystems (Verheij and Coronel, 1991; Arora and Rao, 1995). A wide range of natural plant diversity well adapted to the sub humid, humid tropical and semi arid conditions is the characteristic feature of this region. Besides the domesticated and diversified native fruit species, a large number of species of tropical American origin introduced in the distant past have agro-ecological niche and are well acclimatized (Arora and Rao, 1995). However, only about 20 species are under extensive cultivation comprising banana, citrus, mango, pineapple, papaya, durian, rambutan, jackfruit, litchi, longan etc., and the predominant ones being banana, citrus, mango, pineapple and papaya.

The humid tropic regions of the continent possesses a very rich species diversity of many tropical fruit trees(TFT) which are the major components of poly crop farming systems including the home gardens. Most noted example of such a rich tree fruit biodiversity in Asia is the genus *Mangifera* comprising 58 species naturally distributed in southeast and east Asia (Kosterman and Bompard,1993). The Malay peninsula, the Indonesian archipelago, Thailand, Indo-China and Philippines are the centers of diversity for *Mangifera* species (Mukherjee, 1985; Bompard, 1988; Kosterman and Bompard, 1993). About 26 species have edible fruits, either eaten as fresh fruit or used to prepare jams, jellies, and preserves; the most important being the cultivated mango *Mangifera indica* L. The other important species which produce edible fruits are *M. caesia. Jack, M. foetida Lour, M. kemanga Bl, M. laureina Bl, M. odorata Griff. Lour* (Tanaka, 1976; Bompard, 1992), *M. pajang Kostermans* (Bompard, 1992) and *M. sylvatica Roxb.* (Tanaka, 1976) which, with the exception of latter, are mostly distributed in Malaysia and Indonesia. *Mangifera* species other than

*Mangifera indica* reported from India include *M. andamanica, M. khasiana, M. sylvatica and M. camptosperma* (Mukherjee, 1985). A large array of cultivated and wild types are present in the Indian sub continent. Seedling races derived from mono embryonic mango seeds are the most important diversity sources available in India. Almost all commercial cultivars of mango have arisen as chance seedling selection. Although, most other countries in Asia, Pacific and Oceania regions have two to ten commercial cultivated mango types, India has around 1000 distinct types and about 30 of them are commercially grown.

### 2.1.2 Tropical fruits- economic and nutritional implications

Tropical fruits, the major group under the horticultural crops, contribute much to the overall agricultural development of a region. During the last decade, Asia recorded 66 per cent increase in the fruit production, the highest in the world. The region of south, south east and east Asia is important in this respect and four countries viz., India, Indonesia, Thailand and China account for 50 per cent of the total global fruit production. They account for 30-59 per cent of total farm increase especially for small holders and marginal farmers of this region (TF Net, 2004) leading to better livelihood of the rural people, largely the farming community. They are essential for improved human nutrition and health and designated as protective foods. (Pareek et al., 1998; Hoe and Siong, 1999; Reddy et al., 2010). The native fruit species and local types of this region contribute to the economic welfare of the small farmers in Asia by providing food and nutritional security, income generation, poverty reduction, ecosystem and environmental sustainability etc. The present trend of mono crop based rapid agricultural development and industrialization, changing land use pattern, large scale deforestation along with other social and cultural pressures have all resulted in large scale degradation of natural habitat and loss in native diversity. Hence, it is imperative that the diversity needs to be conserved by adopting effective conservation and management techniques.

### 2.1.3 Conservation of tropical fruit tree genetic resources- 'Bioversity initiatives'

#### 2.1.3.1 *In situ* conservation

Under the ADB funded project on tropical fruits, Bioversity International ['Bioversity' in short and erstwhile IPGRI] promoted the concept of on-farm conservation of fruit genetic resources (Nares et al., 2001). *In situ* conservation activities were initiated in a few countries, namely, Bangladesh, India, Nepal, the Philippines, Sri Lanka and Vietnam and suitable *in situ* conservation sites were identified (IPGRI, 2003). The principles of on-farm/ *in situ* conservation recognize that such efforts will be successful and sustainable only through the active participation of communities who depend and enjoy the fruits of the available resources. Hence, efforts were made to encourage the farmers and communities to participate in the conservation of tropical fruit trees genetic resources. In Nepal, farmer group meetings were organized with the help of Agriculture Development Department and awareness was created about the value of their fruit germplasm materials in terms of income generation, socioeconomic aspects and conservation for future use. Fruit diversity fairs, fruit shows and fruit festivals were organized in Nepal, Bangladesh, Vietnam, Thailand and the Philippines during socio economic surveys and germplasm collection. Close interaction with farmers and communities also motivated them to participate in the germplasm conservation efforts. The striking observations from these initiatives were that, although several farmers were carrying out *in situ* conservation (as they continue to grow traditional types over generations and practice some level of selection while planting new orchards or home gardens) in an unconscious manner, they became more aware of the value of what they have been doing from these interactions. Such efforts also indicated that different approaches (including agro forestry system approach and community biodiversity management (CBM approach) are required to make in situ/on-farm conservation sustainable and beneficial to tropical fruit tree growers (IPGRI, 2003).

### 2.1.3.2. *Ex situ* conservation

The national programmes in the collaborating countries of Bioversity are maintaining germplasm of the target species in the field gene banks at different locations in the respective countries. Fifty two field gene banks were identified/ established for different crops, viz., mango (21), citrus (13), rambutan (8), jackfruit (4), litchi (4) and mangosteen (2). These field gene banks were enriched with more accessions collected during the ADB project, thus enriching the accessible genetic diversity.

*Ex situ* conservation of TFT genetic resources is an expensive and labour intensive process requiring considerable land resources. Hence, any effort in developing and managing fruit tree gene bank should be based on sound planning and viable strategies. Bioversity has standardized a set of improved guidelines for establishment and management of field gene bank of many tropical fruit trees (Saad and Rao, 2001).

### 2.1.4. Ethnic mango biodiversity- The status of Kerala villages

Homestead with rich crop diversity is the landmark of Kerala villages. Local types of mangoes are essentially one among the invariable components of such a poly crop system. They are of seedling origin and many of them belong to the poly embryonic group. But the rapid rate of urbanization, changes in land and crop use patterns etc. are presently posing serious threat to this valuable germplasm.

Early description on mango types of Kerala was made by Kannan (1982) and later, survey and evaluation for locating the types of different regions were also attempted (KAU, 1998; Radha and Nair, 2000 and Jyothi, 2000).

### 2.1.5. Biodiversity analysis and preparation of mango germplasm catalogues and biodiversity registers in the villages

Recognizing the increasing importance and the need of conservation and utilization of tropical fruit trees, Bioversity initiated research on conservation and use of TFT species in Asia in 1993 in collaboration with other national partners. Accordingly, the participating countries identified and catalogued important types of relevant fruit species and these catalogues contain valuable information of different types. Two catalogues on Indian mangoes involving 404 accessions have been prepared accordingly (Rajan, 2003; Rajan et al., 2002; Dinesh and Vasugi, 2002).

Conduct of village level biodiversity analysis of local mango types of Kerala and preparation of germplasm catalogues and biodiversity registers are supposed to be the basic step in locating useful landraces for use as parental material for future hybridization programmes. At present regional field germplasm maintenance is undertaken to an extent at different research stations of Kerala Agricultural University and agricultural farms attached to the Department of Agriculture, Government of Kerala. But such *ex situ* conservation procedures in fruit trees like mango are expensive and labour intensive processes requiring considerable land and other resources.

Undertaking biodiversity analysis of local mango types at the village level by applying a standardized farmer participatory tools and preparing mango biodiversity registers with the help of the household owners is essentially the primary step in locating the useful types for later use in hybridization programme.

Biodiversity cataloguing of the mango types in Kerala villages through participatory approaches is yet to be attempted systematically.

Gautham et al. (2008) while studying the home gardens in Nepal observed that home garden management of key species/ types is the ideal way to conserve the useful diversity from extinction. Home gardens are dynamic in their evolution, composition and uses. They often serve as a place where farmers can experiment

with, introduce and domesticate useful plants (Eyzaguirre and Linares, 2004). Gautham et al. (2008) selected four contrasting eco sites for their study. Site selection was based primarily on species diversity, uniqueness of species, status of home garden and its importance; and secondarily on criteria, *viz.*, accessibility, community interest and ethnic composition of community (Jarvis et al., 2000; Suwal et al., 2005). The criteria for the key species identification in home garden was reported by different workers from studies conducted elsewhere (Watson and Eyzaguirre, 2002 and Trinh et al., 2003). Key species / types refers to the locally important species or plant types that are frequently and extensively grown in home gardens in the context of specific socio cultural and agro ecological considerations and primarily intended for household consumption. During their studies they organized focus group discussion (FGD) in each project site involving farmers. These participatory farmer groups discussed and shared information on the importance of key species/ types and their characteristics. The contributions of different key species/ types for food security, nutrition, and on farm management of biodiversity were highlighted. The groups were also asked to define and prioritize their own criteria for selecting the key species/ types in their home gardens.

### 2.1.6. Diversity estimates

Richness and evenness are the key measures of biological diversity (Frankel et al., 1995). Richness refers to the number of types or species regardless of their frequencies and measured using species/ type count for households. The area of each home garden will also be estimated to understand the relationship between the home garden area and species richness. Evenness compares the frequencies of different types or species with low evenness, indicating dominance by one or a few types (Jarvis et al., 2008).

Gautham et al. (2008) adopted household surveys at two levels for understanding seed systems of home gardens in Nepal. The first level survey

consisted of collecting information from the farmers surveyed through semi structured interviews. In the second level survey, nodal farmers were identified for collecting data through the socio metric method using a snowball sampling method. (Subedi et al., 2003).

Sthapit et al. (2006) reported that participatory four cell analysis (FCA) can be effectively applied for assessing the local biodiversity based on their work on farm management of agricultural biodiversity in Nepal. Walter and Marja (2007) also recommended FCA as a participatory tool for identifying unique, common, rare types or crop species cultivated in a community.

## 2.2. Reproductive biology of mango

A sound knowledge on flowering and fruiting characters of the parental types is essential for starting up with hybridization programme in mango. General aspects on flowering and fruiting in *Mangifera indica* L. have been comprehensively studied by different workers in the past. But varietal variation is often noted with respect to the ecoregional changes. It is conspicuous with the popular varieties of other states when grown in the humid tropic situation of Kerala. Not much information is at present available on the pollen characters, compatibility of many of the local types of Kerala which is essential when these local types are involved in hybridization programme and in this background selected relevant literature on different aspects of flowering and fruiting of mango is reviewed hereunder concisely.

### 2.2.1. Flowering

In mango, flowering commences in November or early December in Andhra Pradesh and West coast of India (Gandhi, 1955). Singh (1958) reported that flowering in mango is preceded by the differentiation of flower bud which occurs in October-December depending upon the local climatic condition.

Gunjate et al. (1977) noted fruit bud differentiation started in August and continued till end of October and flowering starts by December under Konkan condition. According to Yadav and Singh (1985) the South Indian mango varieties attain physiological status of flowering earlier than North Indian cultivars.

Radha and Nair (2000) reported that mango in Kerala commences flowering by November- December which was supported by Anila (2002) while studying flowering and fruit development in the varieties namely Alphonso, Neelum, Priyur, Kalapady and hybrids Ratna and H-151 under Kerala conditions.

**2.2.2. Inflorescence characters**

Thimmappaiah and Suman (1987) noted that the panicle size in mango varied from 11.25 to 42.20 cm. In Alphonso the length of flower panicle ranged from 12.4 to 38.6 cm and number of male flowers/ panicle was maximum when grown under coastal Karnataka conditions (Uthaiah et al., 1988).

Desai et al. (1994) studied the floral biology of variety Sai Sugandh and reported the inflorescence as a conical panicle and the rachis with light green to bright pink coloured.

Anila (2002) reported that inflorescence length ranged from 15 to 30 cm. Ratna showed maximum inflorescence size in terms of length and breadth. Number of inflorescence per square metre showed significant difference between the varieties in which Prior showed maximum number of inflorescences/ square metre and Neelum and Alphonso showed minimum number of inflorescences. The number of hermaphrodite flowers was noted to be highest in Ratna and H-151 and lowest in Muvandan.

### 2.2.3. Anthesis

Wagle (1929) recorded that most of the mango flower buds start opening in the early morning and maximum opening was reported between 9 and 10 am (Sen et al.,1946).Spencer and Kennard (1955) also observed that anthesis starts early in morning and completes at noon which was later confirmed by (Randhwa and Damodaran.,1961).

The floral biology of the variety Sai Sugandh was studied and it was found that the anthesis occurs throughout the day but especially between 7.00 and 11.00 hours (Desai et al., 1994).

### 2.2.4. Sex ratio

Sex ratio varies among mango cultivars and is also influenced by the environmental conditions. Naik and Gangolly (1950) described the South Indian mangoes and a monograph was prepared accordingly. Kalyansundaram (1978) reported the highest percentage of perfect flowers in Neelum and lowest in Malgoa. In Sai Sugandh variety the average of 947.9 flowers/ panicle was observed of which 75.73 per cent were perfect flowers (Desai et al., 1994)

Muhammad et al. (2002) reported that difference in sex ratio may be due to their genetic makeup, time of flowering, response to prevailing climatic conditions and endogenous growth hormones. They also noted that the percentage of hermaphrodite flowers is important to decide the fruit set. The percentage of flowers among the cultivars varied significantly and ranged from 21.1 - 90.6 per cent, more number of flowers was observed in cv. Samar Behisht and Langra.

Afifi et al. (2000) studied the flowering behavior of Langra and Fajri Kalan, and noted that male/ perfect flower ratio of Langra was lower than Fajri Kalan especially in 'on' year for Langra and 'off' year for the variety Fajri Kalan.

Studies on sex ratio of cultivars Anwar Rataul, Langra and Deshehari showed more number of male flowers in Anwar Rataul and Deshehari than Langra

on south and west side of plant and Langra with more number of hermaphrodite flowers on the south side (Muhammad et al., 2001).

Anila (2002) reported that percentage of hermaphrodite flowers ranged from 15.77 to 43.39 in Muvandan and Alphonso respectively under Kerala conditions.

Chatterjee (2007) observed percentage of perfect flowers per panicle in Amrapali, Mallika, Prabhasankar, Mahmud Bahar, Alfazli, Sunder Langra, Neelgoa, Neeluddin, Neelashan, Ratna, Arka Puneet, and Arka Anmol and noted that Amrapali exhibited maximum percentage of perfect flowers per panicle, while Neelashan showed highest number of flowers per panicle.

Shu (2009) observed the sex distribution, sex ratio and natural pollination percentage of mango cultivars *viz.*, Haden, Irwin, Keitt and Tsai Suan and it was noted that Kiett has the highest sex ratio of 1.44 per cent, while Haden showed the lowest of 0.2 per cent.

Kundu et al. (2010) studied the flowering of mango cv. Amrapali in different directions (east, west, north, and south) in West Bengal conditions. The hermaphrodite flowers were highest (22.20-42.91%) in western direction and the male flowers were highest (77.63-86.97%) in southern direction during the studies.

### 2.2.5. Anther dehiscence

Dehiscence occurs soon after the opening of flowers. Singh (1954) reported that cloudy days with consequent high humidity delays full opening and dehiscence in mango. Prapanoppasin (1997) reported that under natural conditions anther dehiscence in mango takes place during 8.00 and 10.00 hours in Thailand and most of the cultivars show high percentage of dehiscence when the inflorescence was collected and kept in chamber with relative humidity higher than 80 percent.

Study on anther dehiscence in three cultivars, namely, Choke Anan, Nam Dok Mai and Khiew Sawoey showed highest anther dehiscence with average of 74.16 per cent in Choke Anan and it was found that at high relative humidity (70-90%) the time

of anther dehiscence exerted no effect on Choke Anan but affected Nam Dok Mai and Kheiw Sawoey showing anther dehiscence of 14.95 per cent and 20.06 per cent respectively leading to poor fruit set. (Jutamanee et al., 2000).

### 2.2.6. Stigma receptivity

In mango, stigma remains receptive under favourable conditions for about two days (Popenoe, 1917). Wagle (1929) suggested that best receptivity is seen on the first day of the opening. Later reports showed stigma receptivity continuing for 72 hours after flower opening (Singh, 1954).

Robbertese et al. (1994) reported that stigma is receptive as evidenced by pollen germination from 18 hours prior to anthesis to at least 72 hours after anthesis with optimum receptivity occurring within 3 hours from anthesis. In variety Sai Sugandh the stigma receptivity was greatest on the day of anthesis and ceased after 3 days (Desai et al., 1994).

### 2.2.7. Pollen morphology

The percentage of viable pollen is quite high in mango. It was reported that all mango varieties possess oblong to oval pollen grains which are slightly broader in some varieties and narrower in others, but are of same shape in all when in normal dry state. When moistened the grains become spherical. In normal dry state they are almost oblong in shape. The other shapes of mango pollen are oval round, triangular, elliptic, rhomboidal and round (Singh, 1954; Randhawa and Damodaran, 1961).

Pollen size in different varieties of mango varied from 24μ-30μ (Mukherjee, 1950) and Singh (1954) observed the average size of pollen grains in Langra and Dasheri as 27.3μm and 28.11μm, respectively.

Singh (1961) observed pollen grains of 50 Indian cultivars of mango and found that the length ranged from 25.3μm to 28.3μm.

Perveen and Qaiser (2010) noted that the size of pollen in family Anacardiaceae is in the range of 22.5µm- 32.31µm.

**2.2.8. Pollen viability**

Pollen viability has great importance in crop improvement through hydridisation. Zirke (1937) described the method of mounting pollen on acetocarmine and the stained pollen are considered viable and unstained being non viable.

Stanley and Linskens (1974) mentioned some other stains as aniline blue, potassium iodide, methyl green etc to indicate viability. Bolat and Pirlak (1997) estimated the pollen viability of stone fruits using TTC.

Desai et al. (1994) observed the pollen viability of variety Sai Sugandh while studying the floral biology of it and found that the pollen viability was 93.75 per cent.

Dag et al. (1999) studied pollen viability of 'Kent' mango in Israel using scanning electron microscope and it was determined that the percentage of stained pollen grains increased significantly from 23-96 per cent.

Jutamanee et al. (2000) determined viability using flurochromatic reaction (FCR) test in mango cultivars like Khiew Sawoey, Choke Anan and Dok Mai and the results indicated that all cultivars had high pollen viability between 81.33 - 91.29 per cent and there was no temperature effect on pollen viability as all the three cultivars viability was about the same.

In diploid bananas the pollen viability was evaluated using acetocarmine staining (Soares et al., 2008). Ferrare et al. (2007) reported the pollen viability of thirteen olive cultivars. In *Ziziphus mauritiana* the pollen viability was determined using acetocarmine (Li et al., 2005). Tosun and Koyuncu (2007) studied the pollen of sour cherries using TTC and reported that pollen viability ratios reached 80 to 93per cent.

### 2.2.9. Pollen production

Nair et al. (1964) studied the pollen production and other pollen characters of guava. According to Godini (1979) the pollen production of 10 Almond cultivars showed significant difference per anther. He noted that in the particular season the number of pollen grains greatly decreased in all the cultivars because of reduced sporogenesis due to cold spells and frost. Ferrante, Genco, Scorze verde and Texas were good pollen producers while Fragiulio grande, Non pareil and Tuono were poor pollen producers.

Rajashekar (2003) recorded that Cricket Ball and Co-2 variety of sapota showed maximum pollen production per anther than others.

Using haemocytometric method, the number of pollen per flower in selected capri fig types was determined (Ilgin, 2007). He noted that the pollen production ranged from 4355 to 7169 pollen grains and highest in 46 EI 03 and 46 EI 02 capri fig types.

### 2.2.10 Pollen storage

Rhee et al. (2003) estimated the pollen storage conditions of eight lily genotypes stored in dark chamber with temperature at 4°C, -20°C, -70°C and ambient room temperature for an year and found that -20°C was the best storage temperature. According to Rajashekar (2003) viability of pollen was maximum when stored in refrigerator at 4°C followed by pollen stored on calcium chloride in desiccator at 5 days after storage, while pollen viability was minimum in pollen stored over calcium chloride in desiccator under refrigerator at 4°C followed by control. Deng and Harbaugh (2004) reported that caladium pollen stored at 4°C were viable for 2 to 4 days and effected successful pollination. According to Aslantas and Purlak (2002) the pollen of Aliso, Brio, Cruz strawberry cultivars maintained germination ability upto 20 months when stored at -18°C, while pollen stored at 4°C lost germination ability after 8 months in all cultivars.

Carreno et al. (2009) stored the pollen of different cultivars of *Vitis vinifera* L. at temperature of -20°C, -40°C and -80°C and results showed that pollen stored at -80°C maintains good germination.

Imani et al. (2011) checked the viability of pollen of 4 apple cultivars, for three and seven months after keeping at 3 temperature levels (4°C, -20°C and -80°C). It showed that 3 months after storage, maximum germination was in Primgold pollen stored at -80°C with 96.21 per cent and the lowest germination (58.33%) in Northern Spy pollen stored at 4°C, but 7 months after storage, maximum germination was in Primgold pollen stored at -80°C with 90.66 per cent and the lowest germination (36.67 %) in Northern Spy pollen stored at 4°C.

**2.2.11. Pollen germination**

Artificial germination of mango pollen is reported to be difficult by different workers. Singh (1954) reported the failure of pollen to germinate in 25 per cent sugar, 0.5 percent agar at temperature of 75° to 80° F and in other media concentrations.

Randhawa and Damodaran (1961) recorded highest pollen germination in 10 per cent sugar solution (28.2%) in mango var. Chausa.

Bolat and Pirlak (1997) noted highest pollen germination in 15 per cent sucrose solution in hanging drop and agar plate test which varied between 49.77-72.90 per cent and 57.83-84.42 per cent in apricot, 47.92-57.38 per cent and 52.40-66.60 per cent in sweet cherry and 49.16 per cent and 53.82 per cent in sour cherry.

Jutamanee et al. (2000) noted that germination of pollen ranged between 24.10 - 32.51 per cent in Nam Dok Mai and Khiew Sawoey cultivars of mango. Gomez et al. (2004) studied the pollen tube growth of Mandarin and found that pollen germination varied from 1 to 4 per cent.

Ilgin et al. (2007) determined the germination of fig pollen using various concentration of sucrose supplemented with $H_3Bo_3$, $KNO_3$ or $GA_3$ in agar medium

and found that germination was higher up to 74 per cent in media containing 20 per cent sucrose with addition of $H_3Bo_3$ or $KNO_3$ but not $GA_3$.

Germination test of eight apricot genotypes was carried out using sucrose with concentrations of 10 per cent, 15 per cent or 20 per cent with 1 per cent agar, 15 per cent sucrose concentration showed highest germination rate (Asma, 2008).

Soares (2008) used media containing 15 per cent sucrose, 0.01 per cent $H_3BO_3$,0.01 per cent $KNO_3$,0.03 per cent $Ca(NO_3)2.4H_2O$, 0.02 per cent, $MgSO_4$ $.7H_2O$, solidified with 0.8 per cent agar showed highest germination up to 90 per cent in genotypes 9187-01 and M-53 of banana diploids.

Khan and Perveen (2009) studied the pollen germination capacity of three mango cultivars viz., Chausa, Dashehari and Langra by hanging drop technique in different concentrations of sucrose solution(5 – 50%) with 1 per cent agar and 0.01 per cent boric acid, of which Langra pollen showed better germination even when kept up to 48 weeks.

Prakash et al. (2010) studied in vitro pollen germination of *Punica granatum* in different concentration of sucrose and found maximum percentage of germination up to 45.58 per cent and 42.25 per cent at 15 per cent sucrose solution.

### 2.2.12. Effect of temperature on pollen germination

Temperature is the important factor that affects pollen performance during the progamic phase (Hedhly et al., 2004). High temperature during flowering severely affects pollen viability (Kakani et al., 2005). Optimum temperature for pollen germination and pollen tube growth is known to vary among the species. Temperature ranges and optimum temperature values for pollen germination and pollen tube growth were studied in different fruit species previously. Pears (Mellenthin et al., 1972; Vasilakakis and Porlingis, 1985), jojoba (Lee et al., 1985), papaya (Cohen et al., 1989), Cherimoya (Rosell et al., 1999).

Issarakraisila and Considina (1994) studied the effect of temperature on pollen viability in Mango cv. Kensington under control conditions. They found that viability was maximum (85%) when temperature was between 20-25°C but when temperature increased from 33 to 36°C it fell from 85 to 60 per cent.

Sukhvibul et al. (2000) studied the effect of variable temperature on pollen germination in Nam Dok Mai, Kensington, Sensation and Irwin and noticed that at 10°C the pollen germination was 53.9 per cent which increased to 76.2-77.4 per cent between 15-25°C and subsequently decreased to 68.2 per cent at 30°C.

### 2.2.13. Compatibility studies

#### 2.2.13.1. Self compatibility

Mukherjee et al. (1968) reported self incompatibility in almost all types of mango and later Sharma and Singh (1970) observed the same in cultivars Dashehari, Langra, Chausa, Amrapali and Mallika.

Desai and Bhandwalkar (1995) reported self incompatibility in cultivars viz., Alphonso, Totapuri, Langra, Vanraj and Baramasi. Taimour mangoes showed self incompatibility as the pollen tubes showed terminal plugs and failed to reach the end of the style.

Self incompatibility in passion fruit was studied in families originated from crosses among plants that presented differences in reciprocal crosses (Suassuna et al., 2003). Javier and Maria (2007) reported self incompatibility in 'Agua de Aranjuez' cultivar of pear. In cashew about 54.55% of the clones showed the evidence of self incompatibility (Aliyu, 2007). Martinez et al. (2009) analysed self incompatibility in 8 pomegranate clones like PTO1, PTO2, PTO4, PTO7, PTO8, CRO1, ME14 andME15.

Kodad and Company (2008) assessed self incompatibility in almond selections by genetic and physiological means, such as PCR with specific primers for

the Sf allele, pollen tube growth and fruit set after self pollination and was observed in bagged branches.

Self incompatibility is a genetically controlled process in angiosperms that result in the recognition and rejection of self or self related pollen and pollen tubes depending on species, pollen is recognized and rejected in stigma and style by sporophytic or gametophytic self incompatibility (De nettancourt, 2001).

**2.2.13.2. Cross compatibility**

Ram et al. (1976) reported incidence of cross incompatibility among certain mango cultivars and suggested use of pollinizers. They reported that Dashehari is cross incompatible with Chausa, Safeda Malihabad, Langra, Rataul and Bombay green while Langra is cross incompatible with Alphonso, Bombay Green, Chausa, and Fazli.

Seth (1962) reported varietal cross incompatibility in guava since neither fruit nor seed set was obtained when crosses where made between Behat coconut and Lucknow-49, Behat coconut and Apple colour.

Pinto et al. (2004) studied compatibility among three mango cultivars viz., Mallika, Tommy Atkins and Amrapali and found that Mallika has lowest compatibility rate and Amrapali × Tommy Atkins had the best fruit set with 16.1 per cent success.

# *Materials and Methods*

# 3. MATERIALS AND METHODS

The materials used and methodology adopted during the implementation of this project, broadly entitled as "Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types" are dealt under two components as described below:

**Component I – Biodiversity analysis of traditional mango types**

## 3. 1 Study site selection

Studies were undertaken in Thrissur and Palakkad districts of Kerala state. In these districts, two gramapanchayaths (GP) were selected for a primary evaluation of mango diversity (Table 1) based on standardized format approved by Bioversity. (Appendix I and II)

**Table 1. Gramapanchayaths selected for mango biodiversity assessment**

| Name of the district | Name of the gramapanchayath |
|---|---|
| Thrissur | Vallachira<br>Pazhayannur |
| Palakkad | Kollemgode<br>Muthalamada |

In these GP's representative homesteads with appreciable varietal diversity of seedling mango types were located through a socio metric survey using snowball sampling method. This technique determines the sample by asking the existing study subjects to recruit future subjects from their acquaintances (Subedi et al., 2003).

Based on the primary assessment conducted during 2009-10 crop season in the above two GP's in each district, Bioversity recommended one GP each in Thrissur and Palakkad districts for the final analysis during 2010-11. Maruthampadam village in Pazhyannur GP of Thrissur district and Eripadam village of Muthalamada GP in Palakkad district were selected accordingly for this purpose.

## 3.2 Basic information of the selected GP's

### 3.2.1 Pazhayannur GP

Pazhayannur GP is located on the eastern end of Thrissur district with a beautiful greenery landscape. It has Palakkad district as eastern border, Thriuvilwamala GP of Thrissur district as the northern border. Along its north eastern border flows the Gayathri river which joins Bharathapuzha later and ends in Arabian sea at Ponnani.

Beautiful mountain patches, small hillocks with many wild animals and rocky areas comprise the upper region of the GP. Hillocks are planted with teak and presently rubber is rapidly spreading cash crop replacing all the conventional tree crops including many land races of mango, jack etc. The plain lands are planted with coconut, arecanut, bananas and a miscellany of other fruit crops.

It has a geographical area of 59.04 sq.km within the altitude range of 30-220 m above MSL. Total annual rainfall is 2972 mm. The soil is predominantly red lateritic.

### 3.2.2 Muthalamada GP

Muthalamada is the largest gramapanchayat in Kerala state and located on the South Eastern side of Palakkad pass adjoining to Tamilnadu. It is typically a dry tract. The grama panchayath has Thenmala on the southern side, Tamilnadu to the eastern side, Pattenchery and Vavannur panchayaths on north eastern and Kollemgode

panchayath on the western side. Total geographical area is 66.76 sq. km with an annual, rainfall of 2269 mm and the major soil types being forest soil, black soil with clay content, red soil, lime rocks etc. Muthalamada is a typical agricultural GP. The plain lands are cropped with paddy, ground nut, coconut and of late with the commercial mango growing

**3.3 Paricipatory identification of common and rare traditional mango types of the villages through focus group discussion (FGD) and four- cell analysis**

Focus group discussion (FGD) and four cell analysis involving participatory farmers were conducted in Marathampadam village in Pazhayannur GP and Eripadam village in Muthalamada GP for identifying the distinct mango types, their distribution and the salient features.

**3.3.1 Four- cell analysis**

FCA is a participatory tool standardized by Bioversity (Walter and Marja, 2007) for

1. Identifying unique, common and rare types of crop species cultivated in a community.
2. Documenting the reasons why crop species or the types are in a dynamic stage within the community.
3. Facilitating the identification of the interventions of the crop species or variety within a specific community.

In Marathampadam village, the interface with the farmers and FGD was undertaken on 10.11.2010 and in Eripadam village on 27.12.2010.

Step 1: Farmers were invited with a request to bring information on types of mango present in their homesteads and other crops grown by them.

Step 2: Discussions were initiated with an introduction on the importance of conserving the traditional mango diversity at the homestead level in the villages.

Along with the discussion the data for the analysis was gathered from the participants.

Step 3: A picture on the existing varietal diversity in the village was arrived at by making questions as mentioned below to the participatory farmers.

- What are the mango types cultivated in large areas in many homesteads?
- What are the mango types cultivated in large areas in few homesteads?
- What are the mango types cultivated in small areas in many homesteads?
- What are the mango types cultivated in small areas in few homesteads?

Step 4. All the local mango types grown in the homesteads in the villages were classified into a 2×2 matrix by distributing them in four different cells.

| | |
|---|---|
| Mango types grown in large area in many homesteads | Mango types grown in small area in many homesteads |
| Mango types grown in large area in few homesteads | Mango types grown in small area in few homesteads |

Step 5. After assigning the types into different cells the characteristics of these types were analyzed in the context of their distribution within and between cell groups.

Step 6. The participatory groups in each of the village were requested to discuss the results to get an insight into the threatened mango types/ varieties in the villages. The groups were also requested to suggest the remedial measures.

### 3.4 Diversity estimates

Richness and evenness are the key measures of biological diversity. Richness refers to the number of types or varieties regardless of their frequencies and measured

using type count per homesteads. Evenness compares the frequencies of the different types or types, with low evenness indicating dominance by one or a few types.

Evenness was calculated by the formula (Sthapit et al., 2006)

$$\text{Evenness} = 1 - \frac{\sum [(V_1)^2 + \ldots\ldots\ldots\ldots\ldots\ldots + (V_n)^2]}{N^2}$$

$V_n$ = No. of trees per variety or type

N= Total no. of trees

**Component II - Studies on basic reproductive biology of selected mango types**

Studies on reproductive biology of selected and popular mango types were undertaken by utilizing the mango germplasm planted in the orchard, Department of Pomology and Floriculture, College of Horticulture, Vellanikkara which is located at an altitude of 22.25 meters above MSL at $10^0$ 32' North latitude and $76^0$ 16' East longitude with a warm humid tropical condition.

### 3.5 Selection of types

Six mango types were included in these studies.

1. Mono embryonic types: Alphonso, Neelum, Banganapalli, Priyur
2. Poly embryonic types: Muvandan, Vellaikolumban

Trees with lower spreading branches were obviously chosen for undertaking the different observations and conducting control pollination under bagged condition for effecting crossing.

### 3.6 Flowering season and floral characters

Present investigations were commenced during 2009-10 crop season and continued in 2010-11. Hundred shoots were selected at random on each tree and observations on the number of shoots flowered, start of flowering and period of flowering were noted. Major part of the observations on flowering aspects was taken

up during 2010-11 season. Data on the climatic parameters of both these crop seasons were collected and recorded.

### 3.7 Intensity of flowering in the tree canopy

Intensity of flowering was estimated by counting the no. of opened inflorescences per ½ $m^2$ area of tree canopy and the mean values worked out.

### 3.8 Panicle emergence

#### 3.8.1 Time taken for emergence

Newly emerging five panicles of each mango types were tagged and the number of days required for complete opening of panicle was noted.

### 3.9 Colour of inflorescence

Colour of inflorescence rachis was described as per the IBPGR descriptor and was expressed as

Light green

Green with red patches

Light red

Dark red

Crimson

### 3.10 Size of the inflorescence

#### 3.10.1 Length

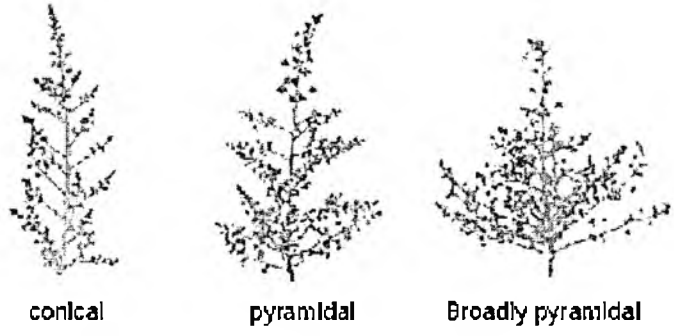
Fully emerged ten panicles were selected at random and length measurement taken and expressed in cm.

### 3.10.2 Breadth

The broadest branches of these same ten panicles from base was considered for breadth measurement and expressed in cm.

### 3.11 Shape of inflorescence

Shape of inflorescence was described by using the IBPGR descriptor. The descriptions of shapes as per IBPGR are




### 3.12 Intensity of flowering in the inflorescence

Intensity of flower production on the individual inflorescence was assessed by visual observations based on the spatial density of flowering on the panicle and noted as laxly or densely flowered inflorescence.

### 3.13 Percentage of hermaphrodite flowers

Five panicles of each cultivar were randomly selected and tagged. The number of hermaphrodite and male flowers on the panicle was counted and the percentage of hermaphrodite flowers was worked out by using formula;

$$\% \text{ of opened hermaphrodite flowers} = \frac{\text{No. of opened hermaphrodite flowers}}{\text{Total no. of flowers opened}} \times 100$$

### 3.14 Sex distribution

Count of flowers during the opening out of panicles was made in five panicles of each type. The number of opened flowers during different intervals was worked out.

### 3.15. Floral biology

#### 3.15.1 Anthesis

Flower opening was recorded at hourly intervals during a 12 hours cycle of the day to find out the peak time of anthesis.

#### 3.15.2 Anther dehiscence

Anther dehiscence was observed by examining the male and perfect flowers with a hand lens at the time of opening of flowers.

#### 3.15.3 Stigma receptivity

Controlled pollination of selected bisexual flowers at definite intervals was done after opening of flowers and the fruit set was noted to work out the maximum receptive stage of stigma.

### 3.16 Pollen studies

#### 3.16.1 Pollen morphology

##### 3.16.1.1 Size and shape of pollen grains

Pollen grains were examined using phase contrast microscope (40X) and size and shape of the grains determined.

### 3.16.2 Pollen fertility

Pollen fertility was worked out by counting the normal well stained grains and expressed in percentage. For this purpose, acetocaramine 1 percent solution was prepared in water. Staining was done by brushing the collected pollen and observing under a phase contrast microscope.

Fertility was calculated as the percentage of normal, well stained pollen grains to the total number of pollen grains from each slide.

$$\text{Pollen fertility (\%)} = \frac{\text{No. of fertile pollen}}{\text{Total no. of pollens}} \times 100$$

### 3.16.3 *In vitro* pollen germination

*In vitro* germination of pollen collected from the different types was attempted during the investigations. For this, sucrose at 5-25 per cent concentration levels with 0.5 per cent agar was tried initially. Since the attempt did not succeed the experiment was repeated at varying levels of agar viz. 0.25, 0.50, 0.75 per cent also.

### 3.16.4 Estimation of pollen production

Pollen grains from a known number of anthers were suspended in a known quantity of water. This suspension was poured in to the well of heamocytometer. The number of pollen grains per well was counted and the number of pollen grains/ anther was calculated. A drop of suspension drawn in a fine pipette was transferred to each of the two counting chambers of haemocytometer. Each chamber has an area of nine square millimeter ruled into small divisions. The counting chambers are 0.1mm 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 was arrived at

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

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 (10 X) objective of the microscope.

### 3.16.5 Pollen storage

With the object of working out a suitable storage condition for pollen the dehisced male flowers collected from the field were subjected to different storage condition. The flowers were taken in clean petri dishes and kept under different storage treatments as given below.

$T_1$- 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 $4^0$C.

$T_4$- Keeping at room temperature without treatment.

After these treatments, the viability was tested by acetocarmine technique and expressed in percentage. This was further confirmed by hand pollination in the field.

### 3.17 Compatibility studies

In order to assess the compatibility behavior of the selected parents for involving them in hybridization, controlled pollination was resorted to in different possible combinations. The procedure as followed by Regional Fruit Research Station, Vengurla, and Maharashtra was adopted for this after undergoing two days 'hands on' training at the station. The procedure is presented as a flow diagram below. [Plate 1-5]

**Plate 1. Collection of male flowers**

**Plate 2. Collected male flowers kept in petri dish for dehiscence in sunlight**

**Plate 3. Removal of male flowers, and stamen from bisexual flowers**

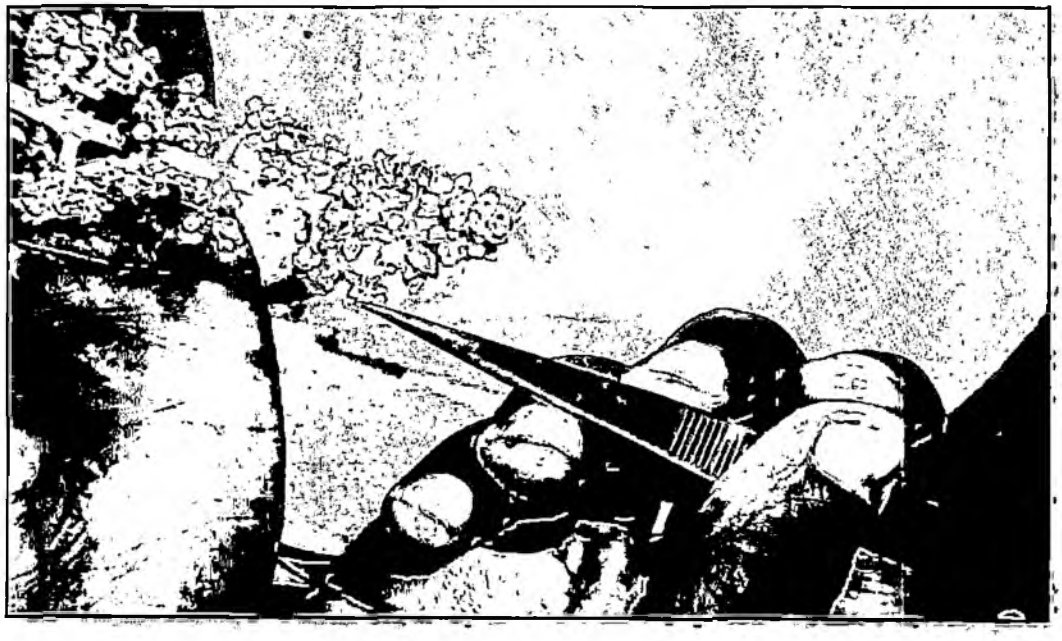


**Plate 4. Artificial pollination using forceps**

**3.18 Steps followed in controlled pollination**

Selection of the male and female parents

↓

Selection of newly emerging panicles expected to open out next day on the female parent

↓

Bagging of panicle with a muslin cloth bag fully stretched and fixed with two rings and rods made of aluminium wire

↓

Removal of the male flowers and the fertile stamens in bisexual flowers in early morning hours

↓

Collection of the male flowers from the selected male parent in petri dishes

↓

Keeping the covered petri dishes in sunlight for anther dehiscence

↓

Brushing of freshly dehisced anther of the male parent on the stigma of the emasculated bisexual flowers and dusting the pollen

↓

Covering of artificially pollinated panicles with muslin cloth bags

↓

Continuation of the artificial pollination on the flowers in a panicle for 3-4 days so as to obtain 15-20 bisexual flowers getting pollinated ultimately

**3.19 Quality evaluation**

Quality evaluations of the fruits were also taken up following standardized procedures.

### 3.19.1 TSS

TSS of the ripe fruits of different types was estimated using a hand refractometer and expressed in degree brix. (A.O.A.C, 1975).

### 3.19.2 Acidity

Titrable acidity of the fruit pulp was estimated as per A.O.A.C procedure (1975) and expressed as percent anhydrous citric acid.

### 3.19.3 Total sugar

Total sugar was determined as per the A.O.A.C (1975).

### 3.20 Statistical analysis

Appropriate statistical tools *viz.*, snow ball sampling technique, FCA, SPSS version 17 test used in ANOVA with post hoc testing using DMRT (Duncan's Multiple Range Test) etc. were adopted at different stages of the investigations.

# *Results*

# 4. RESULTS

Results generated from the current set of investigations on "Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types" are presented in this chapter under two major components.

4.1 Biodiversity analysis of traditional mango types in Thrissur and Palakkad districts of Kerala.

4.2 Basic studies on reproductive biology of popular mango types.

### 4.1.1 Biodiversity analysis- primary assessment

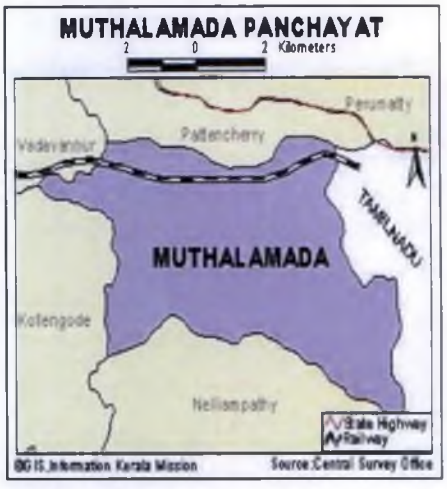
The studies were initiated during 2009-10 with a primary survey in four GP's. Vallachira and Pazhayannur in Thrissur district and Kollemgode and Muthalamada in Palakkad district were selected accordingly (Fig.1 and 2). The consolidated data sheets after surveying 30 homesteads in these GP's are presented in the information format standardised by the Bioversity for the purpose (Appendix I to II).

**General observations**

Information collected from the GP's in Thrissur district indicated that both these GP's are still having homesteads with named local seedling mango types and other unnamed local landraces. Muvandan (green and white types) dominated in the backyards of Pazhayannur GP. Other types such as Puliyan, Tholikaipan etc. were also noted. In Vallachira GP Chandrakaran was the most dominant seedling type observed and other types being Chakiriyan and Columbmanga (Plates 6 and 7). Pazhayannur and Chelakkara are the nearest mango markets in Pazhayannur GP where as Puthukad and Cherpu are the nearest mango markets in Vallachira GP. Sampling also indicated that commercial home scale processing units are being operated to a reasonable level in both these GP's.

Information collected for site selection in two GP's in Palakkad district indicated that most of the homesteads in Kollemgode GP are having 6- 8 seedling


**Fig.1. Map of Kerala state showing the location of the selected gramapanchayaths**


Gramapanchayaths of Palakkad district



Gramapanchayaths of Thrissur district

**Fig.2. Gramapanchayaths selected for primary assessment of mango biodiversity**



**Plate 6a. Homesteads of Thrissur district**



**Plate 6b. Homesteads of Thrissur district**

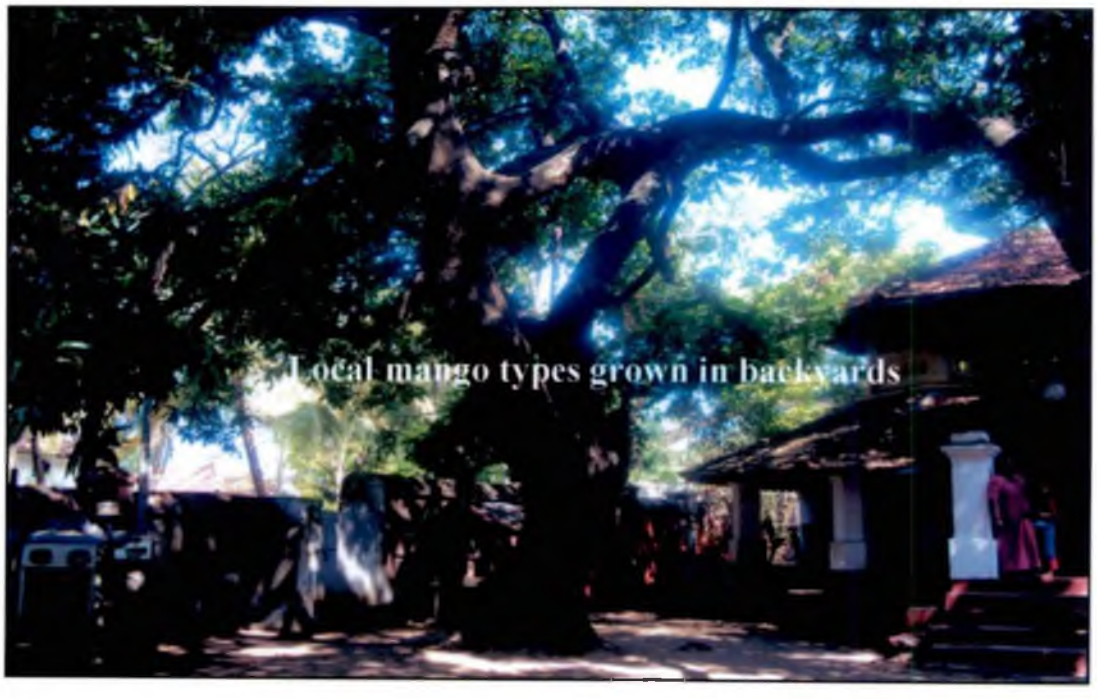




**Plate 7a. Homesteads of Palakkad district**



**Plate 7b. Homesteads of Palakkad district**

mango types in the backyard. Most of them are unnamed types. Unlike in the other three GP's only few local types could be noted in homesteads of Muthalamada, such as White Muvandan, Priyur and Chandrakaran. Direct marketing in the orchards and marketing through Palakkad and Pollachi markets are the general practices of these two GPs. Home scale processing units are not active in both these GP since bulk of the produce is directly lifted from orchards/ homesteads by traders.

### 4.1.2 Final biodiversity assessment through farmers interface, FGD and 4 -cell participatory analysis

Based on the preliminary survey undertaken during 2009-10, two GP's *viz.* Pazhayannur GP of Thrissur district and Muthalamada GP of Palakkad district were selected for the final evaluation.

In these GP's, village level biodiversity analysis was carried out in one selected village. Maruthampadam village of Pazhayannur GP and Erippadam village of Muthalamada GP were accordingly selected for the purpose.

### 4.1.3 Crop diversity status of the villages

Farmers interface was conducted on 10.11.2010 in Maruthampadam village and on 27.12.2010 at Erippadam village. In both these villages farmers were invited with a request to bring all the available information on cropping pattern, details on traditional and other mango types in their orchard and any other related aspects. The proceedings commenced with introductory remarks on the importance of conserving the traditional mango biodiversity at the homestead level in the villages. It was much highlighted at Maruthampadam village where a rapid rate of mono cropping with commercial crop like rubber was noted in almost all the homesteads.

Details of the farmers attended in the interface held in these two villages are presented in Appendix- III and IV along with the cropping pattern of the homesteads. Crop diversity status of these two villages is presented graphically in Fig. 3 and 4.

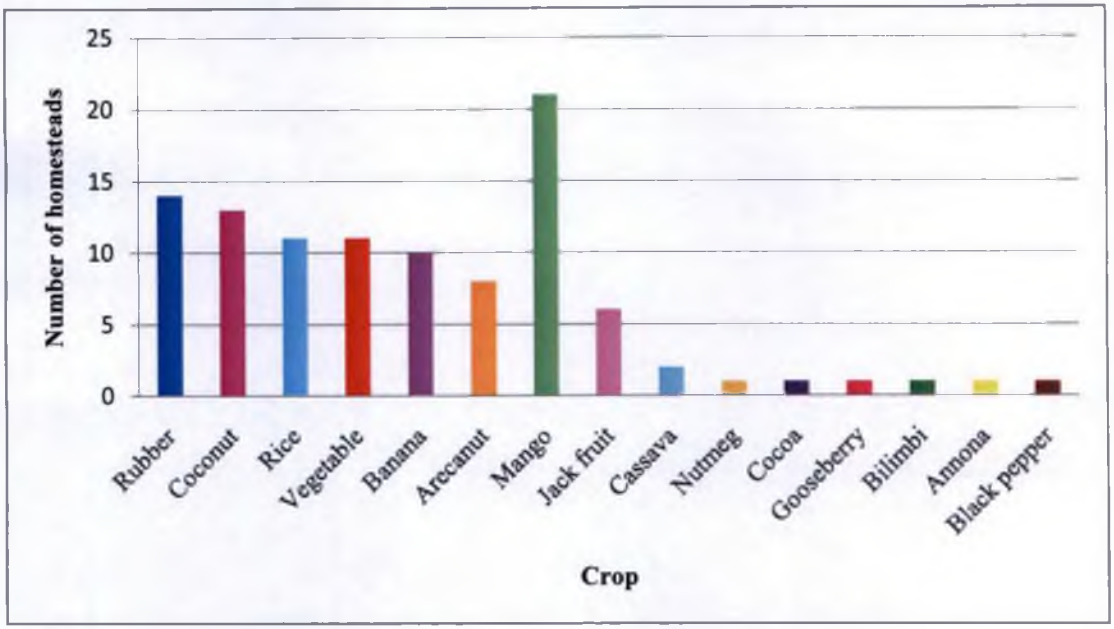



**Fig.3. Crop diversity status of Maruthampadam village (Pazhayannur GP)**

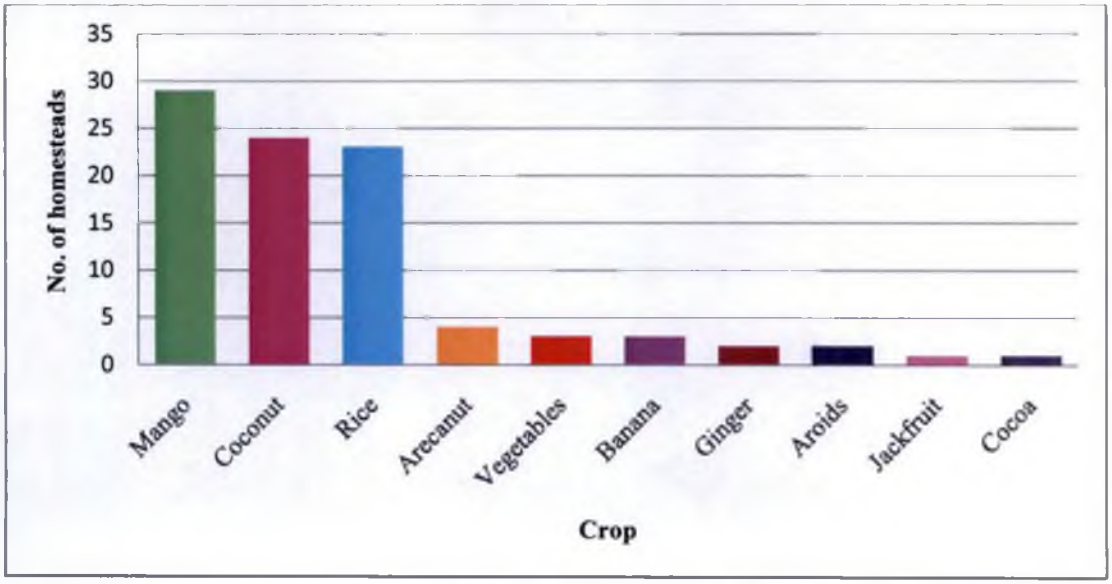



**Fig.4. Crop diversity status of Erippadam village (Muthalamada GP)**

Observations showed that Maruthampadam village is more diverse with respect to the number of crops grown in the homesteads than Erippadam. In Maruthampadam, the worked out measure of crop diversity in terms of richness was 15 where as it was only 10 in Erippadam village. Most striking features of Maruthampadam village were the rapid rate of conversion of farmlands to commercial non food crop like rubber. Such a practice is obviously resulting in cutting and removal of other tree crops from the homesteads especially the traditional seedling mango types.

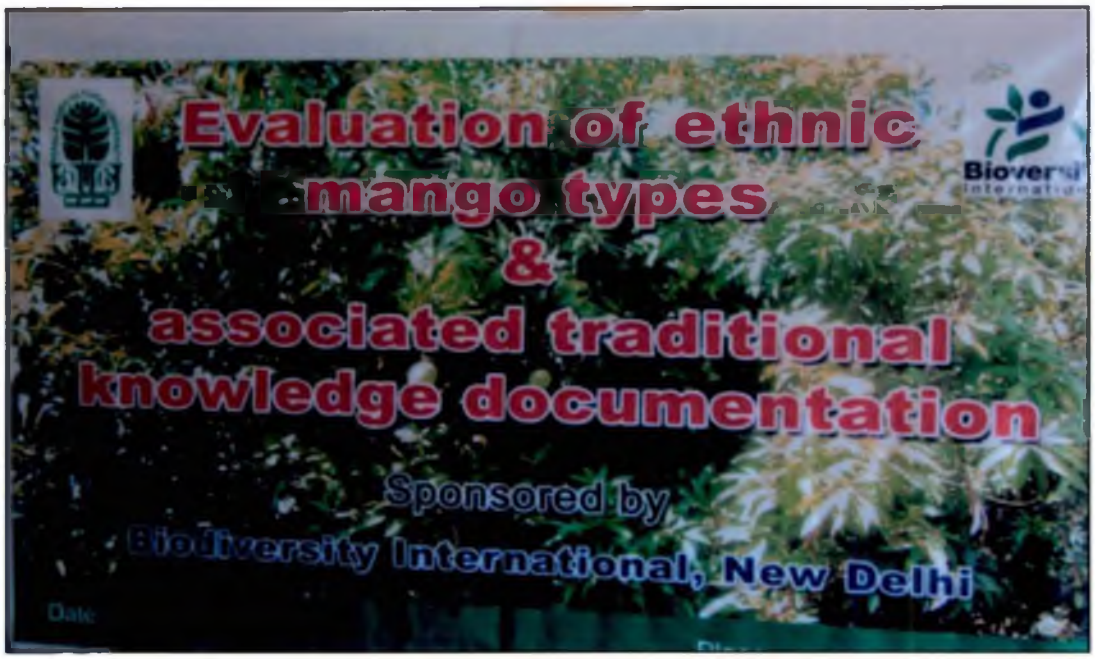
Erippadam village located in the Muthalamada GP of Palakkad district presents a different picture. Crop diversity is comparatively less and mango occupies a higher position among the different crops cultivated. The deviation noted in this case is the increasing trend towards mango mono cropping into larger areas and making it more commercial.

### 4.1.4 Mango biodiversity status of the villages

During the interface arranged with the farmers in these two villages a participatory 4- cell biodiversity analysis was carried out for identifying the common and rare mango types of the villages. This was also supplemented with FGD's (Plates 8 and 9).

The existing diversity levels of mango types in these two villages were classified based on their presence as 'common', 'other distinct', and 'rare' types. They were further distributed into four different categories/ groups as mentioned below:

i. Grown in many homesteads with many trees – Common types
ii. Grown in many homesteads with few trees-Other distinct types
iii. Grown in few homesteads with many trees- Other distinct types



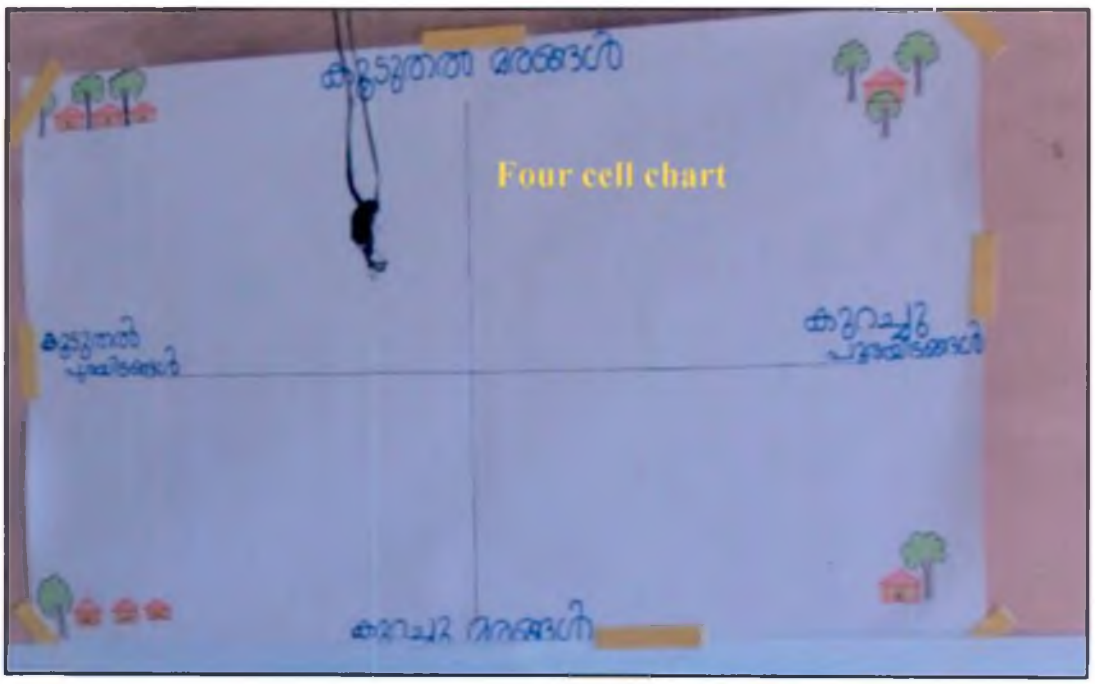




**Plate 8a. Farmers interface conducted at Marathumpadam village**



**Plate 9a. Farmers interface conducted at Erippadam village**



**Plate 9b. Farmers interface conducted at Erippadam village**

iv. Grown in few homesteads with few trees- Rare and vulnerable types

Consolidated results are presented as Fig. 5. As per the analysis, the types which can be grouped as 'common' in Maruthampadam village due to their presence in large numbers in a large number of homesteads are Muvandan, Pulimanga and Gomanga. Other types which are grown in many homesteads but with low plant population and those found in few homesteads with large plant population were designated as 'other distinct' types of the village. Accordingly, the types Vellamanga, Puliyan, Nadasala, Neelum, Kilimook and Priyur were included in this group. The group of 'rare' and 'vulnerable' types in Maruthampadam village comprised of Karpuramanga, Ganapatimookan, Kilichundan, Chandrakaran, Kottamavu, Sindhuram, Marathakam,and Mundappa.

In Erippadam village the 'common' types found in a large number of homesteads comprised of Alphonso, Banganapalli ,Kilichundan, Neelum, Sindhuram, Muvandan, and Nadasala. And the group of 'other distnct' types comprised of Priyur, Himapasanth, Gomanga, Gudadath, Nadanmanga, Kalepad, Mulgoa. 'Rare' and 'vulnerable' types in the village included Chandrakaran, Kilimook, Mallika,and Mundappa.

### 4.1.5 Diversity estimates of the villages

Richness and evenness are the key measures of biodiversity. Richness refers to number of types or varieties regardless of their frequencies and measured by the type count per homestead. Evenness compares the frequencies of different types or in other terms a variety with a low evenness value indicates dominance by one or few types.

Diversity estimate of mango types in Maruthampadam village is presented in Table 2. Overall varietal richness of the village was 17 and at homestead level within a range of 1-13.Estimated evenness values showed higher values for types

**Fig. 5 Four cell participatory analysis**

**Biodiversity status of mango types in the villages**

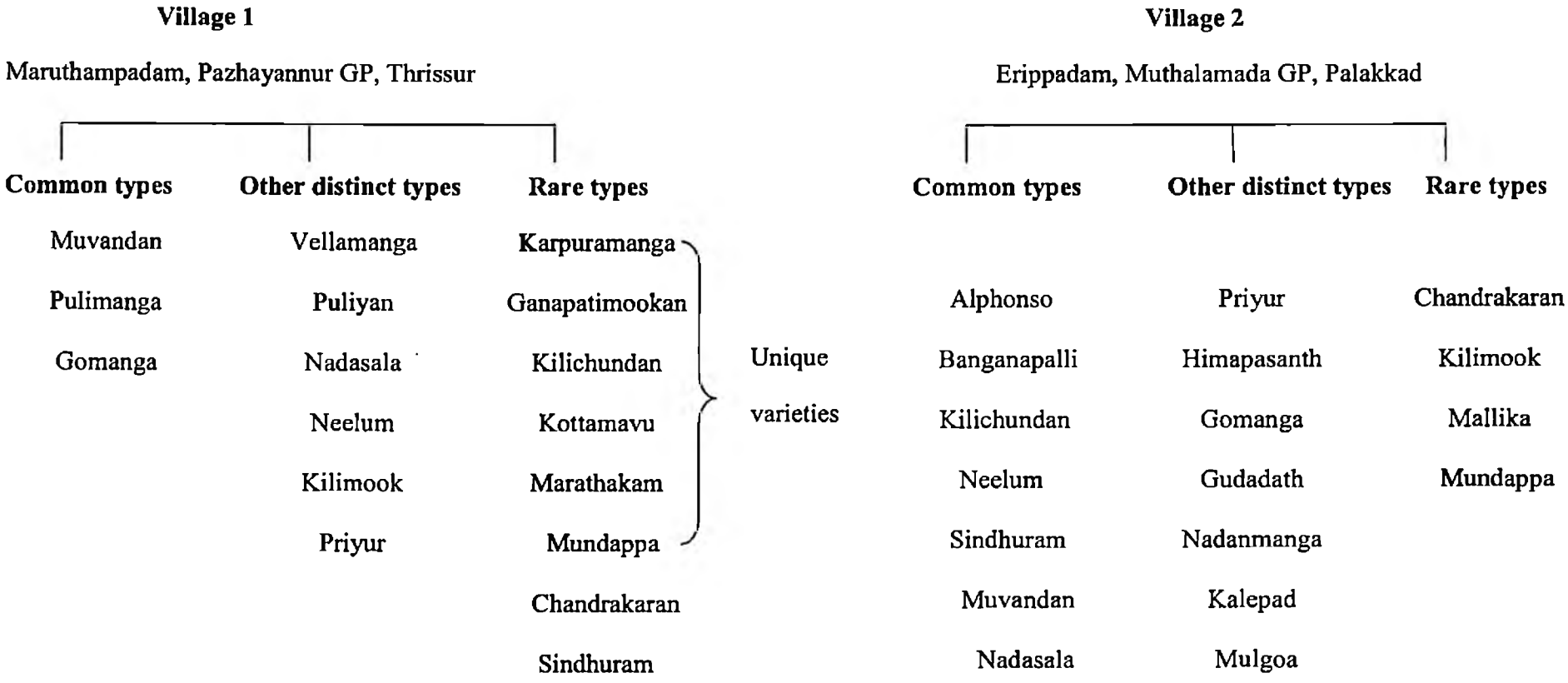


**Table 2. Homestead level mango diversity estimate of Marithampadam village**

| Households / Types | Diversity Estimates | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H 1 | H 2 | H 3 | H 4 | H 5 | H 6 | H 7 | H 8 | H 9 | H 10 | H 11 | H 12 | H 13 | H 14 | H 15 | H 16 | H 17 | H 18 | H 19 | H 20 | H 21 | Varietal Evenness |
| Gomanga | 3 | | 1 | | | | | 1 | | | | | | | | 1 | | 1 | | 1 | | 0.8 |
| Pulimanga | 3 | | 1 | | | 2 | | 1 | | 1 | 1 | 2 | 1 | | | 2 | 1 | 2 | | 3 | | 0.9 |
| Mundappa | | | | | | | | | | | | | | | | | | | | | 1 | 0 |
| Vellamanga | 1 | | | | | | | 1 | | | | | | | | 1 | | 1 | | 1 | | 0.8 |
| Puliyan | 2 | | 1 | | | | | | | | | | | | | | | | | 4 | | 0.6 |
| Nadasala | | | | | | | | | | | | | | | | 1 | 2 | | | | 1 | 0.6 |
| Priyur | 2 | | | | | | | | | | 2 | | | | | | 1 | | | | | 0.6 |
| Muvandan | 3 | 6 | 4 | 4 | 3 | 3 | 5 | 2 | 2 | 4 | 10 | 2 | 1 | 2 | 3 | 3 | 2 | 3 | 5 | 10 | 1 | 0.9 |
| Neelam | 1 | | 1 | 1 | | | | | | | | | | | | 1 | | | | | 1 | 0.8 |
| Karpuramanga | 1 | | | | | | | | | | | | | | | | | | | | | 0 |
| Killimook | 1 | | | | | | | | | | | | | | | 1 | | | | 1 | 1 | 0.7 |
| Ganapatimookan | 1 | | | | | | | | | | | | | | | | | | | | | 0 |
| Killichundan | | | | | | | | | | | | | | | 1 | | | | | | | 0 |
| Chandrakaran | 1 | | | | | | | | | | | | | | | | | | | | | 0 |
| Kottamavu | 1 | | | | | | | | | | | | | | | | | | | | | 0 |
| Sindhuram | 1 | | | | | | | | | | | | | | | | | | | | | 0 |
| Marathakam | | | | | | | | | | 1 | | | | | | | | | | | | 0 |
| Richness | 13 | 1 | 5 | 2 | 1 | 2 | 1 | 4 | 1 | 3 | 3 | 2 | 2 | 1 | 2 | 7 | 4 | 4 | 1 | 6 | 5 | |
| N | 21 | 6 | 8 | 5 | 3 | 5 | 5 | 5 | 2 | 6 | 13 | 4 | 2 | 2 | 4 | 10 | 6 | 7 | 5 | 20 | 5 | |
| Evenness | 0.9 | 0 | 0.7 | 0.7 | 0 | 0.5 | 0 | 0.7 | 0 | 0.5 | 0.3 | 0.8 | 0.5 | 0.5 | 0.4 | 0.8 | 0.3 | 0.7 | 0.8 | 0.7 | 0.8 | |

viz,.Muvandan [0.9], Pulimanga [0.8] and Gomanga [0.8] which were common in the village. Evenness values for other types were Vellamanga [0.8]. Puliyan [0.6], Nadasala [0.6], Neelam [0.8], Kilimook[0.7] and Priyur [0.6].All the types under the rare and vulnerable group comprising Ganapathymookkken, Kottamavu, Kilichundan, Marathakam, Sindhuram and Mundappa recorded an evenness value of zero (Fig.6)

Diversity estimate of Erippadam village is presented in Table 3 .Overall richness value for the village is 18 and at the homestead level in between 1-15.Evenness estimates showed lower values for types, *viz.*, Mulgoa, Chandrakkaran, Mallika and Mundappa and higher values for all the other dominating types of the village (Fig. 7).

### 4.1.6 Relationship between the area of home gardens and the varietal richness of mango

Estimated mango varietal richness of the two villages was plotted against the area of represented home gardens (Fig.8). Home gardens were categorized into four groups viz.,

A) < 1acre

B) 1- <5 acre

C) 5- < 7 acre

D) > 7 acre

Maximum richness values of these groups were taken and plotted.

An increasing trend in richness of the types was noted in Erippadam village and it was highest (14) in group D. But in Maruthampadam village an increasing trend was noted up to group C. But it showed deceleration further in group D.

**Table 3. Homestead level mango diversity estimate of Erippadam Village**

| Households / Types | Diversity Estimates | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H 1 | H 2 | H 3 | H 4 | H 5 | H 6 | H 7 | H 8 | H 9 | H 10 | H 11 | H 12 | H 13 |
| Alphonso | 5 | | | 4 | | | | 1 | | | 50 | 2 | |
| Banganapalli | 8 | | | 2 | | | 1 | 1 | | | 25 | | 3 |
| Priyur | 1 | | 1 | | | | | | | | 2 | | |
| Himapasanth | 8 | | | | | | | | | | 5 | | |
| Kilichundan | 4 | | | | 3 | 4 | | 4 | 8 | 4 | 5 | 1 | 3 |
| Neelam | 10 | | | | 2 | 3 | 1 | 4 | 1 | | 10 | | |
| Sinduram | 240 | 1 | 1 | | | 5 | 3 | 15 | 20 | 1 | 20 | | 3 |
| Muvandan | 8 | | | | | | | | 3 | | 5 | | 1 |
| Nadasala | 3 | | | | | 2 | | 10 | 10 | | 10 | | |
| Kalepad | 4 | 1 | | 10 | | | | 1 | 1 | | 5 | | |
| Nadanmanga | 2 | | | | 2 | 4 | | 3 | 6 | | 25 | | |
| Gomanga | 1 | | | | | | | | | | 3 | 4 | |
| Gudadath | 2 | | | 1 | | 2 | | 2 | 10 | | 1 | | |
| Mulgoa | | | | 1 | | 2 | | 1 | 3 | | 6 | | |
| Mundappa | | | | | | | | | 3 | | | | |
| Chandrakaran | | | | 1 | | | | | | | | | |
| Mallika | 15 | | | | | | | | | | | | 2 |
| Kilimuk | 1 | | | | | | | 1 | | | | | 1 |
| Richness | 15 | 2 | 2 | 6 | 3 | 7 | 3 | 11 | 10 | 2 | 14 | 3 | 6 |
| N | 313 | 2 | 2 | 19 | 7 | 22 | 5 | 43 | 65 | 5 | 172 | 7 | 13 |
| Evenness | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.8 | 0.6 | 0.7 | 0.8 | 0.3 | 0.8 | 0.6 | 0.8 |

**Table 3. (Contd.) Homestead level mango diversity estimate of Erippadam village**

| Households / Types | Diversity estimates | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H 14 | H 15 | H 16 | H 17 | H 18 | H 19 | H 20 | H 21 | H 22 | H 23 | H 24 | H 25 | H 26 | Varietal Evenness |
| Alphonso | 30 | 10 | | 2 | 25 | | 25 | | 10 | 1 | | | | 0.8 |
| Banganapalli | 110 | 6 | 1 | | 45 | | 30 | | 5 | 1 | | 1 | | 0.6 |
| Priyur | | 3 | | 1 | | | 2 | | | | | | | 0.8 |
| Himapasanth | 5 | | | | | | 5 | | | | | | | 0.7 |
| Kilichundan | 20 | 3 | 5 | | 50 | 3 | 15 | 2 | | 1 | | | 2 | 0.9 |
| Neelam | 20 | 7 | 2 | | 10 | 2 | 1 | | 5 | 1 | 4 | 1 | | 0.8 |
| Sindhuram | 120 | 10 | 1 | 10 | 50 | | 60 | | 10 | 3 | | 3 | 1 | 0.9 |
| Muvandan | 60 | 3 | | 5 | 50 | | 50 | | 10 | 5 | 2 | | | 0.7 |
| Nadasala | 5 | 10 | 2 | | 40 | | 20 | | | | | | | 0.9 |
| Kalepad | 5 | 5 | | | | | 15 | | | 1 | | | | 0.8 |
| Nadan | 10 | 12 | 2 | | 5 | 2 | 10 | | | 1 | | | | 0.8 |
| Gomanga | | | | | | | | 1 | | 1 | | | | 0.7 |
| Gudadth | 6 | | | 2 | | | 10 | | | 1 | | | | 0.3 |
| Mulgoa | 7 | | | | | | 20 | | | 1 | | | | 0.2 |
| Mundappa | | | | | | | | | | | | | | 0 |
| Chandrakaran | 2 | | | | | | | | | 1 | | | | 0.6 |
| Mallika | | | | | | | | | | 2 | | | | 0.3 |
| Kilimukh | 1 | | | | | 1 | | 1 | | | | | | 0.8 |
| Richness | 14 | 10 | 6 | 5 | 8 | 4 | 13 | 3 | 5 | 10 | 2 | 3 | 2 | |
| N | 401 | 69 | 13 | 20 | 275 | 8 | 263 | 4 | 40 | 15 | 6 | 5 | 3 | |
| Evenness | 0.8 | 0.8 | 0.7 | 0.6 | 0.8 | 0.7 | 0.9 | 0.6 | 0.8 | 0.8 | 0.4 | 0.6 | 0.4 | |

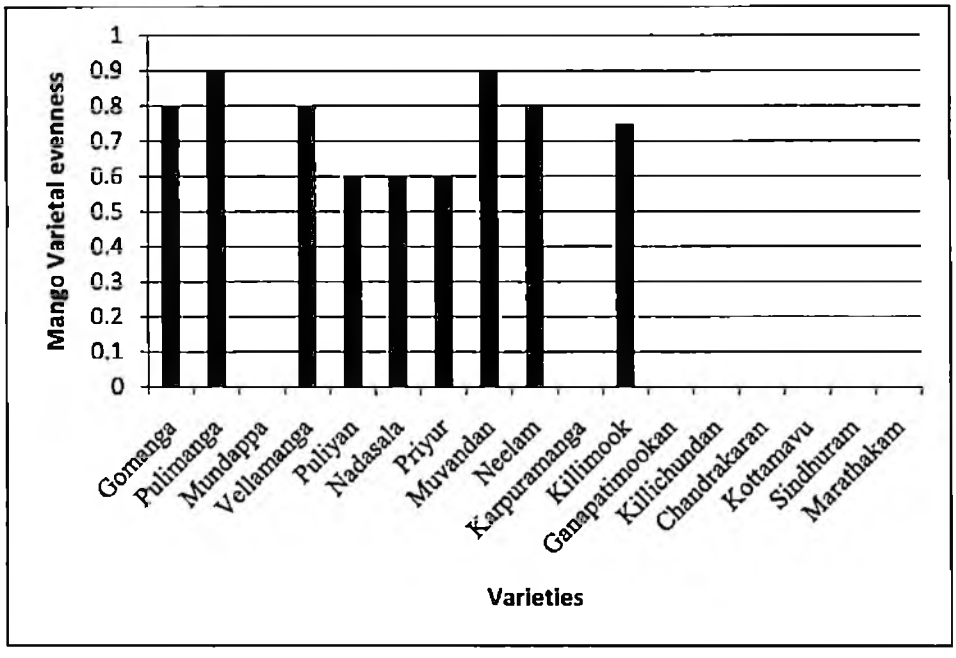



**Fig.6. Varietal evenness of Maruthampadam village**

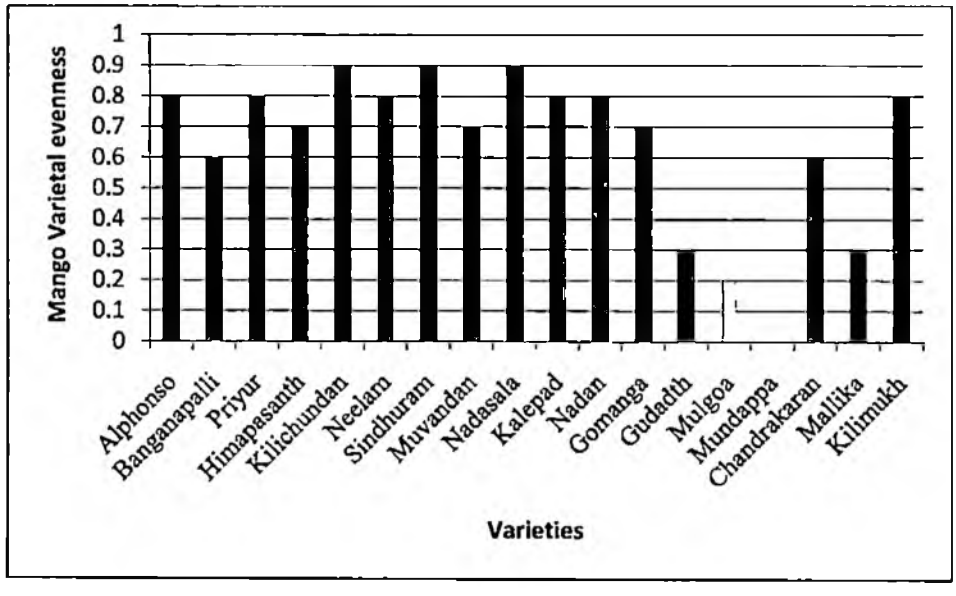



**Fig.7. Varietal evenness of Erippadam village**

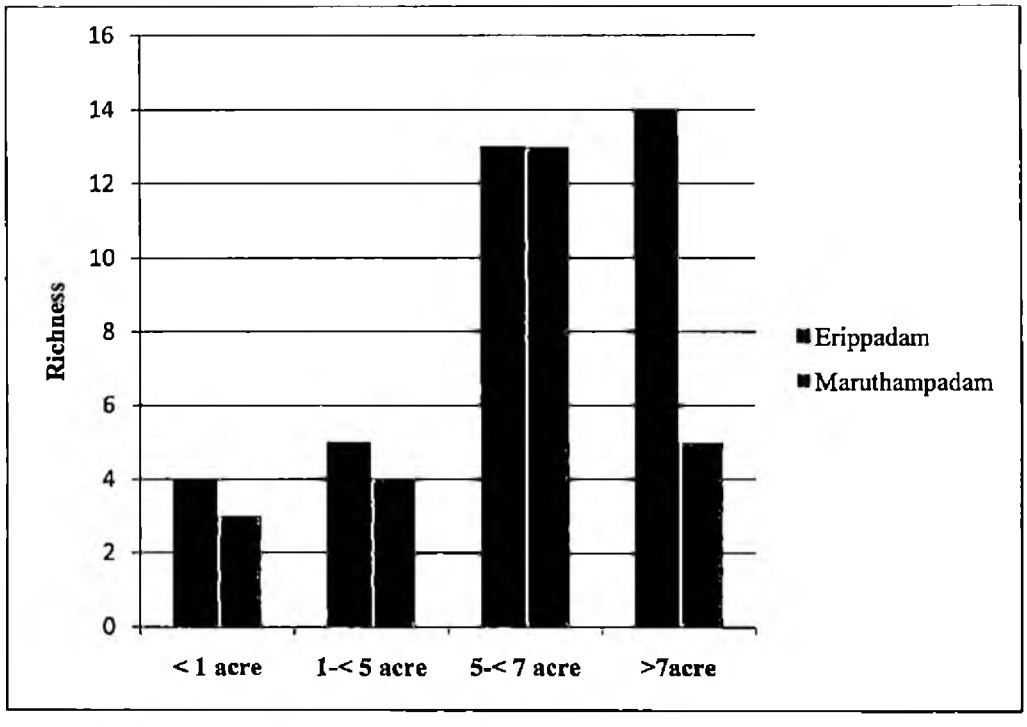



**Fig.8. Relationship between the area of homegardens and varietal richness of mango**

### 4.1.7 Traditional knowledge documentation

Indigenous traditional knowledge (ITK) is the knowledge that people in a given community has developed over time and continues to develop. It is based on experience often tested over long periods of use, adapted to local culture and environment.

Along with the participatory biodiversity analysis undertaken in the villages through interface with farmers an attempt was also made to document the traditional knowledge/ skills practiced by the villagers specifically to mango production and processing at the homesteads.

In Maruthampadam village, drying and preserving of mango fruits is practiced by the farmers. Ripe mangoes collected from the local types are dried in the sun after de-stoning during March April months. And it was informed that the local juicy type 'Puliyan' is extremely suited for the purpose. These dried mangoes are later used for different culinary preparations.

Similarly mango bar locally known as 'manga thera' is also prepared in some of the homesteads. The skin of ripe fruits is removed and the juice squeezed out and blended with fried rice powder for making a solid consistency. The blended mixture will be dried later and cut into flakes and used.

A local preparation named as 'Adamanga' is prepared from green mango in many homesteads. The local type 'Puliyan' is typically suited. Green mango will be cut without removal of skin and sun dried. Yet another interesting aspect noted in Maruthampadam was that the mango stones are used for making different preparations; the practice is not that much common in other places. Extracted seed stones will be dried after cleaning in lukewarm water and smeared with common salt and dried in sun. In some cases the stones will be immersed in water for 5-6 days for removing the astringency before drying. The dried stones will be powdered and stored and later taken for different preparations.

In many of the homesteads, preparation of 'Kadumanga' [Tender mango pickle] is common. They take much care to harvest the fruits without touching with hands using bamboo pole harvesters with net bags. The fruits will be harvested at marble stage. They will be washed and transferred to big china clay containers. Later common salt is sprinkled over the fruits in layers in 1:5 ratio and the container will be closed and kept as such for a period of 3 weeks. The vessels will be opened and the fruits after thorough cleaning and sorting added with chilli powder, fenugreek powder, asfoetida powder, mustard powder etc. in required proportions and covered with a cloth soaked with gingelly oil on the top surface. No synthetic preservatives are added. The china clay vessels (Bharani) will be then closed with a lid and wrapped air tight and covered with mud caps over and kept as such. The spoilage in such an indigenous eco friendly storage method is reported as minimal even without any chemical preservatives and the product lasts 2-3 years without much quality loss.

Unlike in Maruthampadam, direct selling of the fruits from the orchard is the common practice in Erippadam and as such not much traditional processing practices of mango fruits are followed in the homesteads and hence available for documentation (Plate 10).

## 4.2 Basic studies in reproductive biology undertaken at dept. of Pomology and Floriculture, COH, Vellanikkara

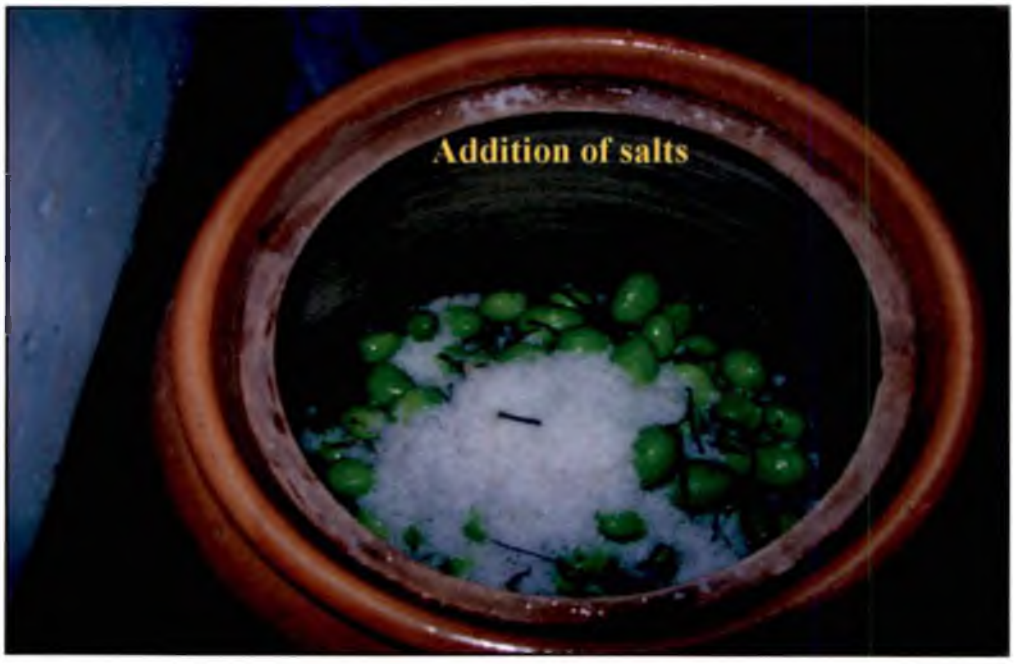
### 4.2.1 Mango flowering during 2009-2010 and 2010-2011 seasons

Data on flowering and related characters of the varieties are presented in Table 4.

Corresponding weather data for 2009-10 and 2010-11 are presented graphically along with the rainfall data of Thrissur district for five years (2005-2010) in Table 5 and Appendix V and VI.



**Plate 10a. Tender mango processing and storage followed in Maruthampadam village**



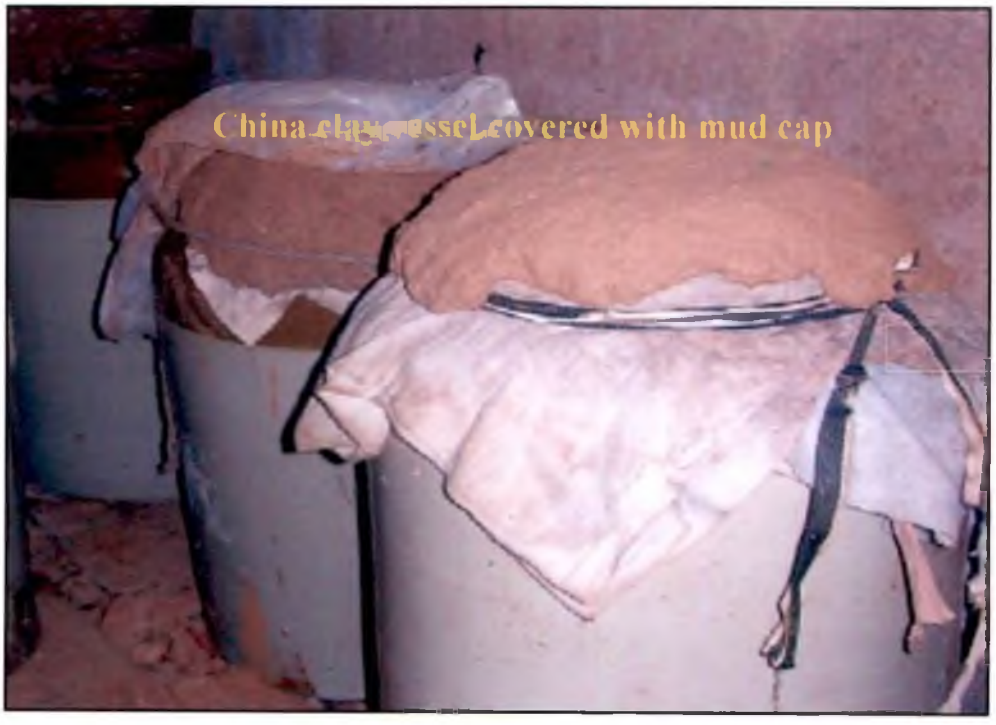




**Plate 10b. Tender mango processing and storage followed in Maruthampadam village**

**Table 4. Flowering (pattern) in mango types in two seasons (2009-10) and (2010-11) seasons at Vellanikkara, Thrissur, Kerala**

| Variety | Intensity of flowering % | | Period of flowering 2009-10 | | Period of flowering 2010-11 | |
|---|---|---|---|---|---|---|
| | 2009-10 | 2010-11 | Commencement | Peak | Commencement | Peak |
| Muvandan | 20.50 | 82.36 | Dec last week | Jan 1st week | After 26th Dec | Jan 1st week |
| Vellaikolumban | 12.30 | 80.00 | Jan 2nd week | Feb 1st week | Jan 1st week | Jan 4th week |
| Priyur | 10.10 | 81.23 | Dec last week | Jan 1st week | Jan 1st week | Jan 2nd week |
| Banganapalli | 5.20 | 79.60 | Jan 2nd week | Jan last week | Jan 1st week | Jan 3rd week |
| Neelum | 10.00 | 78.59 | Feb 2nd week | March1st week | Jan 1st week | Jan last week |
| Alphonso | 10.00 | 85.36 | Dec last week | Jan 1st week | Dec last week | Jan 1st week |

## Table.5 Rainfall data of Thrissur district for the period 2006-2010

**District: Thrissur**

**Note : (1) The District Rainfall(mm.)(R/F) shown below are the arithmatic averages of Rainfall of Stations under the District.**

**(2) % Dep. are the Departures of rainfall from the long period averages of rainfall for the District.**

**(3) Blank Spaces show non-availability of Data.**

| Year | January | | February | | March | | April | | May | | June | | July | | August | | September | | October | | November | | December | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep | R/F | % Dep |
| 2006 | 0.8 | -86 | 0.0 | -100 | 45.9 | 94 | 60.6 | -31 | 617.5 | 99 | 644 | -12 | 553.6 | -28 | 516.6 | 20 | 588.9 | 122 | 371.6 | 39 | 176.5 | 31 | 0.7 | -98 |
| 2007 | 0.0 | -100 | 0.0 | -100 | 0.0 | -100 | 100.1 | 15 | 240.8 | -22 | 783.2 | 7 | 1170.2 | 52 | 533.3 | 24 | 660.3 | 149 | 413.3 | 55 | 48.6 | -64 | 4.5 | -89 |
| 2008 | 0.0 | -100 | 21.0 | 116 | 218.1 | 824 | 45.7 | -48 | 59.8 | -81 | 523.4 | -29 | 537.7 | -43 | 260.2 | -39 | 345.5 | 30 | 384.7 | 44 | 9.0 | -93 | 5.0 | -88 |
| 2009 | 0.0 | -100 | 0.0 | -100 | 49.4 | 109 | 53.9 | -38 | 289.4 | -7 | 586.1 | -20 | 972.1 | 26 | 385.1 | -10 | 361.4 | 36 | 156.9 | -41 | 206.3 | 53 | 29.7 | -27 |
| 2010 | 18.4 | 229 | 0.0 | -100 | 9.3 | -69 | 74.7 | -14 | 197.4 | -36 | 775.8 | 6 | 601.5 | -22 | 236.6 | -45 | 308 | 16 | 539.6 | 102 | 332.6 | 146 | 20.5 | -50 |

Data collected from the site www.imd.gov.in

Observations showed that the flowering was much delayed and poor in all these varieties in 2009-10 season. In varieties Muvandan, Priyur and Alphonso, commencement of flowering as emergence of stray inflorescences was noted during the last week of December. In Vellaikolumban and Banganapalli, it was during 2nd week of January 2010 and in Neelum during 2nd week of February. The peak flowering was noted during the first and 2nd week of January 2010 in Muvandan, Priyur and Alphonso. In Vellaikolumban and Banganapalli, it was during first week of February and in Neelum, during 1st week of March 2010.

During 2010-11 mango season, Muvandan and Alphonso started flowering during last week of December 2010 and Vellaikolumban, Priyur, Banganapalli and Neelum during the first week of January 2011. The peak flowering was noted during the 2nd week of January 2011 to the last week for the other four varieties.

The intensity of flowering observed during these two seasons showed great variation. In 2009-10 season, 20.50 per cent of shoots put forth inflorescence in the cultivar Muvandan, where as it was only 12.30, 10.10, 5.20, 10.00, 10.00 per cent respectively for the cultivars Vellaikolumban, Priyur, Banganapalli, Neelum and Alphonso.

In 2010-11 season showed 82.36 percent flowering was noted in Muvandan and 80.00, 81.23, 79.60, 78.59 and 85.36 percent for Vellaikolumban, Priyur, Banganapalli, Neelum and Alphonso respectively.

In both these seasons, the weather data showed an extraordinary intensification of the north east monsoon from October to the month of November. In 2009, the north east monsoon remained active during 1st week of October; progressed with stray showers during the 2nd week and much vigorous in November also recording a distributed heavy rainfall than the previous month (Total rainfall recorded in October and November 2009 were 166.8 mm and 180.6 mm respectively)

In December 2009, after a rain free spell, rainfall was noted on 27/12/09 to the tune of 42.7mm and thereafter no rainfall noted during January and February 2010.

Weather data for 2010-11 season showed that unlike as in the previous season the north east monsoon become highly vigorous during November 2010. During the month of October, rainfall was recorded for a period of 21 days with a total of (667.6 mm) and the month of November 2010 also recorded rainfall for a period of 15 days with a total of (282.2 mm). In the month of December 2010 also, stray rainfall spreading over first 3 weeks of December with a total of (24.5 mm) was recorded. Thereafter a rain free spell of 11 days was noted in December and for the entire month during January 2011, and about 21 days in February (Fig.9-16).

**4.2.2 Emergence of panicle**

Shoots randomly chosen for undertaking different floral biological studies were observed for the emergence of panicles and subsequent development. Emergence of three types of shoots could be noted based on floral induction;

1. Purely vegetative shoot
2. Purely reproductive shoot
3. Partially reproductive shoot

**Vegetative shoots**

Vegetative shoots are the new shoots bearing only leaves.

**Reproductive shoots**

Reproductive shoots are the cymose inflorescences producing flowers. The terminal inflorescence or panicles are initiated in dormant apical buds on stems that developed vegetatively from lateral buds following the previous season flowering.

**Mixed shoots**

In this case, both leaf primordial and bud bracts, and axillary meristems develop into the respective leaves and flowering structures (Plate 11).

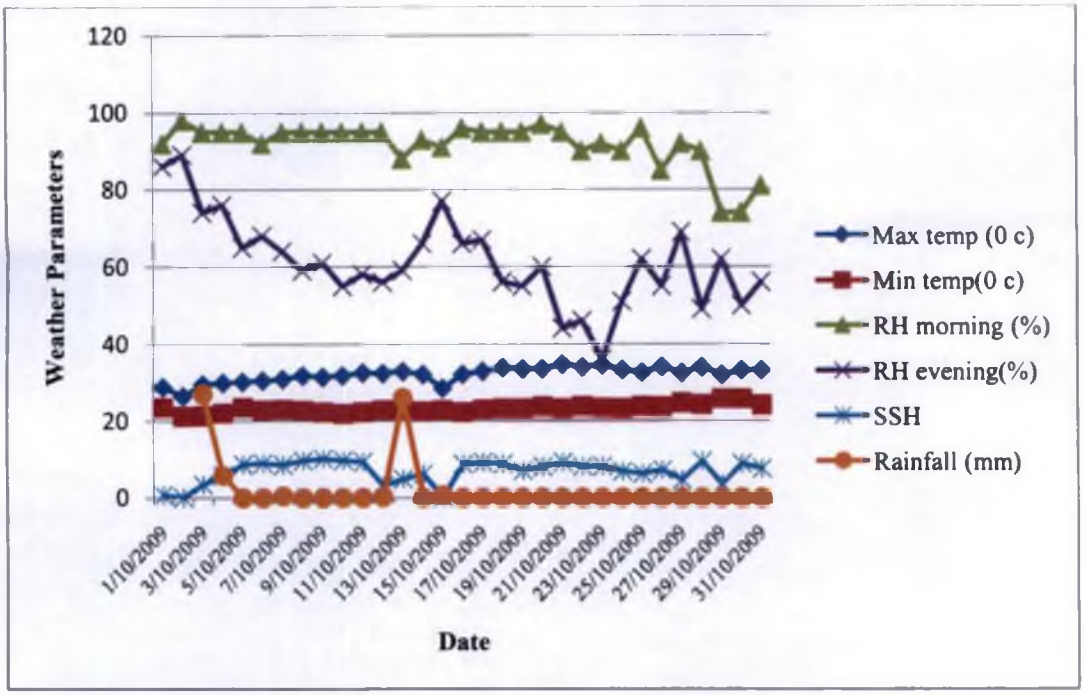



**Fig.9. Weather parameters -October 2009**

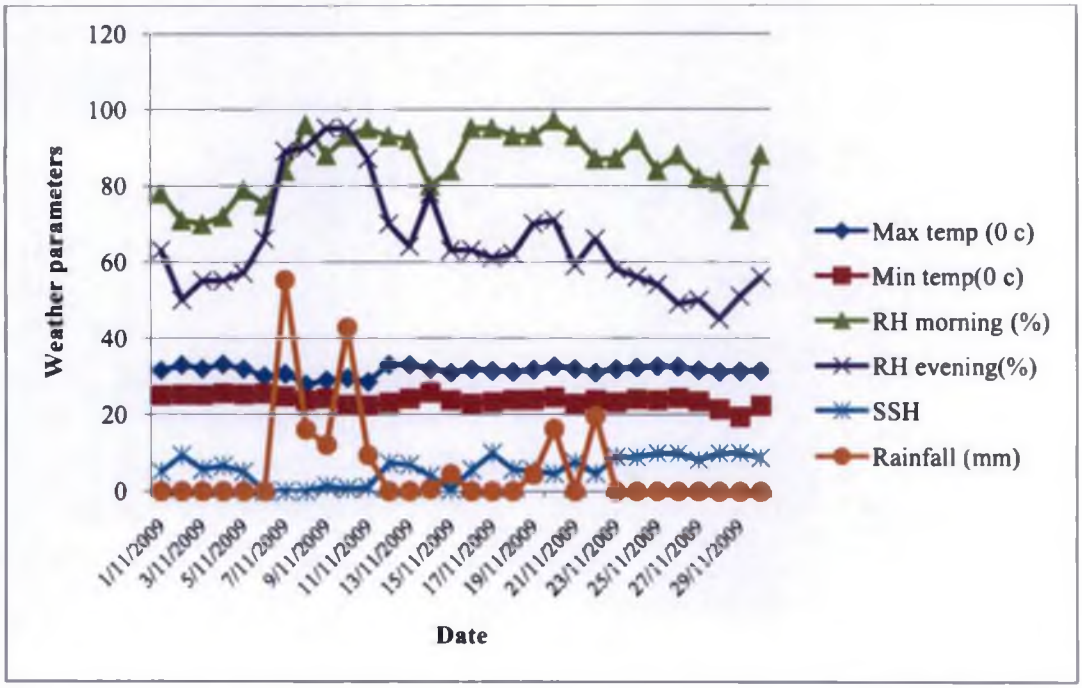



**Fig. 10. Weather parameters - November 2009**

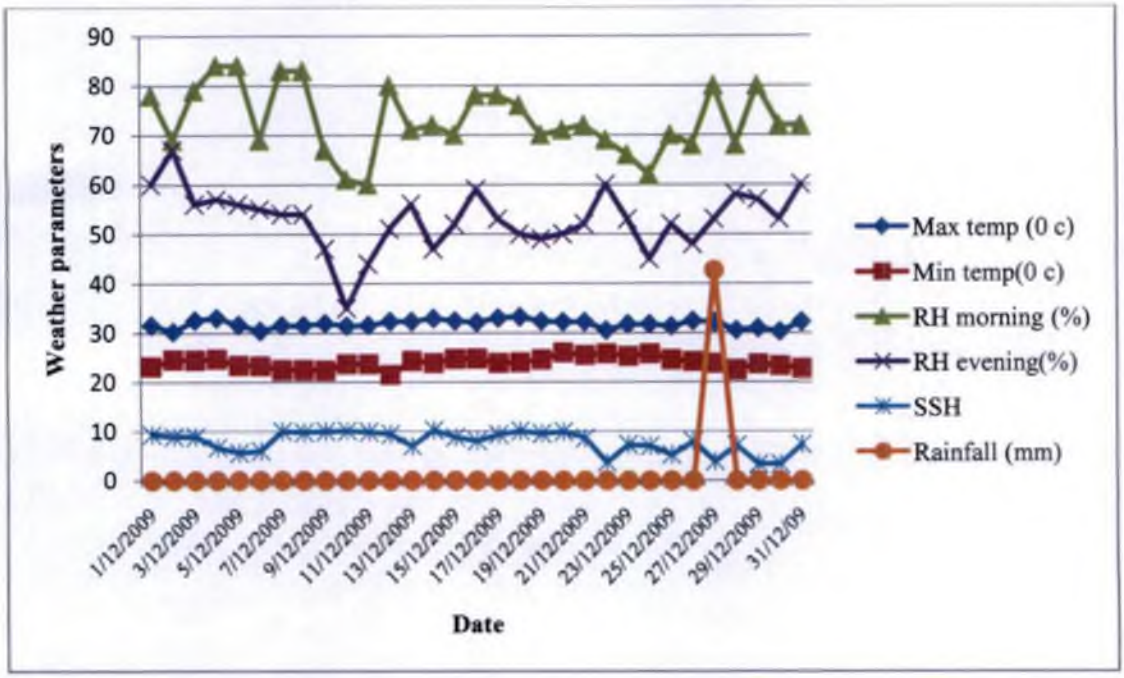



**Fig.11. Weather parameters - December 2009**

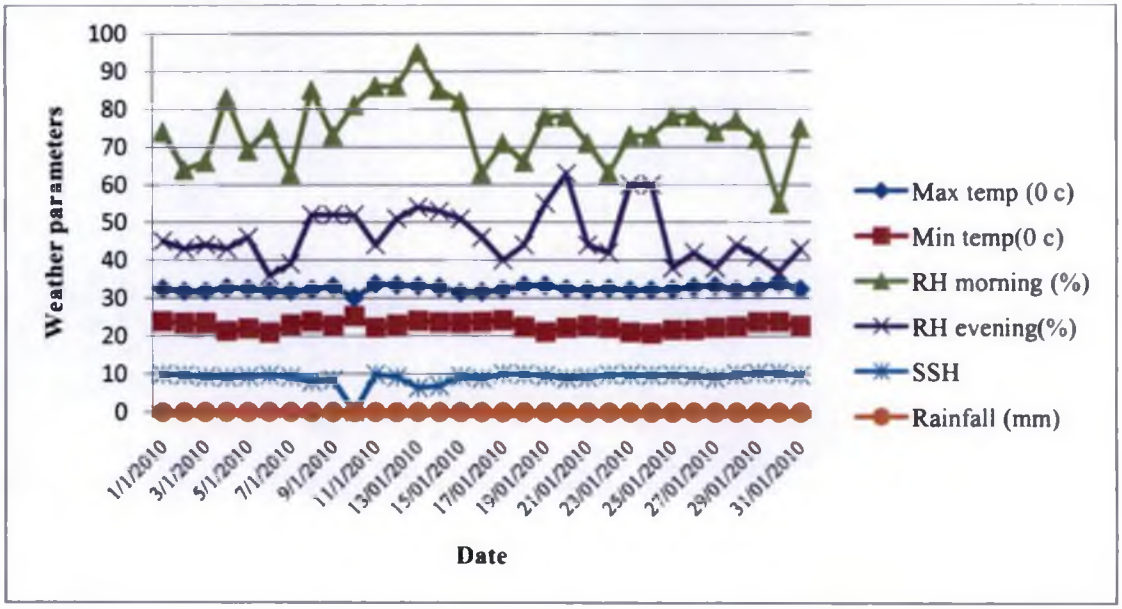



**Fig.12. Weather parameters- January 2010**

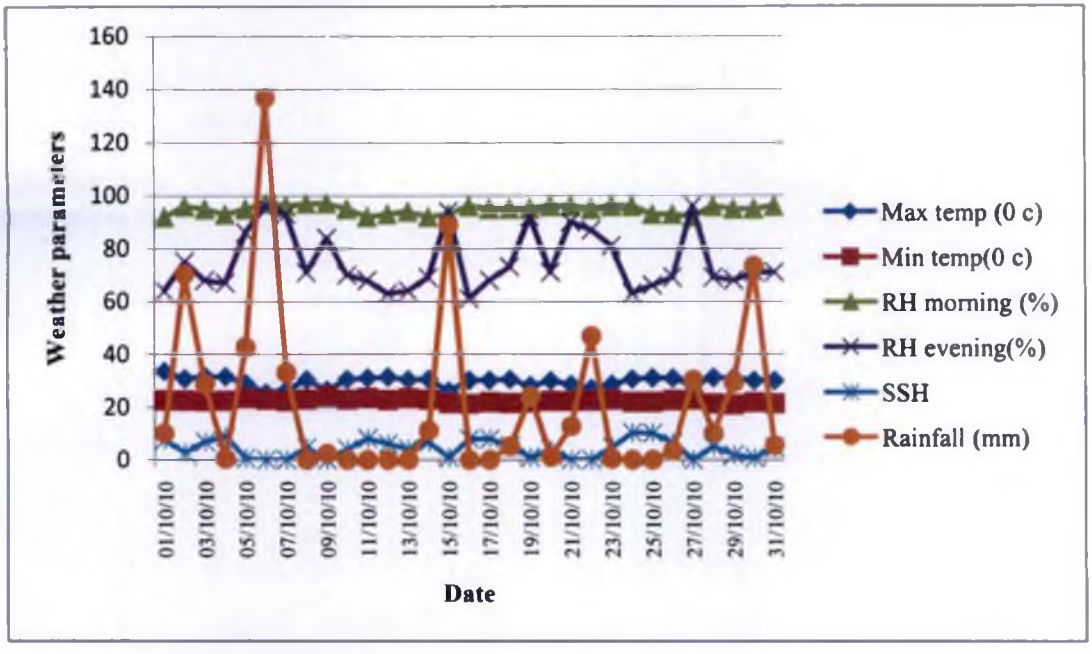



**Fig.13. Weather parameters - October 2010**

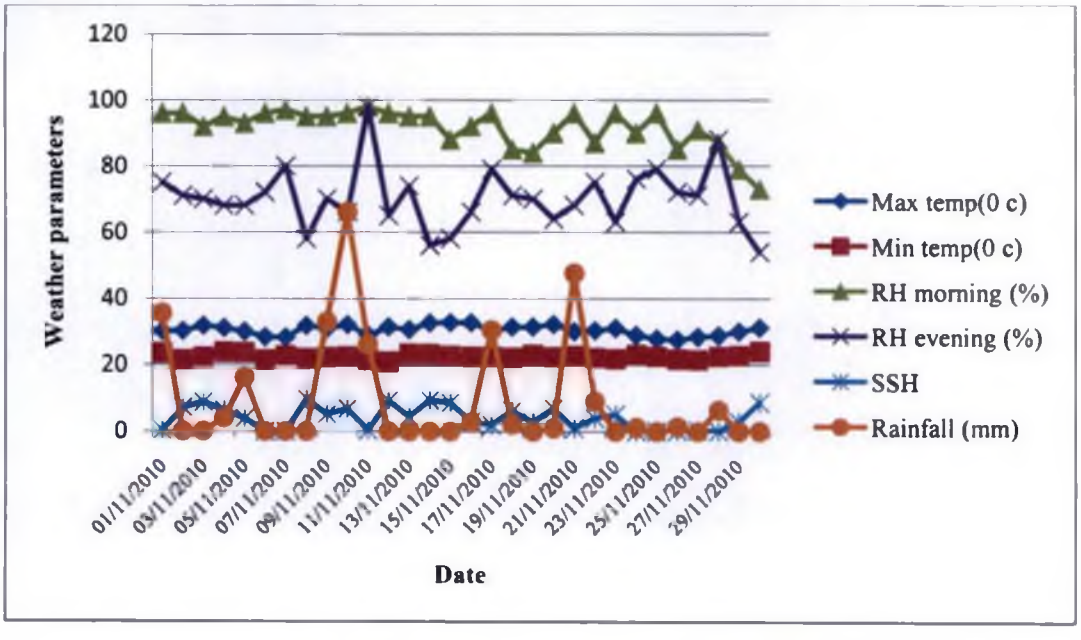



**Fig.14. Weather parameters - November 2010**

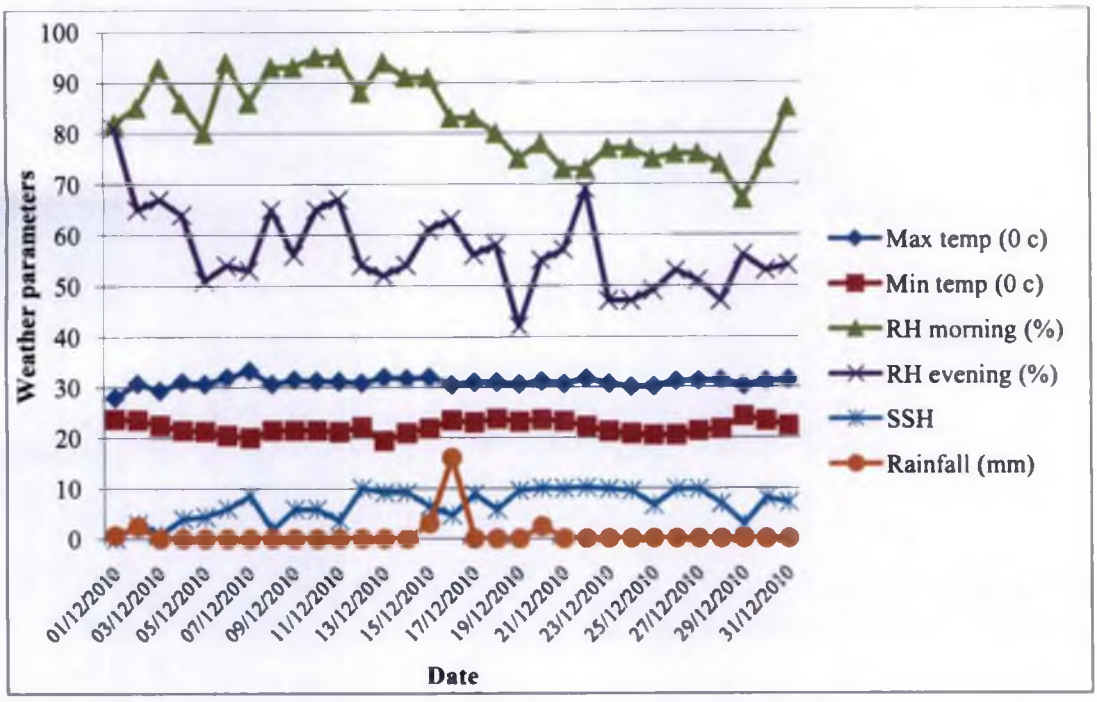



**Fig. 15. Weather parameters - December 2010**

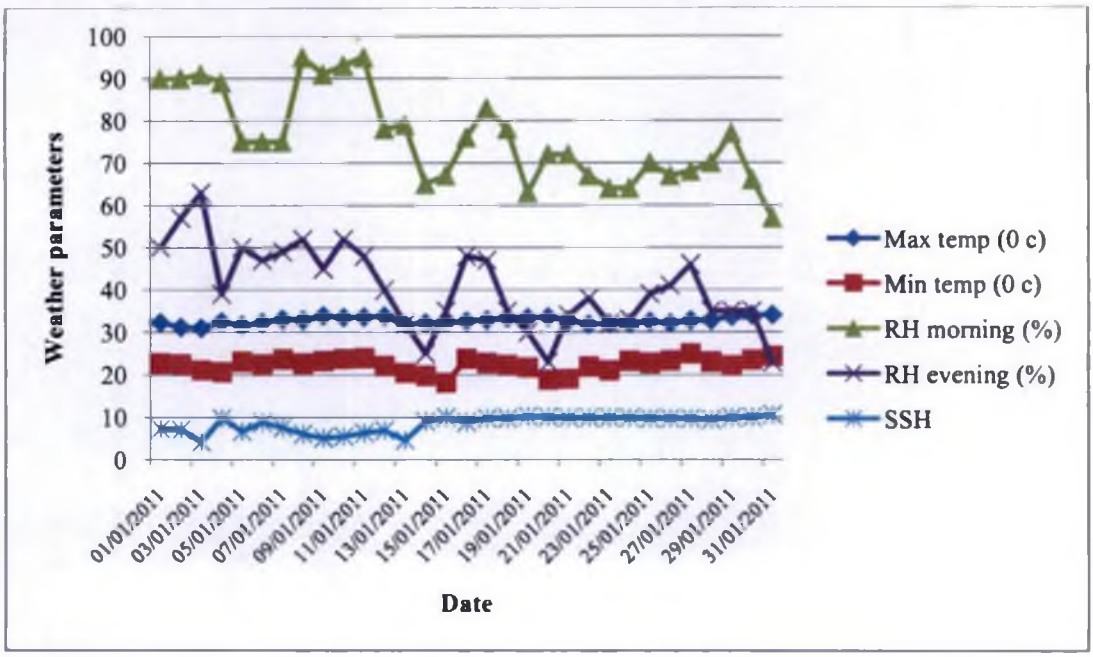



**Fig.16. Weather parameters - January 2011**

a.Vegetative shoot

b. Reproductive shoot

c. Mixed shoot

**Plate 11. Types of shoots in mango**

### 4.2.3 Colour of panicle

Emerging panicles were light green in colour and gradually faded out into different colour shades specific to the types at fully opened out stage (Plate 12). Inflorescence characters at emergence and subsequent stages are presented in Table 6.

### 4.2.4 Inflorescence architecture

The panicles are borne on the past seasons shoots. The emergence of panicle is caused by swelling of the axillary meristems, which develop into an inflorescence that is borne on primary peduncle. Thereafter, the apical meristem begins to form new primordia for panicle development. On basis of internode elongation, the panicle may be open or compact. The inflorescence is narrow to broadly conical upto 30cm.long. It is usually teritary, but the final branching is always cymose (Fig .17).

### 4.2.5 Biometric parameters

Biometric characters of the opened out panicle are presented in the Table 7. The size of inflorescence was the highest in Alphonso (34.00 cm) followed by Muvandan (32.90 cm), Vellaikolumban (30.70 cm), Banganapalli (27.40 cm), Priyur (26.70 cm) and the lowest in Neelum (26.20 cm). Panicle length in Neelum, Banganapalli and Priyur was on par with each other. The breadth showed no significant difference among the varieties.

### 4.2.6 Intensity of flowering/ unit area of tree canopy.

A wooden frame of half meter square was used for estimating the intensity of flowering. The number of emerged out panicles within the unit area was counted and the data is shown in Table 8.

Results show that flowering was intense in all the varieties except the variety Vellaikolumban. Values were 7.00, 8.25, 7.25, and 7.00 respectively for Neelum,

Pyramidal
Muvandan

Conical
Banganapalli

Pyramidal
Neelum

Pyramidal
Vellaikolumban

Broadly pyramidal
Priyur

Pyramidal
Alphonso

**Plate 12. Shape of inflorescence**

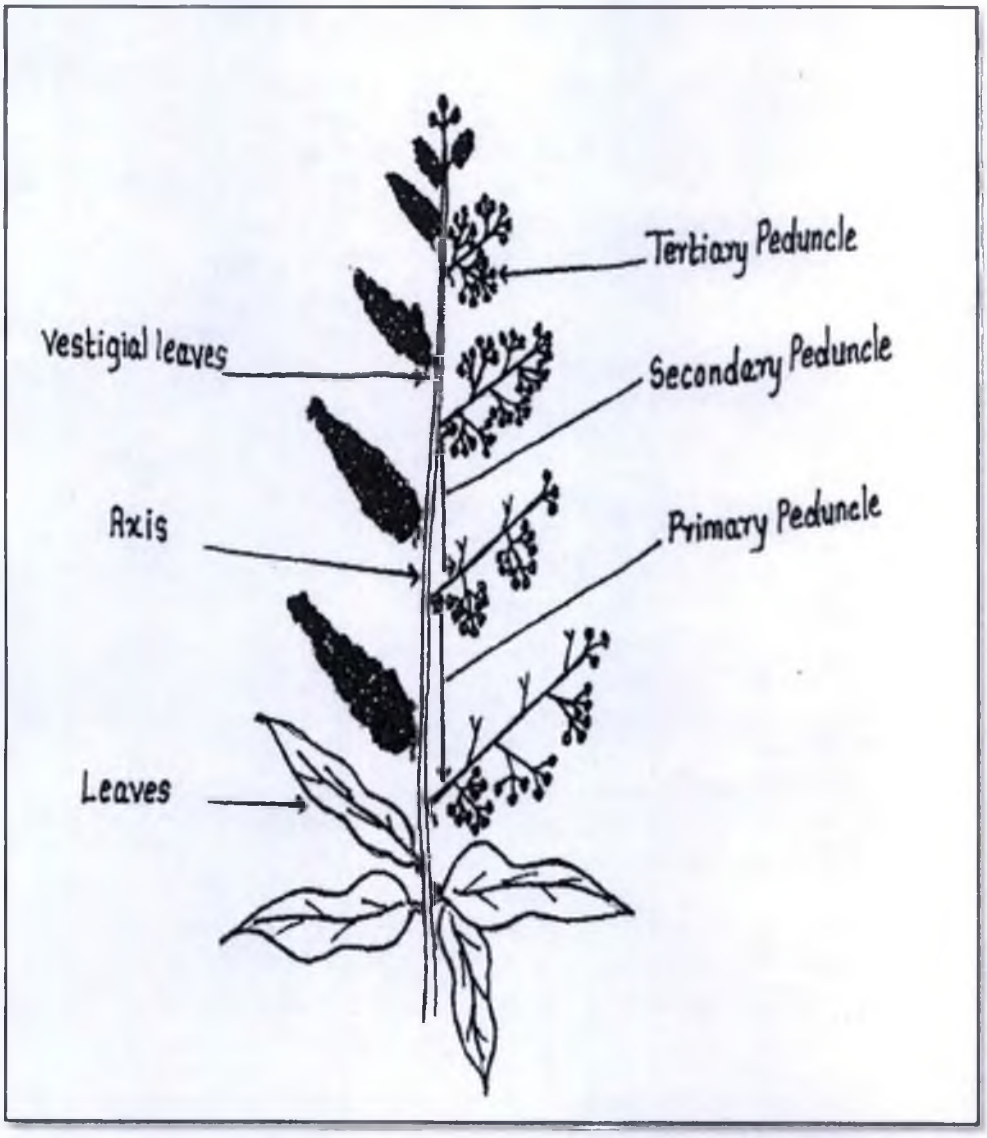



**Fig.17. Inflorescence architecture of mango**

**Table 6. Inflorescence characters at emergence and subsequent stages**

| Variety | Inflorescence Characters | | | |
|---|---|---|---|---|
| | **Colour change at emergence** | **Colour change at fully opened stage** | **Shape of the inflorescence** | **Flower density on the inflorescence** |
| Muvandan | Light green | Crimson | Pyramidal | Medium |
| Vellaikolumban | Light green | Light green | Pyramidal | Laxly |
| Priyur | Light green | Light green with red patches | Broadly pyramidal | Densely |
| Banganapalli | Light green | Light green | Conical | Medium |
| Neelum | Light green | Light red | Pyramidal | Medium |
| Alphonso | Light green | Light red | Pyramidal | Densely |

**Table 7. Inflorescence characters at fully opened out stage**

| Variety | Length of inflorescence (cm) | Breadth of inflorescence (cm) |
|---|---|---|
| Muvandan | 32.90[a] | 19.80[a] |
| Vellaikolumban | 30.70[ab] | 19.50[a] |
| Priyur | 26.70[b] | 18.30[a] |
| Banganapalli | 27.40[b] | 19.10[a] |
| Neelum | 26.20[b] | 18.20[a] |
| Alphonso | 34.00[a] | 22.80[a] |

Values with similar superscript letter did not differ significantly

**Table 8. Intensity of flowering / unit area of tree canopy**

| Variety | Number of panicles/(1/2 sq. m) unit area of tree canopy |
|---|---|
| Muvandan | 7.00[a] |
| Vellaikolumban | 2.00[b] |
| Priyur | 7.30[a] |
| Banganapalli | 7.50[a] |
| Neelum | 7.00[a] |
| Alphonso | 8.30[a] |

Values with similar superscript letter did not differ significantly

Alphonso, Banganapalli, Priyur and Muvandan where as Vellaikolumban recorded smallest intensity of 2 shoots per unit area.

### 4.2.7 Time taken for opening out of inflorescence

Time taken for full opening of the panicle in the different varieties was worked out by noting the interval between opening of first flower and opening of last flower in the panicle. Data is presented in Table 9.

### 4.2.8 Sequence of flower opening and sex distribution in different mango types

Flower opening sequence in the opened panicles was closely followed and the numbers of flowers opened at different intervals were worked out. This was done with the object of assessing the dominance of any pure sex phase during the opening, such as pure male phase involving only opening of male flowers and mixed phase involving opening of male and bisexual flowers simultaneously.

In variety Muvandan, male flowers opened out on the first day followed by male and hermaphrodite flowers together in subsequent days indicating a mixed phase. A second male phase could be noted towards the final stages.

In Neelum, both male and hermaphrodite flowers opened simultaneously in the panicle indicating a mixed phase of opening from beginning itself. No pure male phase could be observed. Such a trend could be noted in Priyur, Alphonso, and Vellaikolumban in which the last few days of flower opening were predominantly of male phase.

In Banganapalli, a pure male phase extending for first 5 days of flower opening and thereafter a mixed phase of both types could be noted (Fig 18-23).

**Table 9. Duration of flower opening**

| Variety | Time taken for full opening out of panicle (days) |
|---|---|
| Muvandan | 19.60[a] |
| Vellaikolumban | 13.80[b] |
| Priyur | 17.60[a] |
| Banganapalli | 13.00[b] |
| Neelum | 14.60[b] |
| Alphonso | 9.60[c] |

Values with similar superscript letter did not differ significantly

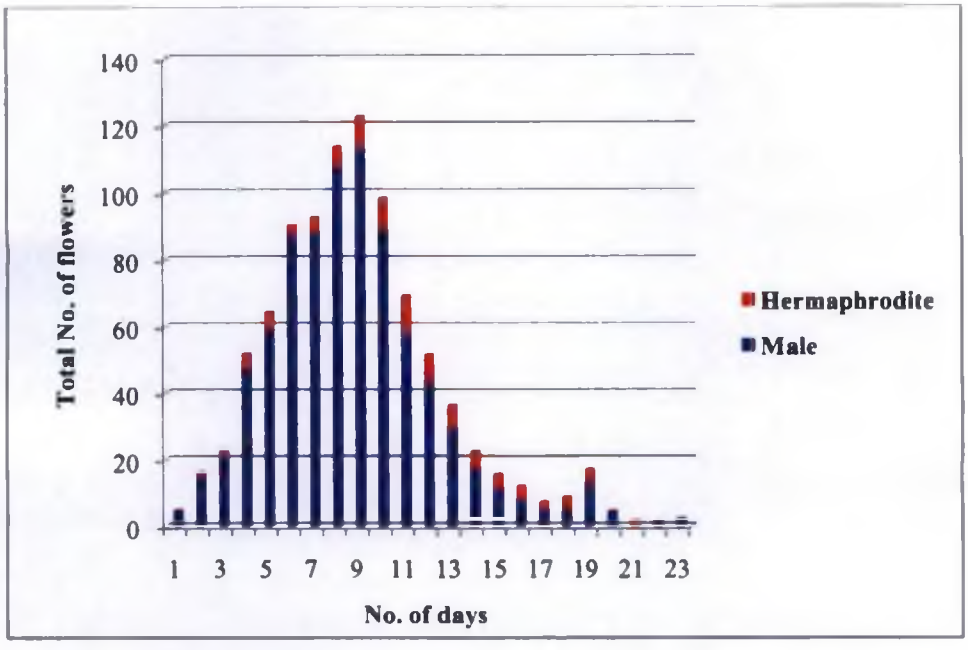



**Fig.18. Sex distribution (hermaphrodite and male flowers) in 'Muvandan' variety**

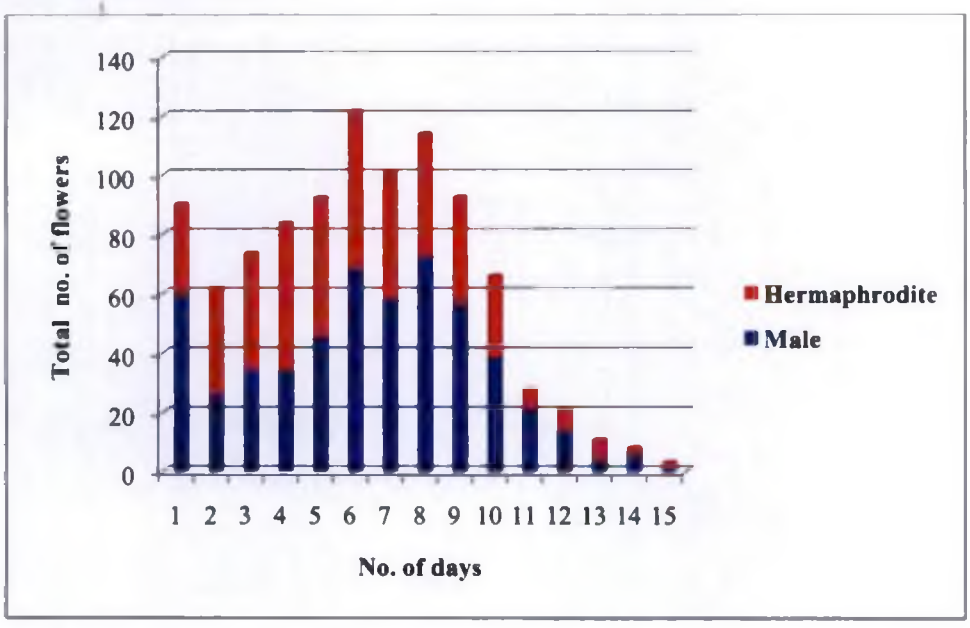



**Fig.19. Sex distribution (hermaphrodite and male flowers) in 'Vellaikolumban' variety**

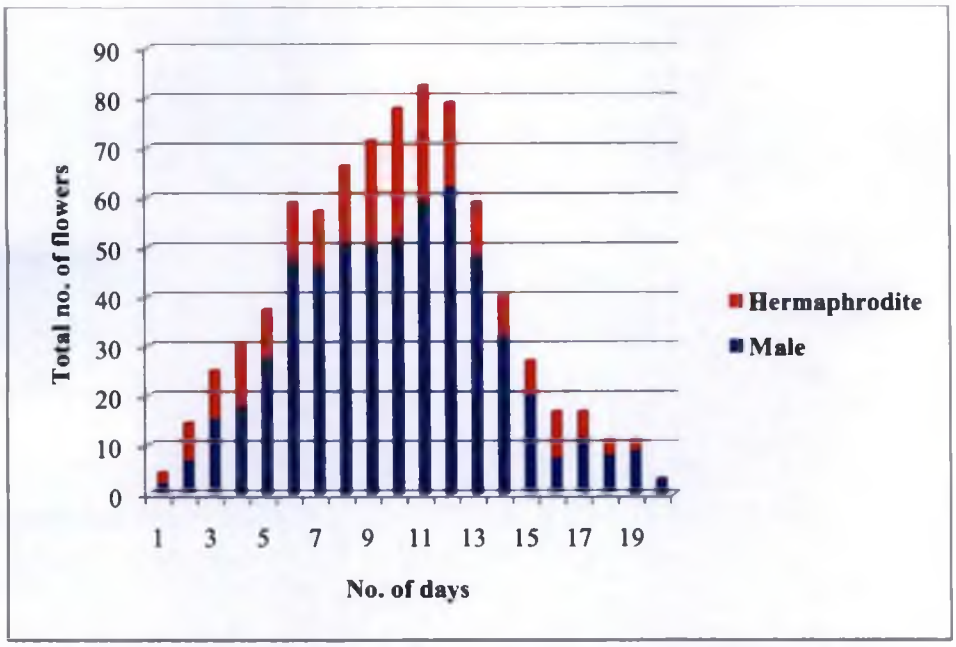



**Fig.20. Sex distribution (hermaphrodite and male flowers) in 'Priyur' variety**

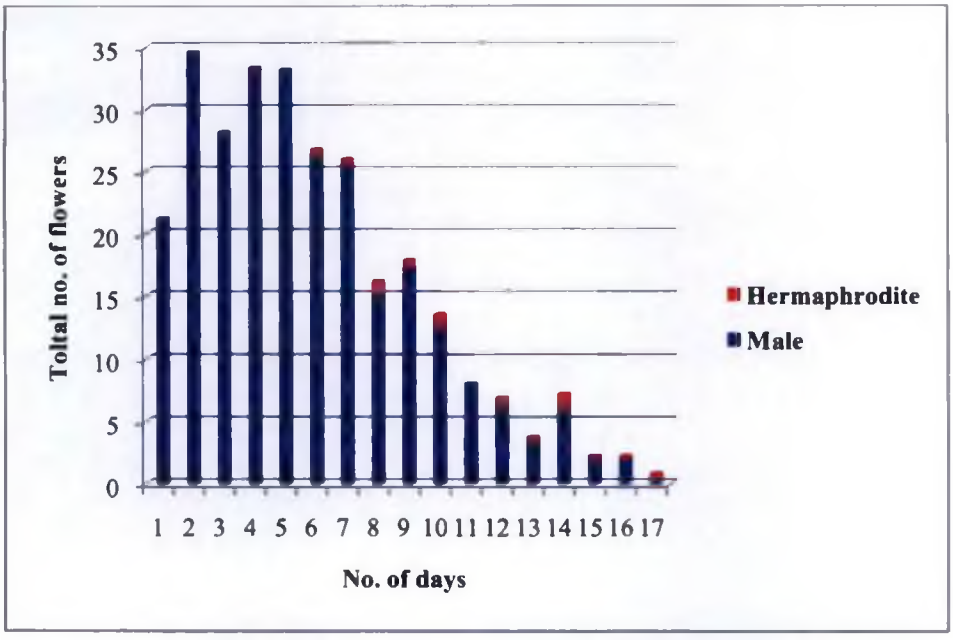



**Fig.21. Sex distribution (hermaphrodite and male flowers) in 'Banganapalli' variety**

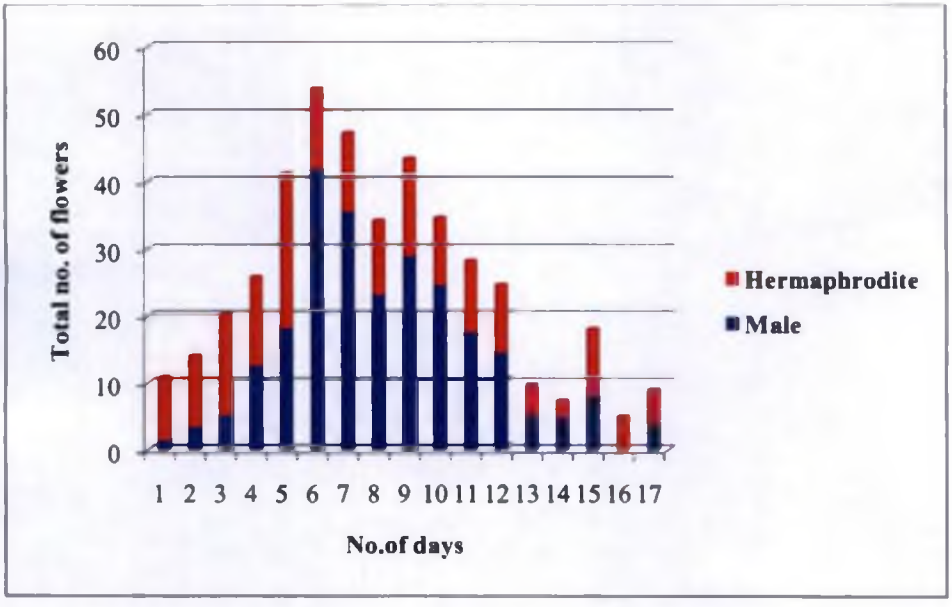



**Fig. 22. Sex distribution (hermaphrodite and male flowers) in 'Neelum' variety**

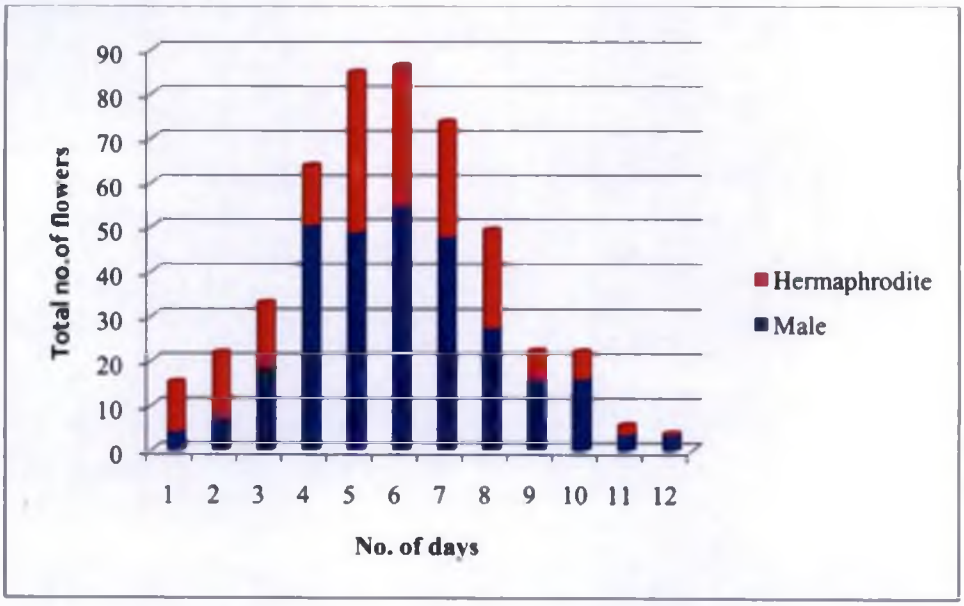



**Fig.23. Sex distribution (hermaphrodite and male flowers) in 'Alphonso' variety**

### 4.2.9 Positional differences in opening of flowers in a panicle

Observations showed that flowers started opening in the panicle from the basal primary peduncle, continued upwards through middle portion and ended with apical portion.

In cultivars Muvandan and Banganapalli in which a sequence of male – mixed- male phases were noted, flower opening commenced with male flower on basal peduncle and entered into mixed phase in the middle peduncle and ended with male phase at tip.

### 4.2.10 Percentage of hermaphrodite flowers opened in the panicle

Proportion of the hermaphrodite to male flowers opened in the panicle was worked out by counting the number of hermaphrodite and male flowers opened and expressed as a percentage of total flowers (Table 10).

The varieties Neelum, Vellaikolumban and Alphonso recorded higher percentage of hermaphrodite flowers i.e. 40.50, 46.48, 43.13 respectively than the other three cultivars. Muvandan (10.18), Priyur (27.17) and Banganapalli (2.10) Fig. 24.

### 4.2.11 Floral characters

#### 4.2.11.1 Floral morphology

The panicle was borne on the terminal shoots. It consisted of male and hermaphrodite flowers. The size of the flowers varied from 6 to 8 mm in diameter. Both male and hermaphrodite flowers were pentamorous with five pale yellow petals which turns pink on fading, they are rarely pedicellate and have sweet smell. Both male and hermaphrodite flowers showed one fertile stamen and four sterile stamens (staminodes) and the length of fertile stamen was longer than staminodes. Hermaphrodite flowers had pistils equal to the length of fertile stamen. The colour of anther is pink which turn purple at time of shedding (Fig. 25-26)

**Table 10. Percentage of hermaphrodite flowers**

| Variety | Total number of opened flowers | Number of hermaphrodite flowers | Hermaphrodite flowers (%) |
|---|---|---|---|
| Muvandan | 903 | 92 | 10.18 |
| Vellaikolumban | 940 | 436 | 46.48 |
| Priyur | 769 | 208 | 27.17 |
| Banganapalli | 285 | 6 | 2.10 |
| Neelum | 400 | 162 | 40.50 |
| Alphonso | 466 | 201 | 43.13 |

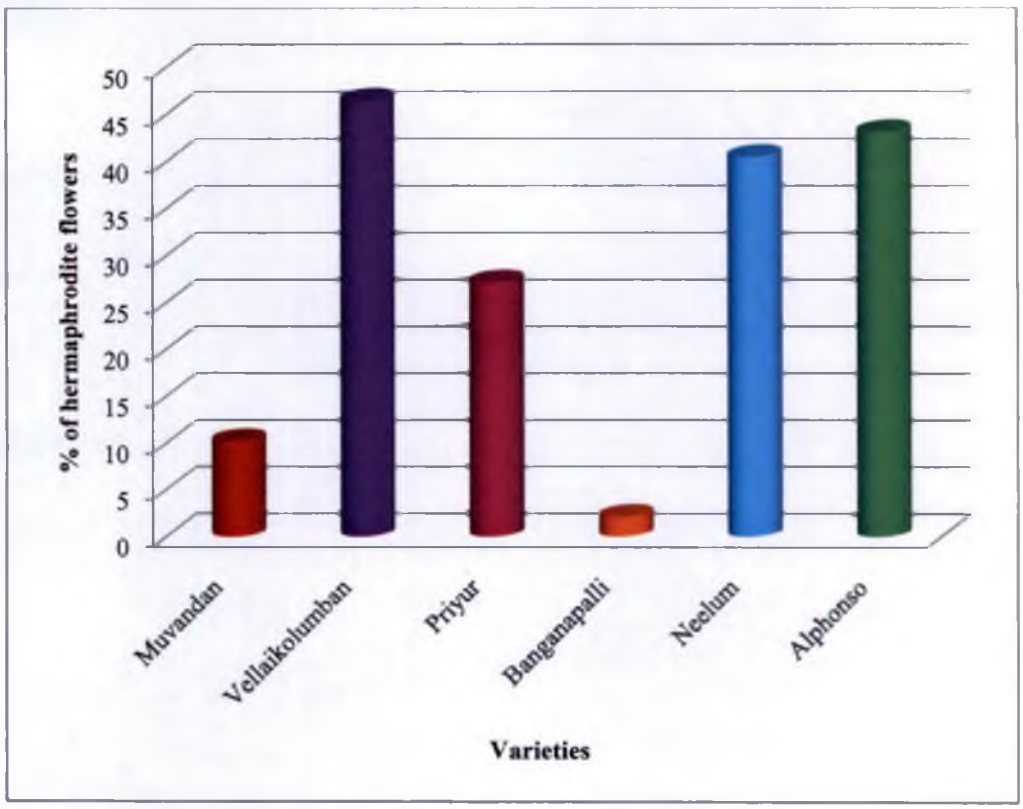



**Fig. 24. Percentage of hermaphrodite flowers**

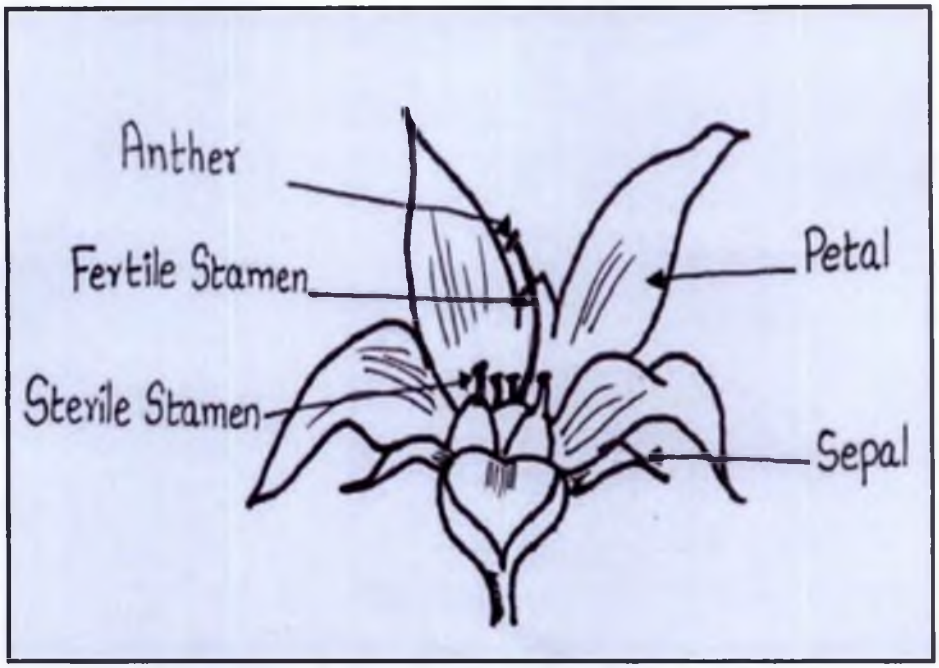



**Fig.25. Male flower**

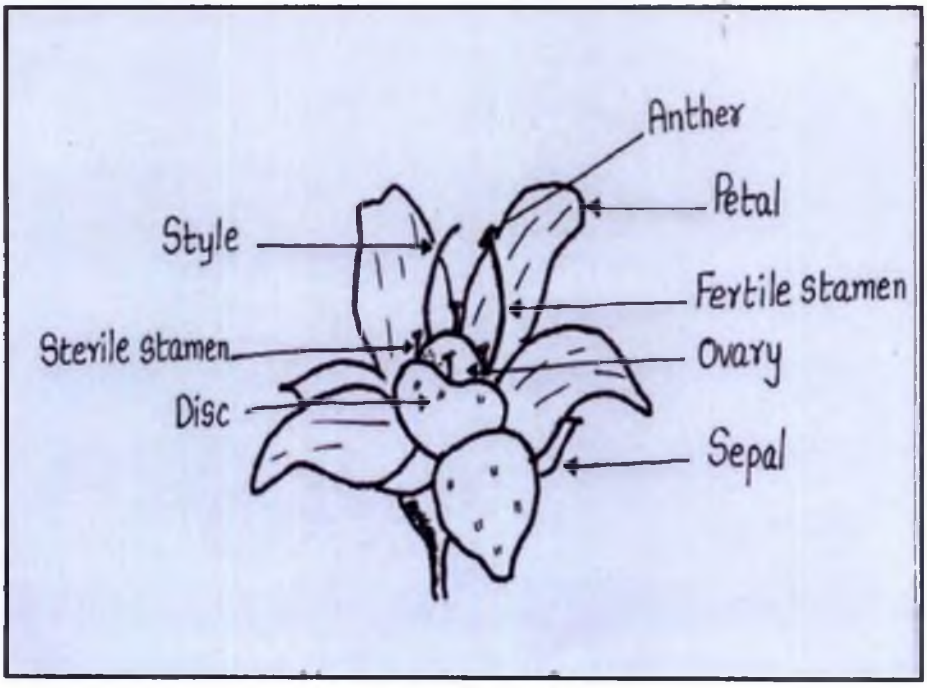



**Fig.26. Hermaphrodite flower**

#### 4.2.11.2 Anthesis and dehiscence of flowers

Opening of the flowers at 2 hourly time interval was observed from early morning to evening. Maximum flower opening was noted in between 8- 10 am on a normal sunny day (Table 11).

The flowers in the panicles started opening early in the morning and completed by the forenoon (12 noon ). Only stray flowers opened in the afternoon hours.

Anthesis commenced at the lower portion of panicle and progressed acropetally. Anther dehiscence took place only after the opening of flower.

#### 4.2.11.3 Receptivity of stigma

The stigma was shiny and whitish on the day of anthesis and started fading thereafter. Receptivity was studied by pollinating 30 flowers at definite intervals after opening. The results are presented in the Table 12.

In all the varieties maximum stigma receptivity was noted on the day of anthesis and it was found to decrease thereafter during the $1^{st}$, $2^{nd}$, $3^{rd}$ day of opening.

### 4.2.12 Pollen studies

#### 4.2.12.1 Pollen morphology

Morphology of the pollen collected from different varieties was studied by observing the pollen under a Phase contrast microscope (Plate 13-18).

In Neelum, Alphonso, Priyur and Vellaikolumban a roundish pollen could be noted whereas it was oval in Banganapalli and oblong in Muvandan. Muvandan recorded maximum value for pollen size (33.34 µm) where as it was 31.10 and 31.67 µm respectively for Alphonso and Banganapalli. The values recorded for Vellaikolumban, Neelum and Priyur were 29.75, 27.49 and 27.29 µm respectively (Table. 13).

**Table 11. Time of anthesis and dehiscence in mango flowers**

| Variety | Date of observation | Start of flower opening | Maximum flower opening | Maximum dehiscence | Temp Max ($^0$c) | Temp Min ($^0$c) | RH (%) | SSH hrs |
|---|---|---|---|---|---|---|---|---|
| Muvandan | 7.2.11 | 7.00 am | 8.00 -10.00 am | 8.30- 10.30 am | 34.1 | 19.7 | 65 | 7.7 |
| | 8.2.11 | 7.00 am | 8.00-10.00 am | 8.30- 10.30 am | 34.5 | 22.4 | 72 | 8.7 |
| | 11.2.11 | 7.00am | 7.30-10.00 am | 8.30-11.00 am | 34.4 | 20.9 | 66 | 10.5 |
| Vellaikolumban | 10.1.11 | 8.00 am | 8.30-10.30am | 9.00-11.00 am | 33.5 | 23.8 | 93 | 5.5 |
| | 12.1.11 | 8.00am | 8.30-11.30am | 9.00-11.00am | 33.8 | 22.1 | 78 | 6.9 |
| | 14.1.11 | 7.30 am | 8.00-11.00 am | 9.00-12.00 pm | 32.2 | 19.8 | 65 | 9.0 |
| Priyur | 17.1.11 | 8.00 am | 8.30-11.00 am | 9-11.30 am | 32.9 | 22.8 | 83 | 9.8 |
| | 19.1.11 | 7.30 am | 8.00-11.00 am | 8.30-11.30 am | 33.4 | 21.7 | 63 | 10.2 |
| | 21.1.11 | 7.30 am | 8.00-11.00 am | 8.30-11.30 am | 32.8 | 19.0 | 72 | 9.9 |
| Banganapalli | 17.1.11 | 8.00 am | 8.30-11.00 am | 9-11.30 am | 32.9 | 22.8 | 83 | 9.8 |
| | 19.1.11 | 7.30 am | 8.00-11.00 am | 8.30-11.30 am | 33.4 | 21.7 | 63 | 10.2 |
| | 21.1.11 | 7.30 am | 8.00-11.00 am | 8.30-11.30 am | 32.8 | 19.0 | 72 | 9.9 |
| Neelum | 7.2.11 | 8.00 am | 8.30-11.00 am | 8.30- 10.30 am | 34.1 | 19.7 | 65 | 7.7 |
| | 8.2.11 | 8.00 am | 8.30-11.00am | 8.30- 10.30 am | 34.5 | 22.4 | 72 | 8.7 |
| | 11.2.11 | 8.00am | 8.30-11.00am | 8.30-11.00 am | 34.4 | 20.9 | 66 | 10.5 |
| Alphonso | 10.1.11 | 8.00 am | 8.30-10.30am | 9.00-11.00 am | 33.5 | 23.8 | 93 | 5.5 |
| | 12.1.11 | 8.00am | 8.30-11.30am | 9.00-11.00am | 33.8 | 22.1 | 78 | 6.9 |
| | 14.1.11 | 7.30 am | 8.00-11.00 am | 9.00-12.00 pm | 32.2 | 19.8 | 65 | 9.0 |

**Table 12. Stigma receptivity**

| Time | Muvandan (%) | Neelum (%) | Vellaikolumban (%) | Priyur (%) | Alphonso (%) | Banganapalli (%) |
|---|---|---|---|---|---|---|
| On the day of anthesis | 70.00 | 65.00 | 60.00 | 68.00 | 71.00 | 62.00 |
| 1st day after anthesis | 32.00 | 26.00 | 28.00 | 23.00 | 38.00 | 29.00 |
| 2nd day after anthesis | 18.00 | 11.00 | 10.00 | 17.00 | 10.00 | 8.00 |
| 3rd day after anthesis | 5.00 | 4.00 | 5.00 | 3.00 | 2.00 | 3.00 |
| 4th day after anthesis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

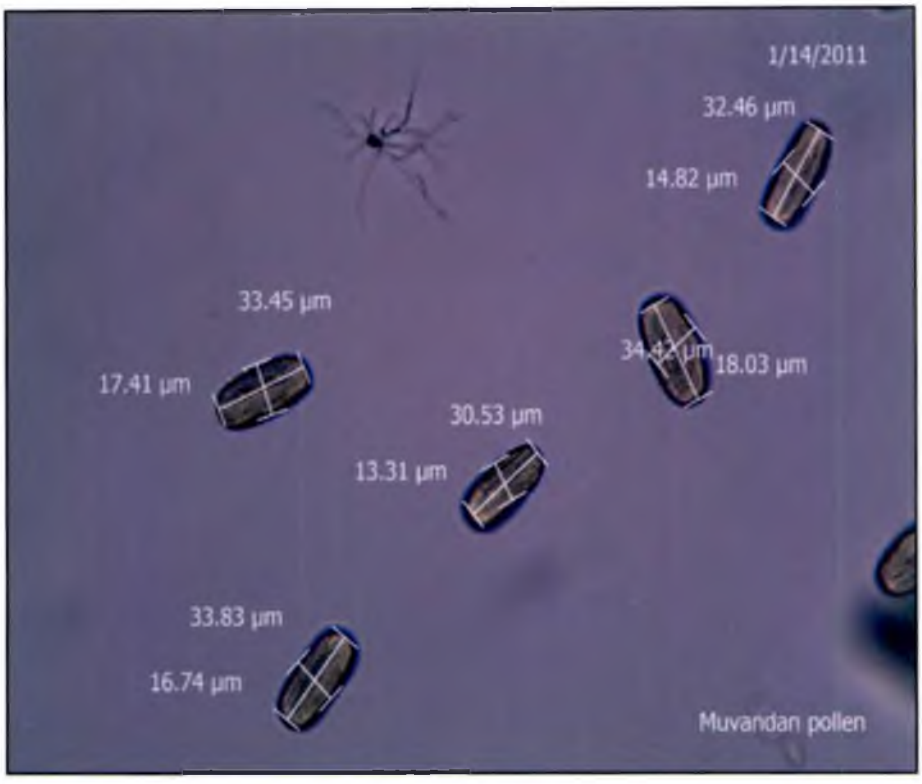



**Plate 13.Pollen shape and size of Muvandan**

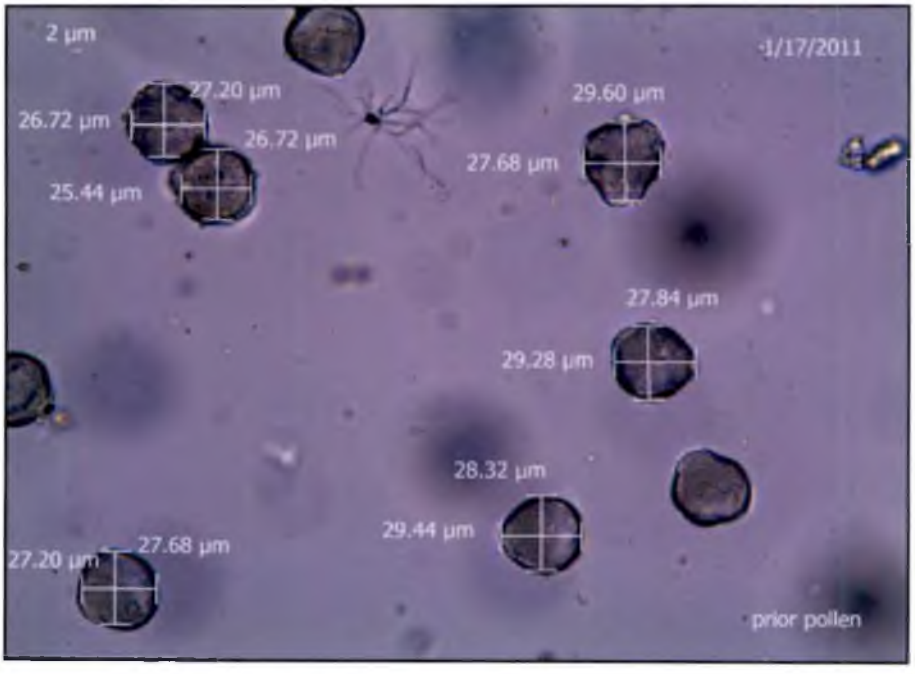



**Plate 14. Pollen shape and size of Priyur**


**Plate 15.Pollen shape and size of Alphonso**

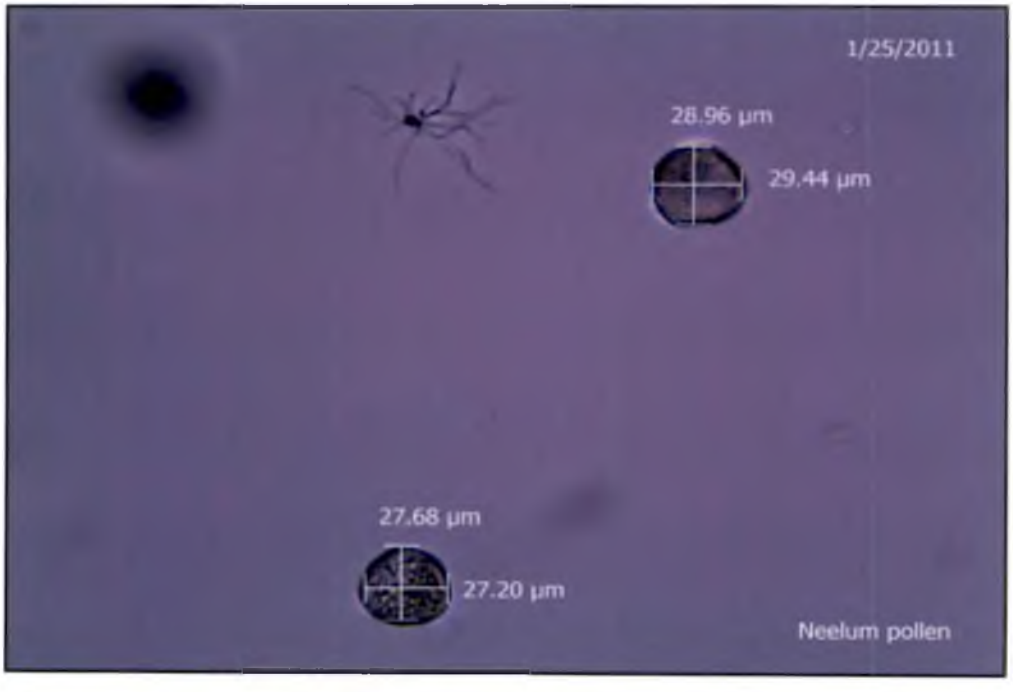



**Plate 16. Pollen shape and size of Neelum**

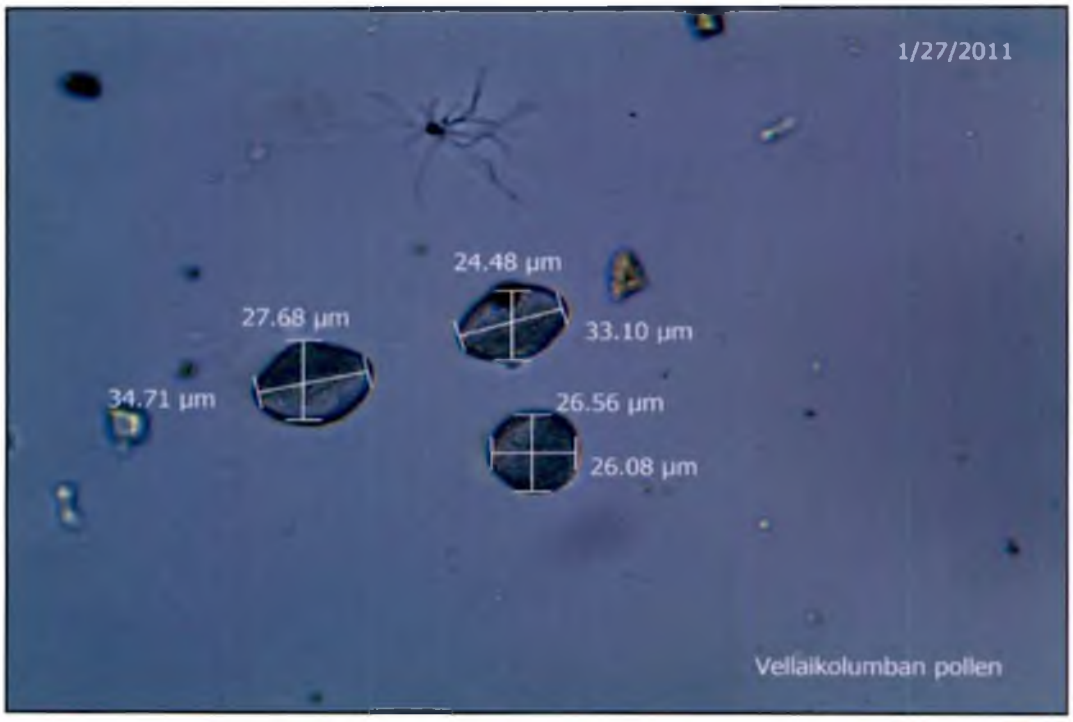



**Plate 17. Pollen shape and size of Vellaikolumban**

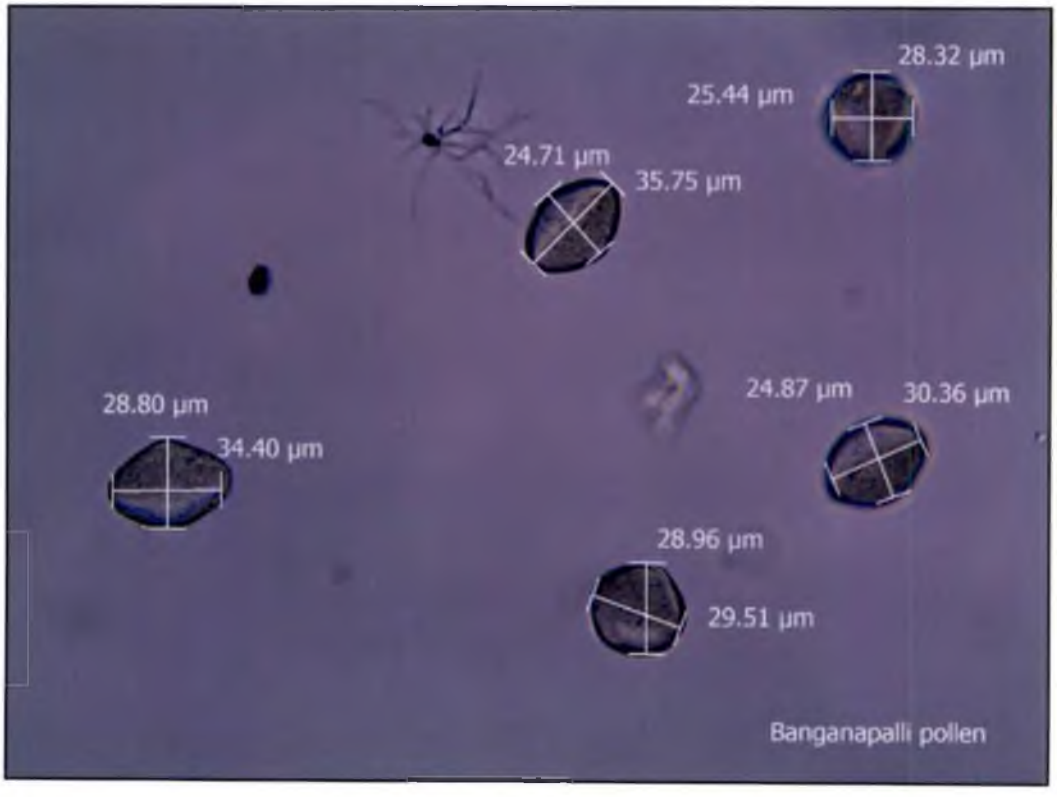



**Plate 18. Pollen shape and size of Banganapalli**

**Table 13. Morphological features of mango pollen**

| Variety | Pollen shape | Pollen size (µm) |
|---|---|---|
| Muvandan | Oblong | 33.34[c] |
| Vellaikolumban | Round | 29.75[abc] |
| Priyur | Round | 27.29[c] |
| Banganapalli | Oval | 31.67[a] |
| Neelum | Round | 27.49[bc] |
| Alphonso | Round | 31.10[ab] |

Values with similar superscript letter did not differ significantly

#### 4.2.12.2 Pollen production per anther

Pollen production per anther was estimated by the haemocytometer method. Pollen production was worked at in all the varieties during January 2011 and March 2011 (Table.14).

Pollen production was maximum during the month of January 2011 and the highest for Vellaikolumban and Banganapalli (500). In Priyur, it was 400 and corresponding values for Neelum, Alphonso, Muvandan and Neelum were 300 and 250 respectively. The corresponding weather data was recorded during the period of estimation; and the values were 32.9, 21.0, 72.5 and 9.9 for maximum, minimum temperature, RH and sunshine hours respectively.

Pollen production estimation during March 2011 recorded lower values. Pollen counts were 198, 188, 70, 218, 89, and 223 for the varieties Muvandan, Vellaikolumban, Priyur, Banganapalli, Neelum and Alphonso respectively. And the corresponding weather data were 33.2, 25.0. 92.5 and 7.2 respectively for maximum, minimum temperature, RH and sunshine hours.

#### 4.2.12.3 Pollen fertility

Pollen fertility was assessed by acetocarmine staining technique during January 2011 and in March 2011(Table 15 - 16).

Maximum pollen fertility was recorded during January 2011 and the corresponding values were 80.70, 93.52, 87.87, 87.35, 92.67, and 93.52 per cent in Muvandan, Vellaikolumban, Priyur, Banganapalli, Neelum and Alphonso, respectively.

Comparatively smaller values were recorded with respect to the pollen fertility during March 2011; and the values were 45.90, 54.92, 40.70, 41.37, 60.00, 44.11 per cent for the varieties Muvandan, Vellaikolumban, Priyur, Banganapalli, Neelum and Alphonso, respectively.

**Table 14. Pollen production in mango**

| Variety | Pollen count/ anther | | Climatic parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | January 2011 | | | | March 2011 | | | |
| | Jan 2011 (17-22 Jan) | Mar 2011 (24-25 March) | Max Temp ($^0$c) | Min Temp ($^0$c) | RH % | Sushine hours | Max Temp ($^0$c) | Min Temp ($^0$c) | RH % | Sunshine hours |
| Muvandan | 250 | 198 | 32.9 | 21.0 | 72.5 | 9.9 | 33.2 | 25.0 | 92.5 | 7.2 |
| Vellaikolumban | 500 | 188 | 32.9 | 21.0 | 72.5 | 9.9 | 33.2 | 25.0 | 92.5 | 7.2 |
| Priyur | 400 | 70 | 32.9 | 21.0 | 72.5 | 9.9 | 33.2 | 25.0 | 92.5 | 7.2 |
| Banganapalli | 500 | 218 | 32.9 | 21.0 | 72.5 | 9.9 | 33.2 | 25.0 | 92.5 | 7.2 |
| Neelum | 250 | 89 | 32.9 | 21.0 | 72.5 | 9.9 | 33.2 | 25.0 | 92.5 | 7.2 |
| Alphonso | 300 | 223 | 32.9 | 21.0 | 72.5 | 9.9 | 33.2 | 25.0 | 92.5 | 7.2 |

**Table 15. Pollen fertility of mango noted in the month of January 2011**

| Variety | Total number of pollen grains observed | Total number of stained grains | Total number of unstained grains | Pollen fertility (%) |
|---|---|---|---|---|
| Neelum | 355 | 387 | 26 | 92.67 |
| Banganapalli | 443 | 387 | 56 | 87.35 |
| Priyur | 396 | 348 | 48 | 87.87 |
| Muvandan | 451 | 364 | 87 | 80.70 |
| Alphonso | 297 | 274 | 23 | 92.25 |
| Vellaikolumban | 309 | 289 | 20 | 93.52 |

**Table 16. Pollen fertility of mango noted in the month of March 2011**

| Variety | Total number of pollen grains observed | Total number of stained grains | Total number of unstained grains | Pollen fertility (%) |
|---|---|---|---|---|
| Neelum | 61 | 28 | 33 | 45.90 |
| Banganapalli | 71 | 39 | 32 | 54.92 |
| Priyur | 113 | 46 | 67 | 40.70 |
| Muvandan | 58 | 24 | 34 | 41.37 |
| Alphonso | 50 | 30 | 20 | 60.00 |
| Vellaikolumban | 68 | 30 | 38 | 44.11 |

**4.2.12.4 Pollen storage**

In order to study the optimal condition for storing pollen with minimum loss of viability, pollen collected irrespective of the varieties was subjected to storage in different atmospheric conditions. Results are presented in Table 17.

The studies showed that the mango pollen can be stored without a much loss in viability upto 72 hours after dehiscence when it is stored in refrigerated conditions, but the viability was high (76.34 per cent) after 24 hours of storage but then declining to 68.57 per cent and 59.06 per cent after 48 hours and 72 hours respectively. Keeping over calcium chloride in desiccator retained the viability upto 70.93 per cent after 24 hours of storage but thereafter suddenly reduced to 9.12 and 8.49 per cent at 48 hours and 72 hours of storage. Keeping over calcium chloride and placing under refrigerated conditions retained to 59.21 and 41.76 per cent viability after 48 and 72 hours respectively. Keeping pollen at room temperature conditions recorded 51.68 per cent viability after 24 hours of storage which further declined to 41.74 per cent and 33.08 per cent after 48 and 72 hours respectively.

**4.2.12.5. Standardization of *in vitro* medium for pollen germination**

In order to standardize the optimum *in vitro* medium for pollen germination in mango, media containing sucrose (5 to 25 percent levels) and agar (0.5 to 1 per cent) was tried. Results were not positive and in none of the media pollen grains germinated even after trying repeatedly.

**4.2.13 Compatibility studies**

The varieties included in the studies were subjected to crossing in different possible combinations in order to assess the pollen compatibility in different varieties.

The controlled pollination procedure as standardised by Regional Fruit Research Station, Vengurla, Maharashtra for hybridization of mango varieties was

**Table. 17 Pollen viability under different storage conditions**

| SL. No | Treatments | Pollen viability (%) | | | |
|---|---|---|---|---|---|
| | | Interval after storage | | | |
| | | 24 hours | 48 hours | 72 hours | 96 hours |
| 1. | Keeping over calcium chloride in a dessicator | $70.93^{ab}$ | $9.12^{c}$ | $8.49^{c}$ | - |
| 2. | Keeping in refrigerator at $4^0C$ | $76.34^{a}$ | $67.87^{a}$ | $59.06^{a}$ | $49.57^{a}$ |
| 3. | Keeping over calcium chloride and refrigerator at $4^0C$ | $68.57^{ab}$ | $59.21^{a}$ | $41.26^{ab}$ | - |
| 4. | Keeping at room temperature | $51.68^{b}$ | $41.74^{b}$ | $33.08^{b}$ | - |

Values with similar superscript letter did not differ significantly

adopted and undertaken during 2nd fortnight of January 2011 and continued upto February 2011(Table.18 and 19).

Selfing in the varieties *viz.*, Muvandan, Banganapalli, Priyur, Vellaikolumban, Alphonso and Neelum did not result in fruit setting.

Crossing undertaken among these types resulted in fertilization and successful fruit set in all the tried combinations. Due to high rate of fruit drop observed during initial stages of fruit development, only 5 to 6 combinations yielded mature fruits.

Muvandan was crossed as female parent with Neelum, Priyur, Vellaikolumban and Banganapalli. In Muvandan× Neelum cross combination there was 100 per cent initial fruit set and after subsequent fruit drop in other stages of development only two fruits reached final maturity (22%). In Muvandan× Priyur combination also there was 100 per cent initial fruit set and at mustard stage it was only 61 per cent and at pea nut stage (52 %) and final retention was 3 per cent only. In Muvandan× Vellaikolumban combination 5 per cent reached final maturity for harvest and further assessment. In Muvandan× Banganapalli combination even though there was 100 per cent initial fruit set further fruit drop during different developmental stages resulted in zero fruit retention at the mature stage.

Three cross combinations involving Neelum as female parent were tried. In Neelum×Vellaikolumban combination, 100 per cent initial fruit set was noted. Mustard stage accounted about 68 per cent fruit set and fruit retention noted at other two stages were 54 per cent, 40 per cent, 20 per cent respectively for the peanut, marble and pre mature stages; the final fruit set was 7 per cent of total flower pollinated. In Neelum×Muvandan combination only 62 per cent set could be noted at the pin head stage itself but further complete drop of set fruits in this stage resulted in zero retention in the final stage. In Neelum× Banganapalli combination fruit retention upto 5 per cent was noted till the pre mature stage. No fruit could be carried to final retention and final evaluation.

**Table 18. Compatibility behaviour of mango during selfing**

| Sl no. | Combination | No. of flowers crossed | Set at Pin head stage | Mustard stage | Pea nut stage | Marble stage | Pre mature stage | Mature stage | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Muvandan× Muvandan | 10 | 2 | 0 | 0 | 0 | 0 | 0 | Incompatible |
| 2 | Banganapalli× Banganapalli | 15 | 0 | 0 | 0 | 0 | 0 | 0 | Incompatible |
| 3 | Priyur× Priyur | 16 | 8 | 0 | 0 | 0 | 0 | 0 | Incompatible |
| 4 | Vellaikolumban × Vellaikolumban | 20 | 0 | 0 | 0 | 0 | 0 | 0 | Incompatible |
| 5 | Alphonso× Alphonso | 14 | 0 | 0 | 0 | 0 | 0 | 0 | Incompatible |
| 6 | Neelum× Neelum | 23 | 1 | 0 | 0 | 0 | 0 | 0 | Incompatible |

**Table 19. Compatibility behaviour of mango varieties during crossing**

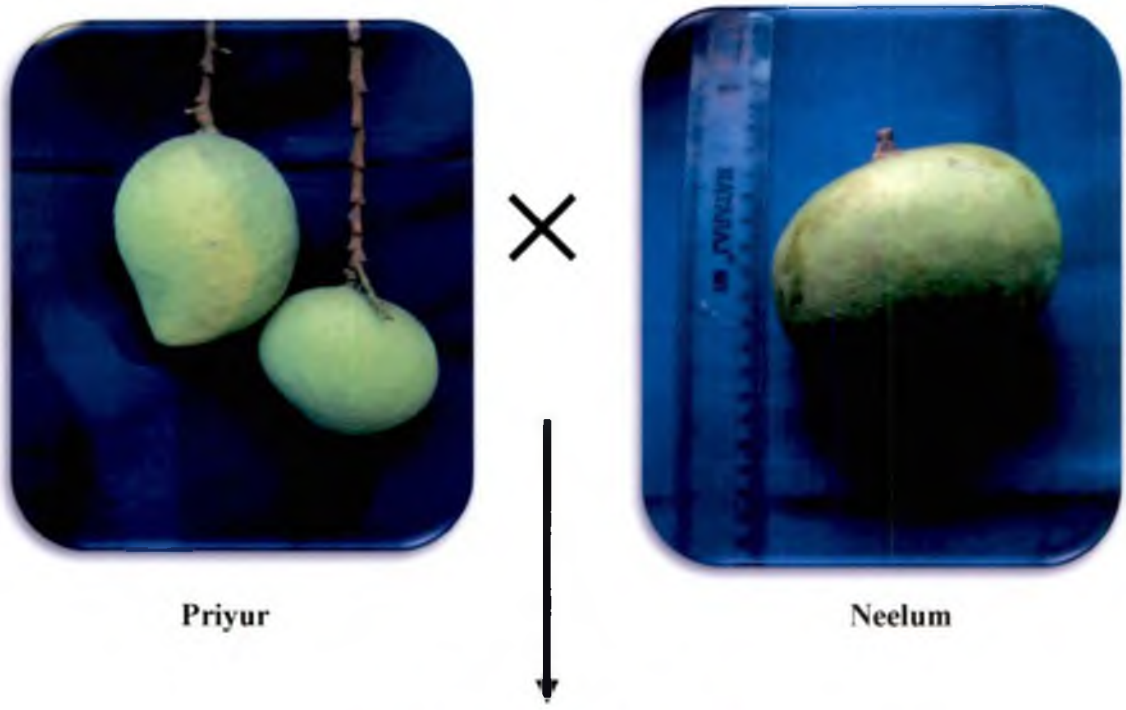
| Sl no. | Combinations | No. of flowers crossed | Fruit retention at different stages (%) | | | | | | Final fruit retention (%) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Initial fruit set | Pin head | Mustard stage | Pea nut stage | Marble stage | Pre mature stage | | |
| 1 | Muvandan× Neelum | 9 | 100 | 78 | 66 | 56 | 33 | 22 | 22 | Compatible |
| 2 | Banganapalli× Neelum | 12 | 100 | 75 | 42 | 25 | 8 | 0 | 0 | Compatible |
| 3 | Priyur× Neelum | 42 | 100 | 71 | 48 | 26 | 12 | 0 | 0 | Compatible |
| 4 | Muvandan× Priyur | 31 | 100 | 61 | 52 | 20 | 7 | 3 | 3 | Compatible |
| 5 | Priyur× Banganapalli | 23 | 100 | 70 | 44 | 30 | 17 | 4 | 4 | Compatible |
| 6 | Neelum× Vellaikolumban | 15 | 100 | 68 | 54 | 40 | 20 | 7 | 7 | Compatible |
| 7 | Priyur× Vellaikolumban | 14 | 100 | 71 | 50 | 21 | 14 | 0 | 0 | Compatible |
| 8 | Banganapalli×Muvandan | 12 | 100 | 33 | 25 | 0 | 0 | 0 | 0 | Compatible |
| 9 | Banganapalli×Vellaikolumban | 8 | 100 | 63 | 50 | 25 | 0 | 0 | 0 | Compatible |
| 10 | Banganapalli× Priyur | 7 | 100 | 58 | 14 | 14 | 14 | 14 | 14 | Compatible |
| 11 | Neelum× Banganapalli | 18 | 100 | 67 | 50 | 28 | 11 | 5 | 0 | Compatible |
| 12 | Neelum×Muvandan | 13 | 100 | 62 | 0 | 0 | 0 | 0 | 0 | Compatible |
| 13 | Muvandan× Vellaikolumban | 20 | 100 | 55 | 40 | 30 | 15 | 10 | 5 | Compatible |
| 14 | Muvandan× Banganapalli | 31 | 100 | 67 | 52 | 26 | 10 | 0 | 0 | Compatible |
| 15 | Vellaikolumban× Alphonso | 15 | 100 | 40 | 20 | 13 | 0 | 0 | 0 | Compatible |
| 16 | Vellaikolumban× Neelum | 8 | 100 | 63 | 25 | 0 | 0 | 0 | 0 | Compatible |
| 17 | Alphonso× Muvandan | 13 | 100 | 23 | 0 | 0 | 0 | 0 | 0 | Compatible |

Cross combinations with Banganapalli as female parent was attempted. Banganapalli× Neelum combination resulted 100 per cent initial fruit set. The fruit set noted in subsequent stages were 75, 42, 25 and 8 per cent in mustard, peanut, marble and pre mature stage respectively and in this combination no fruit was found to reach maturity for further evaluation. In Banganapalli×Vellaikolumban combination also, though the initial fruit set was 100 per cent the subsequent heavy drop during other developmental stages resulted in zero retention at final mature stage. In Banganapalli×Muvandan cross combination also the initial set was cent per cent and only 33 per cent fruit retention could be noted in pin head stage. Further subsequent drop in mustard and pea nut stage resulted in zero retention at the mature stage. In Banganapalli× Priyur combination the initial fruit set was cent per cent but the subsequent drop was to the tune of 42 per cent in pin head as well as mustard stage. Final retention was 14 per cent and only one fruit could be harvested at mature stage for further evaluation.

In combinations involving the variety Priyur as female parent, Priyur× Neelum combination resulted in cent per cent initial fruit set but the subsequent heavy drop at other developmental stages resulted in zero retention for final harvest. In Priyur× Banganapalli combination the initial fruit set was cent per cent but only 4 per cent carried to final maturity. In Priyur× Vellaikolumban combination no fruit was carried to final maturity for evaluation even though the initial fruit set at the pin head stage was 100 per cent.

In cross combinations involving Vellaikolumban as the female parent, (Vellaikolumban× Alphonso, Vellaikolumban× Neelum), the initial fruit set indicating successful fertilization was 100 per cent but due to the subsequent heavy fruit drop during further developmental stages resulted in no fruit carried to final maturity and evaluation.

Only one combination of Alphonso× Muvandan was tried using Alphonso as female parent. In this combination also initial fruit set was 100 per cent but there



Priyur

Neelum

Priyur × Neelum

**Plate 19. Cross between Priyur and Neelum**

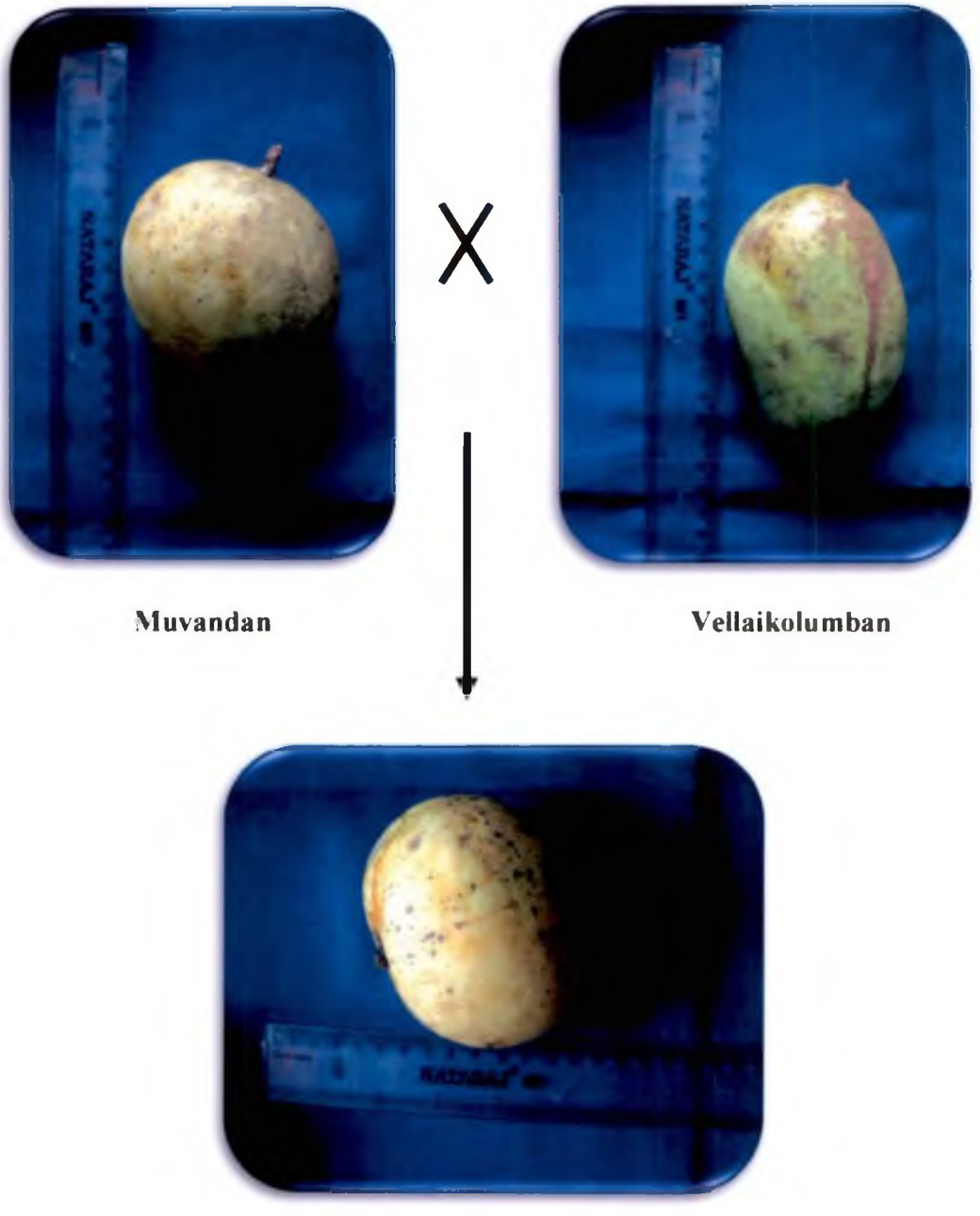
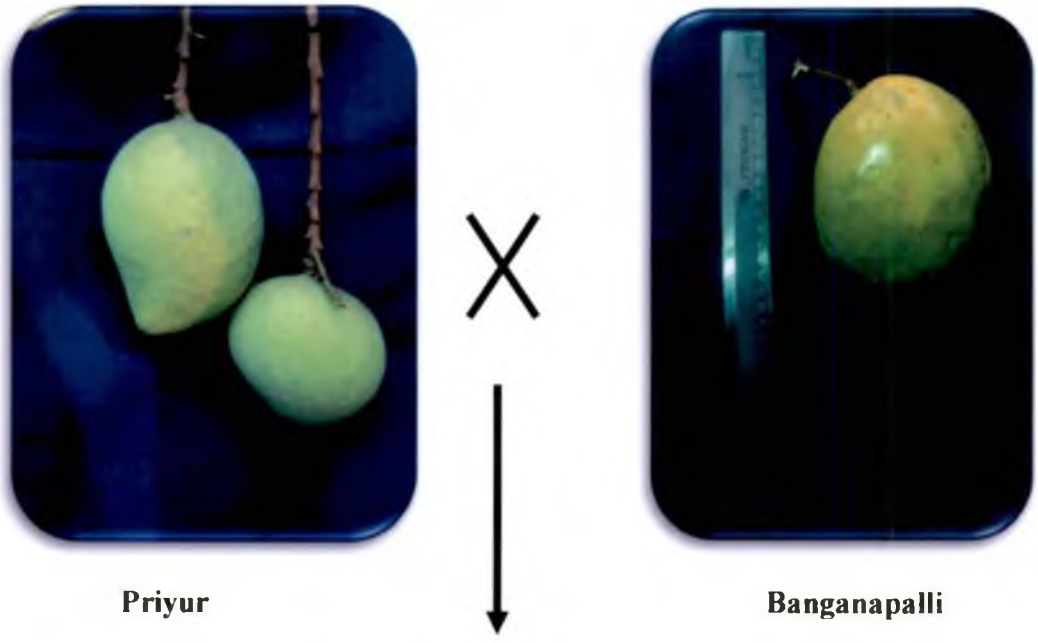



**Plate 20. Cross between Muvandan and Vellaikolumban**

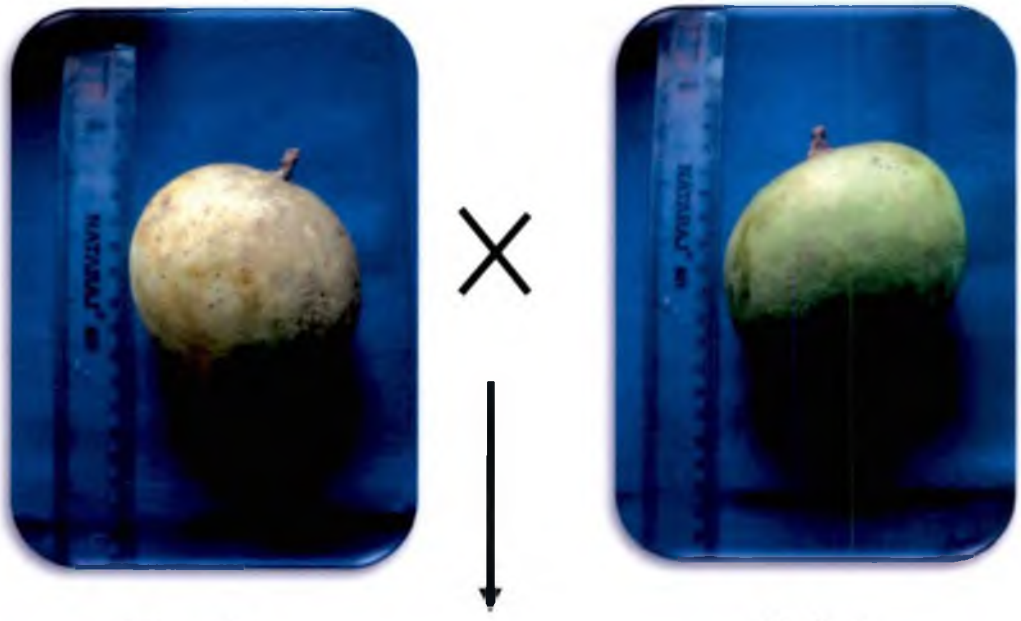


Priyur

Banganapalli

Priyur × Banganapalli

**Plate. 21. Cross between Priyur and Banganapalli**

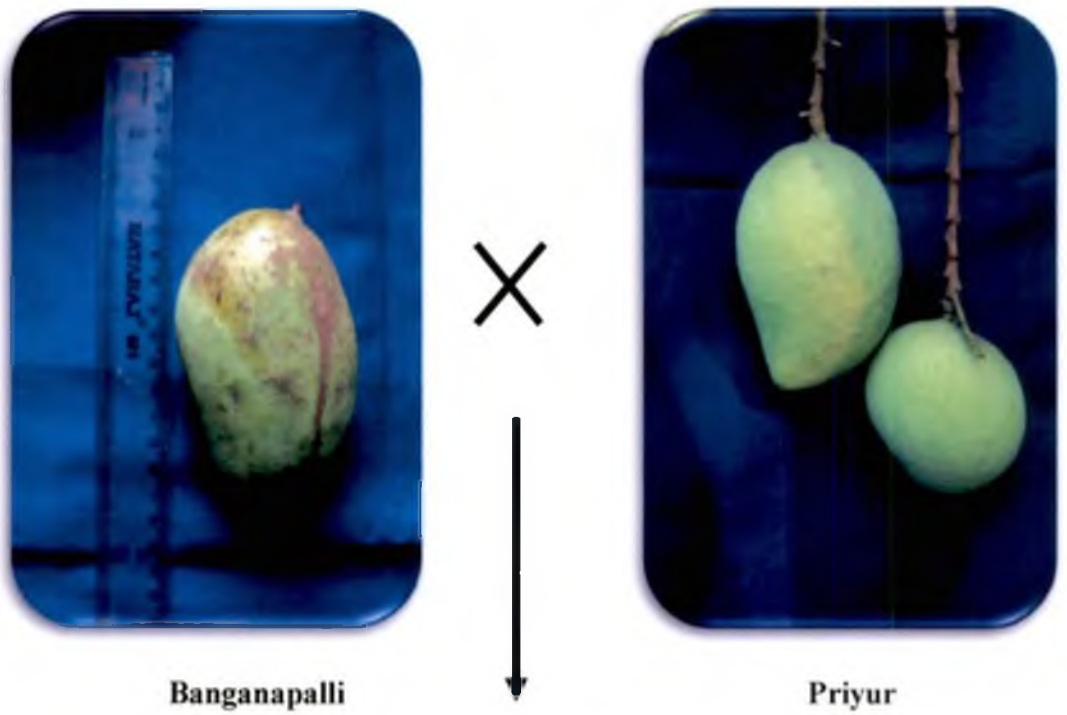


Muvandan

Neelum

Muvandan × Neelum

**Plate.22. Cross between Muvandan and Neelum**



Banganapalli × Priyur

Plate. 23. Cross between Banganapalli and Priyur

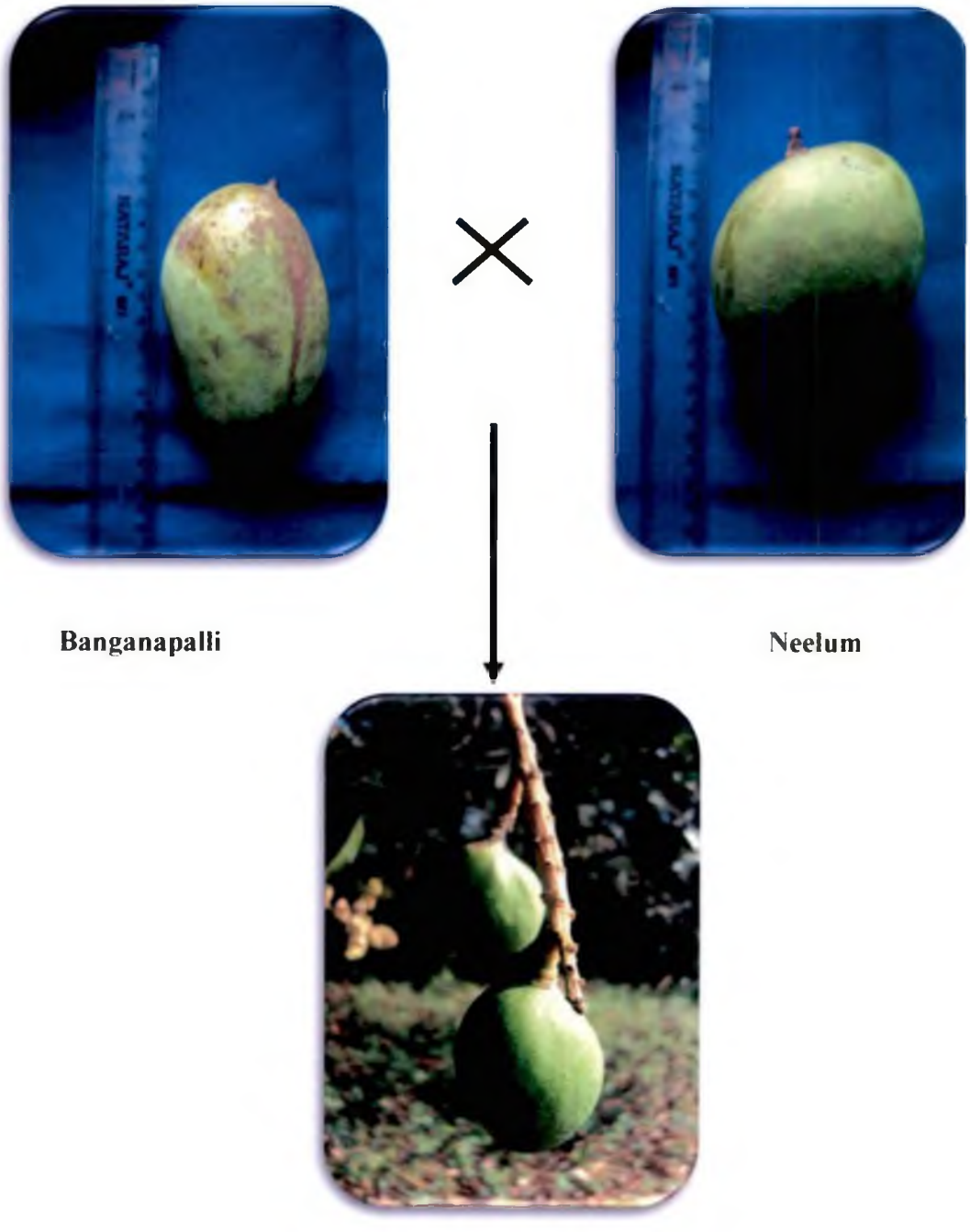



**Plate.24. Cross between Banganapalli and Neelum**

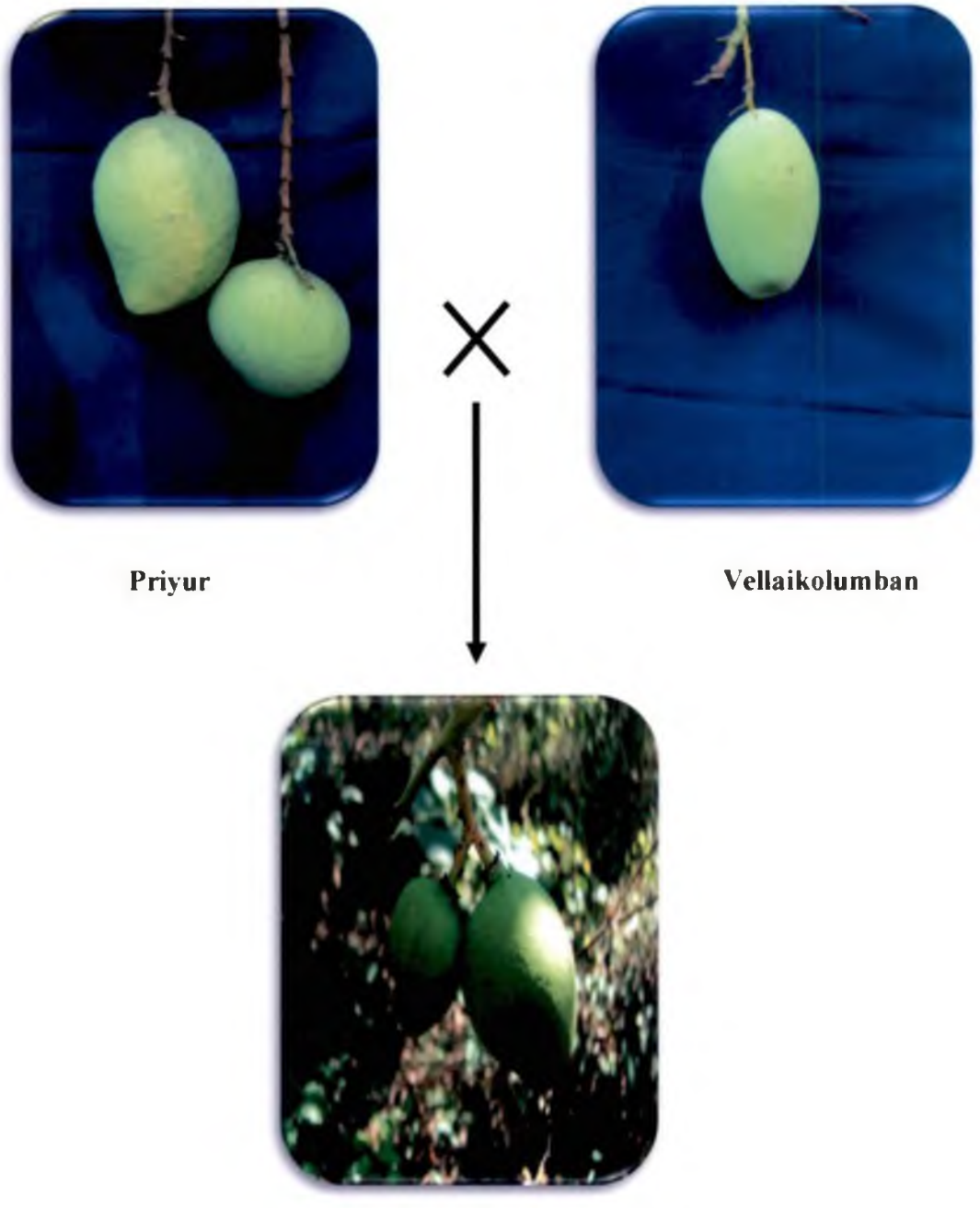



**Plate.25. Cross between Priyur and Vellaikolumban**

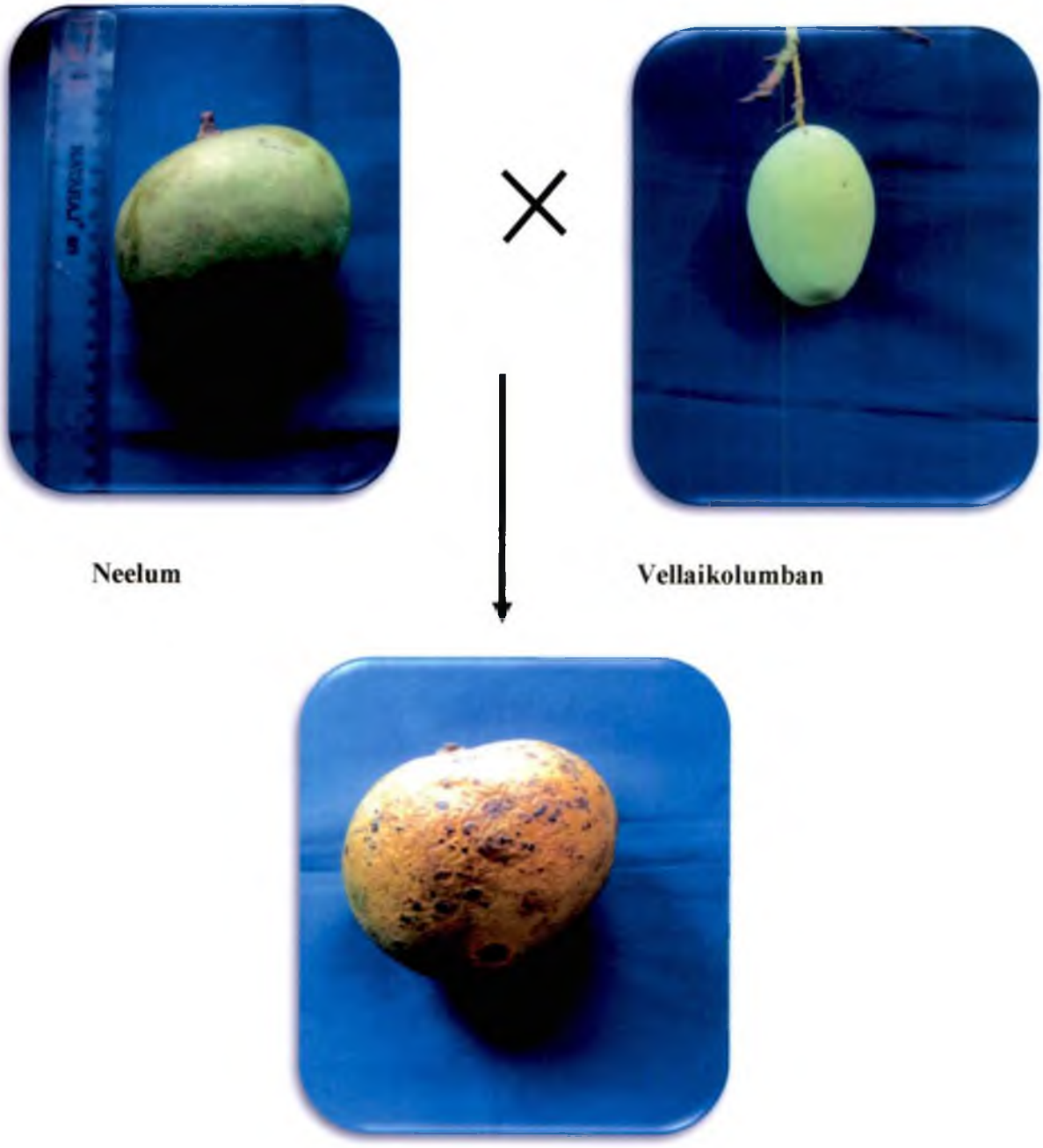
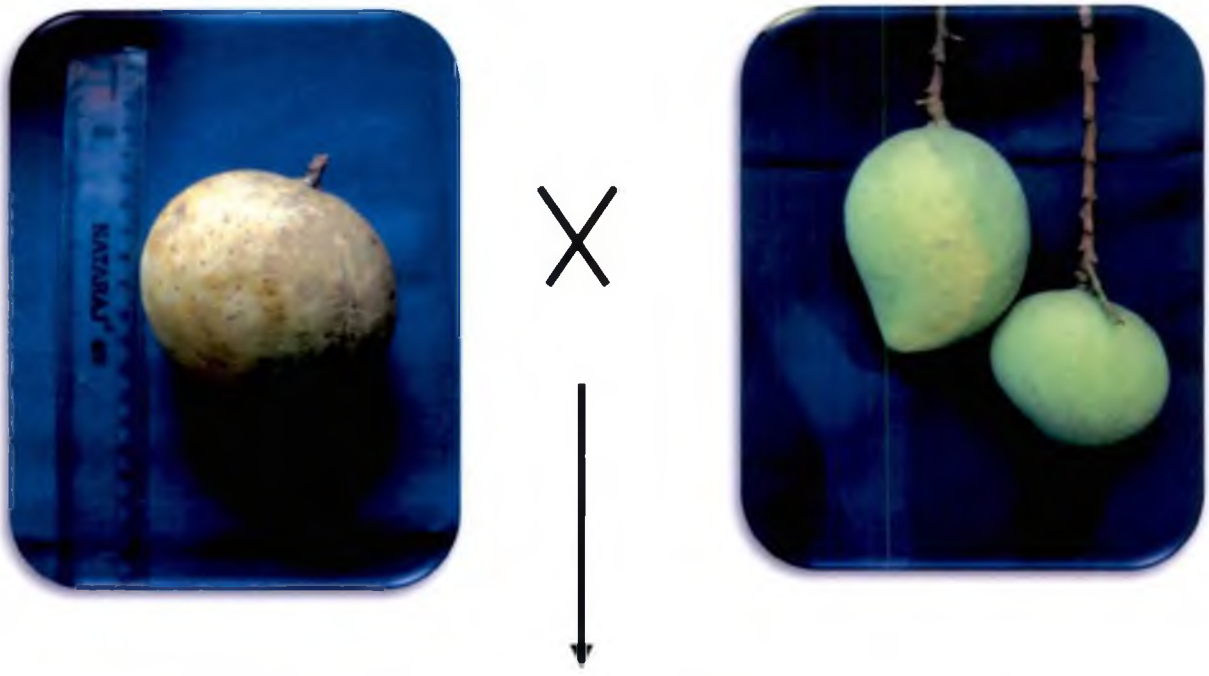



**Plate.26. Cross between Neelum and Vellaikolumban**



Muvandan

Priyur

Muvandan × Priyur

Plate.27. Cross between Muvandan and Priyur

Alphonso

Vellaikolumban

Vellaikolumban× Alphonso

**Plate.28. Cross between Vellaikolumban and Alphonso**

after complete drop of fruits in the initial stages itself resulted in zero retention of fruits to final mature stage and evaluation (Plate. 19 -28).

**4.2.14 Basic evaluation of hybrid seedlings of successful hybrid combinations**

Crossing undertaken in different varietal combinations during the present investigations resulted in successfully evolving four hybrid seedlings for further evaluation (Plate 29). Data on fruit quality evaluation of the parental varieties taken for reference is presented as Appendix VII.

Seed stones extracted from the fruits of successful hybrid crosses were sown in the nursery and observations on time taken for germination, growth at 10 days after emergence and 30 days after were noted and data presented in Table 20.

a.Muvandan × Neelum

b. Priyur × Banganapalli

Plate.29. Seedlings of successful hybrid combinations

c. Muvandan × Vellaikolumban

d. Muvandan × Priyur

**Plate.29. (Contd.) Seedlings of successful hybrid combinations**

**Table 20. Biometric observations of the hybrid seedlings finally available for evaluation**

| Cross combination | Date of sowing | Date of germination | Height (cm) 10 days | Height (cm) 30 days | No. of Leaves (10 days) | No. of leaves (30 days) |
|---|---|---|---|---|---|---|
| Muvandan× Neelum | 22nd May 2011 | 17th June 2011 | 12.50 | 25.90 | 7 | 11 |
| Priyur× Banganapalli | 24th May 2011 | 16th June 2011 | 7.00 | 21.80 | 4 | 17 |
| Muvandan× Vellaikolumban | 26th May 2011 | 13th June 2011 | 6.90 | 20.30 | 5 | 5 |
| Muvandan× Priyur | 29th May 2011 | 19th June 2011 | 7.5 | 26.6 | 5 | 6 |

# *Discussion*

# 5. DISCUSSION

Assessment of the biodiversity status of the local mango types grown in the village homesteads of Kerala and preparing data bases for reference are the primary steps for any location specific varietal improvement attempt in the crop. A breeder should also acquire sound information on the flowering and fruiting characters, pollination and pollen compatibility aspects of such types before initiating the process. It is of much significance in a crop like mango in which a lot of eco regional variations are frequently noted. The present investigations entitled **"Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types"** were taken up in this perspective as a prelude to the original project on **"Hybridization of mango varieties of Kerala"** operated at the department of Pomology and Floriculture, College of Horticulture. Results generated from these investigations are discussed hereunder.

## 5.1 Mango diversity status in Thrissur and Palakkad districts- feedback from the primary assessment of gramapanchayaths

Primary evaluation of mango biodiversity provided much useful information on the status of traditional and other mango types grown in the homesteads of Thrissur and Palakkad districts. Location centered predominance of certain mango types in the homesteads could be noted in Pazhayannur and Vallachira GP's. Commercial mango mono cropping was conspicuously absent. Muvandan was the common variety observed in the homesteads of Pazhayannur and Chandrakaran in Vallachira GP. Priyur and local landraces *viz.*, Tholikaipan and Puliyan were also observed in Pazhayannur , whereas Muvandan, Priyur and local types including Chakiriyan and Columbmanga (Vellaikolumban) were observed in Vallachira GP. Most of the seedling mango trees in the homesteads of both these GP's are 50-60 years old.

In Kollemgode and Muthalamada GP's commercial mango types are dominating in the homesteads than seedling types. Muvandan (White) and Chandrakaran could be noted in backyards of few homesteads of Muthalamada, whereas some unnamed seedling types, Muvandan (green type) etc. in Kollemgode GP.

### 5.1.1 Crop diversity status of the villages selected for final analysis and relative position of mango

Home gardens are the oldest agro ecosystems reported (Soemarowoto, 1987; Hodel et al., 1999; Nair 2001; Trinh et al., 2003); and form an integral component of the traditional farming systems. During the present investigations a homestead based land use practice was largely noted in both the villages (Maruthampadam and Eripadam) with many annual and perennial species planted and maintained around the households. A multi species diversity – characterstic feature of the home gardens as reported by Gautham et al., 2008. – was notable in these gardens especially in Maruthampadam village.

Crop diversity assessment of the two villages chosen for final analysis provided a clear picture on the position occupied by mango among the other crops in the villages. Being an invariable tree component of homestead system, presence of the species was conspicuous in majority of the homesteads. On a biodiversity point of view, even the presence of a single plant will add to the richness of the variety. Accordingly the crop richness value for Maruthampadam village was 15 whereas it was only 10 in Erippadam. But a rapid mono cropping with rubber was notable in Maruthampadam resulting in eradication of all other useful species including the local landraces of mango.

In Erippadam, where crop diversity richness was lower than the former, mango occupied a higher position both in terms of biodiversity richness and the plant

population. Unlike the other village, mango is gradually emerging as commercial crop and the consequent mono cropping pattern is notable.

### 5.1.2 Biodiversity status of traditional and other mango types in the villages – final assessment- utility of farmer participatory tools in identifying the common and rare types

Four cell biodiversity analysis is a participatory tool standardized by Bioversity (Walter and Marja, 2007; Sthapit, 2006) for

1. Identifying unique, common and rare types of crop species cultivated in a community.
2. Documenting the reasons why crop species or the types are in a dynamic stage within the community.
3. Facilitating the identification of the interventions of the crop species or variety within a specific community.

Village level biodiversity assessment of the traditional and other types of mango by FCA and FGD facilitated in identifying the common and rare mango types; their diversity estimates, and the conservation strategies for different groups.

Accordingly, the 'common' types identified in Maruthampadam village included the traditional types *viz.*, Muvandan, Pulimanga and Gomanga which were found in sufficient numbers in many of the homesteads. As such the diversity is at much secure level with respect to these types in this village.

The types under the 'other distinct category' include the local types Vellamanga, Puliyan and other types viz., Nadasala, Neelum, Kilimook and Priyur. An imminent threat to the biodiversity of these types is a meagre possibility, since sufficient plant population is available in different homesteads of the village. Even in this group, conserving the village landraces *viz.*, Vellamanga and Puliyan is more important, since the other types , though categorized in the same group are the commercial types of elsewhere and chances for biodiversity loss is less.

The types grouped under the 'rare' group or the 'vulnerable' group comprised of those landraces and types in the village with few trees and in few households. Such local landraces comprising Karpuramanga, Ganapatimookan, Kilichundan, Chandrakaran, Kottamavu, Sindhuram, Marathakam, Mundappa are the vulnerable ones in which the chances of biodiversity loss is more. Careless cutting of trees for some or other purposes results in loss of valuable germplasm as such from the site.

Except for the variety Muvandan, all the other 'common' types grown in homesteads in Erippadam village are the commercial mango types comprising Alphonso, Banganapalli, Kilichundan, Neelum, Sindhuram, Nadasala. Mango plant population per homestead was much higher in this village than Maruthampadam village. Farmers are gradually turning to commercial mango growing with few choice types preferred in markets than the traditional types.

The types that could be categorized under the "other distinct types" of the village based on the FCA also comprised of a number of commercial types grown elsewhere. Traditional types in this group included Gomanga, Nadanmanga and Kalepad; and the other types being Priyur, Himapasanth, Gudadath and Mulgoa.

The types under the 'rare' or 'vulnerable' group of the village comprised of Chandrakkaran, Kilimook, Mallika and Mundappa which were noted in few homesteads with small plant population. Chandrakaran and Mundappa can be grouped under the traditional types where as the other two types belong to the commercial group.

### 5.1.3 Diversity estimates

Richness and evenness are the key measures of biological diversity (Frankel et al., 1995). Richness refers to the number of types or species regardless of their frequencies and measured using species/ type count for homesteads. The average home garden richness will be the average number of traditional types per

homesteads. Evenness compares the frequencies of different types or species, with low evenness indicating dominance by one or a few types (Jarvis et al., 2008).

Applications of these concepts in the case of traditional types require prior identification of the types at the home garden level. They are simple and useful estimates of diversity and often not given due importance when single crop studies are taken up.

During the present investigations, the biodiversity estimate of mango types in both the villages was worked out from the data collected during the farmers interface. Accordingly, the mango varietal richness of Maruthampadam village was 17; and at homestead level within the range of 1-15. Evenness values were also worked out for the different types and the values were higher in 'common' types and lowest in 'rare and vulnerable' group.

Overall richness value for Erippadam village is 18; and at the homestead level in a range of 1-15. Estimated evenness values were higher in 'common' types and lower in the 'rare' types.

Diversity estimates in terms of richness and evenness values serve as a ready reckoner to identify the status of particular types in the villages. They are simple variables to locate the dominant and rare types and facilitate in chalking out appropriate conservation strategies.

### 5.1. 4. Farm/home garden size -biodiversity relationship

Varietal richness as related to the size of home/ farm gardens in the villages indicated an apparent positive relationship in Erippadam whereas in Maruthampadam it could be noted up to a farm size range of 4-4.5 acres. Such a differential trend may be due to the fact that, Erippadam village being a part of Muthalamada is also in the transitional phase of conventional to commercial mango growing in almost all the homesteads. Mango mono cropping with more commercial types is taking place with the consequent varietal enrichment especially of commercial types. But in

Maruthampadam, mango growing is confined to the immediate periphery surrounding the houses of the farmers and the commercial crop 'rubber' is replacing all the other crops including mango beyond this area.

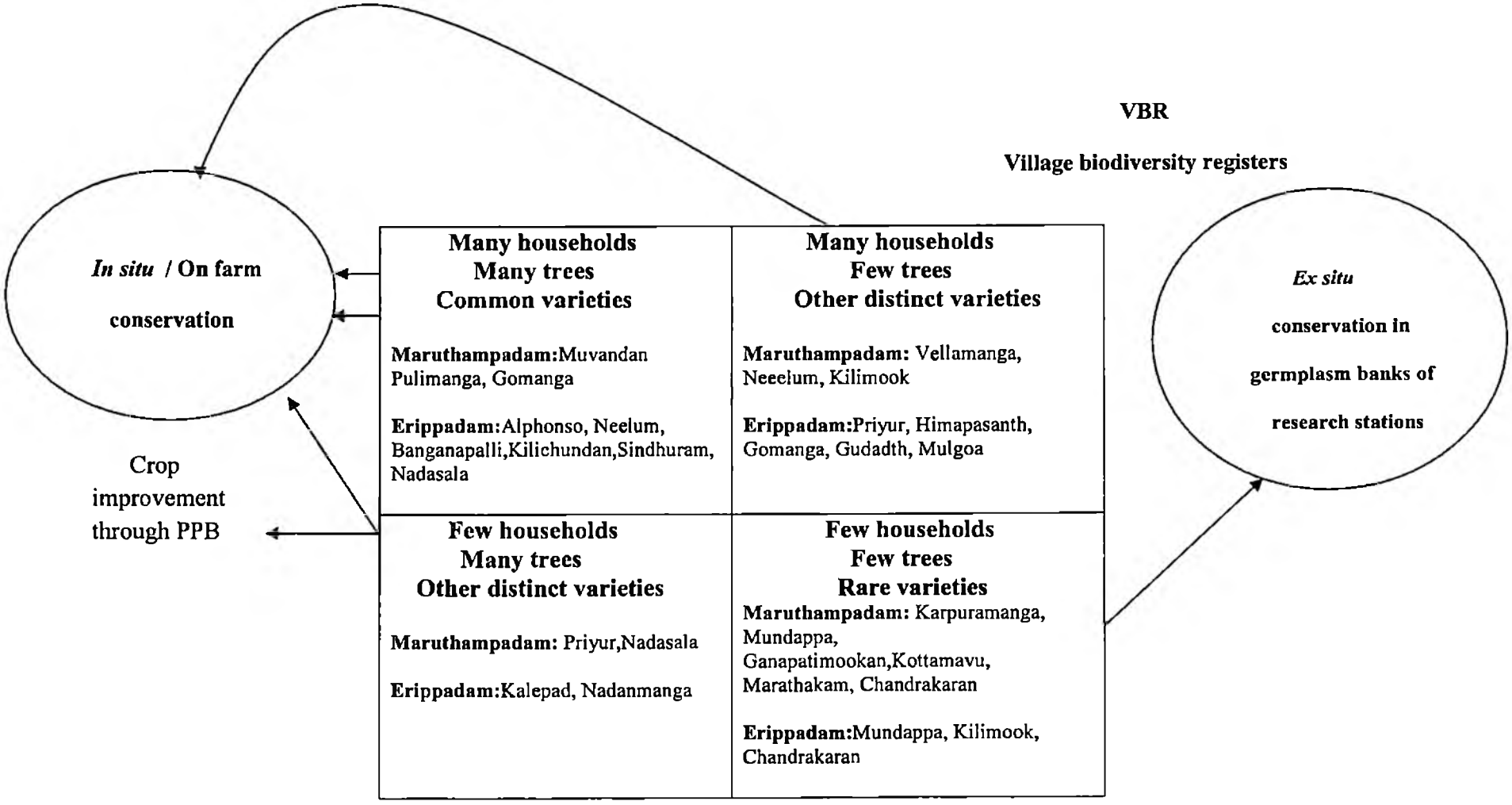
### 5.1.5 Village based management of mango biodiversity -- community awareness for setting development and conservation strategies

Application of 4 cell participatory tool during the investigations not only facilitated in identifying the types but could also categorize them into different groups. Accordingly a conceptual model worked out for mango biodiversity management of these villages is presented in Fig. 27.

Home gardens are characterized by abundance of multipurpose species (Gautham et al., 2008). In many of the cases such gardens often serve as a field where farmers can experiment with, introduce and domesticate useful plant species including many tropical fruit species and provide an ideal location for PPB [Participatory plant breeding). They provide an ideal situation for the 'on farm management' of a wide range of plant genetic resources often not found in other large agro ecosystems (Agnihotri et al., 2004; Sthapit et al., 2004).

Any viable strategy for mango biodiversity management at the village level starts primarily from creating an awareness among the villagers about the importance of conserving the rare traditional/ landraces of the villages in particular and other types in general. Interface conducted with the farmers in the villages and FGD's served to a great extent in this direction. Accordingly the emerging strategy for conserving the 'common' and the 'other distinct' types is essentially the 'on farm' / *in situ* conservation by the farmers themselves. Varietal improvement and enrichment of the types with only few trees in a large number of homesteads through PPB is also a viable proposition. Being more vulnerable to biodiversity loss, conservation of the types included in the 'rare group' is more important. Any unscrupulous cutting of the trees results in complete loss of the biodiversity. Proper awareness alerts to the

**Fig.27. Village based management of mango biodiversity- A conceptual model**



farmers may prevent this to a great extent. But it is more secure by taking steps for an *ex situ* conservation of these types in the germplasm banks of research stations.

Preparation of mango biodiversity registers of the villages and documenting all the available information on the location, age group, flowering and fruit characters especially of the rare types or local landraces is yet another aspect to be considered. It can be taken up as a part of the preparation of village biodiversity registers and serves as reference material for researchers and helps in chalking out strategies for conservation of rare traditional types or landraces of the villages.

### 5.1.6. ITK (Indigenous Traditional Knowledge)

Indigenous knowledge also referred to as traditional or local knowledge is embedded in a community and is unique to a given culture, location of the society. The term refer to the large body of knowledge and skills (Indigenous Knowledge Systems and Practices/ IKSP, Indigenous Technological Knowledge/ ITK) that has been developed outside the formal educational system, and that enables communities to survive (Ray, 1999).

Documenting ITK is extremely important since it gives very useful information on farmer's preferences and uses of indigenous production methods and on the role of growers on conservation which could be used in developing appropriate research and development strategies on the specific fruit tree species.

Along with the participatory biodiversity analysis undertaken in the villages through interface with farmers an attempt was also made to document the indigenous traditional knowledge/ skills practiced by the villagers pertaining to mango at the homesteads.

Farmer participants at Maruthampadm village provided with some useful information on some of the traditional practices still followed in many households of the village. They shared their experiences on some of the traditional processing methods of mango which are of organic and eco friendly nature. They also provided

some indigenous mango recipes. Practice of processing and making delicious products out of mango seed stones [kernals] otherwise not used generally as a food item is worth considerable. A good exposure on the conventional storage vessels was also provided during some household visits.

Discussions held during the interface at Erippadam village did not contribute much in this line.

### 5.2 Reproductive biology of mango types

A sound knowledge on flowering and fruiting characters of the parental types is essential for starting up with hybridization programme in mango. General aspects on flowering and fruiting in *Mangifera indica* L. has been comprehensively studied by different workers in the past. But varietal variations are often noted in this aspect as related to the eco regional changes. It is conspicuous with the popular varieties of other states when grown in the humid tropic situation of Kerala. Not much information is at present available on the pollen characters, compatibility of many of the local types of Kerala which is essential when these local types are involved in hybridization programme. Such aspects were taken into consideration in the present investigations and accordingly, studies on reproductive biology and other aspects were taken up in six popular varieties such as Muvandan, Priyur, Banganapalli, Alphonso, Vellaikolumban and Neelum.

#### 5.2.1 Flowering pattern of mango in Thrissur district of Kerala during 2009-10 and 2010-11

Mango seasons during 2009-10 and 2010-11 in Thrissur district and Kerala as a whole were typically characterized by erratic and delayed flowering resulting in very poor crops.

In Muvandan, Priyur and Alphonso commencement of flowering was noted during the last week of December 2009 and in other varieties such as Vellaikolumban

and Banganapalli ,it just extended upto second week of January 2010 and in Neelum during 2nd week of February. Peak flowering was noted during the 1st and 2nd week of January 2010. In the first three varieties it was during 1st week of February in Vellaikolumban and Banganapalli and in Neelum in 1st week of March. In 2010-11 mango seasons also Muvandan and Alphonso started flowering in last week of December only, and other varieties such as Vellaikolumban, Banganapalli, Neelum during the 1st week of January. The peak blooming period during these seasons was noted during 2nd week to last week in other four varieties. The mean values of intensity of flowering was 11.4 per cent during 2009-10 season where as it was 81.2 per cent in 2010-11 season.

In mango, flowering starts in November or early December in Andhra Pradesh and West coast of India (Gandhi, 1955). Singh (1958) reported that flowering in mango is preceded by the differentiation of flower buds which occurs in October-December depending upon the local climatic conditions.

Gunjate et al. (1977) noted fruit bud differentiation started in August and continued till end of October and flowering starts by December under Konkan conditions. According to Yadav and Singh (1985) the South Indian mango varieties attain physiological status of flowering earlier than North Indian cultivars.

Radha and Nair (2000) reported that mango in Kerala commences flowering by November- December which was supported by Anila (2002) while studying flowering and fruit development in the varieties namely Alphonso, Neelum, Priyur, Kalapady and hybrids Ratna and H-151 under Kerala conditions.

During 2009-10 and 2010-11 seasons the flowering pattern of the mango varieties included for the present investigations showed a great variation from the conventional flowering season of the state. Normally, the flowering commences by November- December in Kerala resulting harvesting of fruits by March – April. On the contrary all the varieties started flowering only during last week of December in both the seasons.

In 2009-10 flowering was not only delayed but it was also poor and resulting in low fruit set and yield. In 2010-11 season flowering was profuse but again delayed resulting in heavy drop of flowers and fruits ultimately leading to poor crop.

Such variation noted in the flowering pattern of the mango during these two seasons can only be explained as related to the variations noted in some of the major climatic elements especially rainfall.

Kerala which is located in the southern part of India enjoys a humid tropical climate in general with an annual rainfall of 307 cm. distributed in two main seasons as June-July (South west monsoon) and October – November (North east monsoon) the mean annual temperature varying from 25.4-31$^0$c.

In 2010 season north east monsoon set in by October 2009. It was active during the month, but more vigorous during November 2009 during which a record rainfall was noted in central Kerala than the previous years. Unexpected rainfall during December 2009 and January 2010 was also recorded.

In 2010-11 period also the north east monsoon was much vigorous during November recording the highest rainfall for the last four years. The season also recorded stray rainfall during December 2010.

A close analysis of this data for the two seasons as related to mango flowering clearly shows the influence of the rainfall pattern in delaying the flowering and causing sparse flowering.

In 2010-11 season the flowering was delayed due to rainfall in December and January but the poor flowering in the previous season made the plants to profuse flowering; but during peak flowering and fruit setting stages the atmosphere was much hotter resulting in heavy drop of flowers and fruits.

It should be presumed that the unexpected variations noted in the rainfall pattern of the northeast monsoon in the state has resulted in breaking the much needed moisture stress conditions for induction of flowering. It also interfered with

the normal low temperature stress during December-January winter period suppressing the stimulus for flower induction and resulting in poor flowering.

Whiley and Schaffer (1997) and Davenport and Nunez Elisea (1997) have clearly indicated that the environmental factors play a great role in bringing about the transition of a dormant bud to vegetative or reproductive growth in mango. Such a transition is presumed to be induced by a fall or rise in the atmospheric temperature or in combination with moisture availability.

Davenport and Nunez- Elisea (1997) further stated that the mangoes grown in the tropical countries rely less on low temperature condition for induction of flowering as in case of trees grown in sub tropical condition. The plant water stress is generally presumed to provide the necessary stimulus for flowering in such situations.

Pongsompoon et al. (1991) observed flowering in field grown mango trees in tropical conditions following six weeks of withholding water. Flowering responses was co-related with the level of stress imposed on the trees. Davenport and Nunez-Elisea (1997) reported increased flowering [85%] after imposing water stress for a period of 12 weeks in mango plants under control conditions whereas it was only 57 per cent in the irrigated plants.

### 5.2.2 Shoot development

Extension growth of the mango stem progressively leads to the formation of a determinate panicle. Basically the three types of shoots based on floral induction described by (Davenport and Nunez- Elisea, 1997) could be noted during these investigations also. They are

Vegetative shoots: New shoots having only leaves and without any inflorescence. The shoots are with zero floral induction

Reproductive shoots: Reproductive shoots are cymose inflorescences producing only flowers and those with full floral induction

Mixed shoots: Such shoots arising in weekly inductive conditions was found to develop both leaves and primary pedunculate inflorescences from the same nodes. The presence of such shoots (< 3%) could be noted in variety Muvandan during 2010-11 crop season.

**5.2.3 Panicle emergence and subsequent events**

Detailed descriptions of the paniculate inflorescences, individual flowers have been reported by many workers previously (Soule, 1985 and Oosthuyse, 1991). Emerging panicles were light green in colour gradually fading into different shades. Inflorescence architecture and other biometric parameters recorded are in conformity with the previous reports in this aspect.

But the varieties exhibited much variation with respect to the full-opening-out time of the panicles. Full opening out of panicle was completed in a short span of 10 days in Alphonso whereas in Muvandan, the duration extended upto 20 days. Priyur also took a lengthy duration of about 18 days where as the other three varieties were on par and completed the process within a fortnight.

Right from the early works on mango flowering by Mukherjee (1953); reported literature is comprehensive on the subject with respect to flowering, sex ratio, fruitset and other aspects. (Singh, 1954; Pimental et al., 1984; Muhammad et al., 2001; Shu, 2009).

Total number of flowers in a panicle and hermaphrodite flower counts exhibit much variation among the varieties under different eco- regional conditions. In the present investigations the varieties exhibited lot of variation with respect to different floral characters. Percentage of bisexual flowers in Banganapalli was lowest (2.1%) where as Vellaikolumban recorded highest with (46.48%). Alphonso recorded 43.13 per cent whereas in Muvandan and Priyur it was 10.18 percent and 27.17 per cent respectively.

Detailed descriptions of paniculate inflorescences (Mallik, 1957; Soule, 1985; Oosthuyse, 1991) and individual flowers (Sturrock, 1966; Pimental et al., 1984) in mango have been published earlier. Observations during the present investigations are in general conforming to these reports except for the total number of flowers produced -a highly variable character.

### 5.2.4 Floral characters

Anthesis, anther dehiscence and related factors in mango are all aspects widely studied earlier (Pimental et al., 1984; Singh 1954; Randhawa and Damodaran, 1961; Singh, 1960). Observations taken during the present course of investigations were mainly for working out the most suitable time for undertaking controlled pollination for hybridization with maximum number of opened bisexual flowers. Observations showed that peak time of flowering in these types under observation was between 8-10 am. Anthers were found to dehisce in about 30 minutes after flower opening on clear sunny days.

Earlier reports showed stigma being receptive from 12 hours before flower opening and continuing during day of opening and 48 hours further. (Sen, 1946; Spencer and Kennard, 1955, Randhwa and Damodaran, 1961, Gunjate et al., 1983; Robbertse et al., 1994). They also reported that the receptivity was maximum within three hours of opening of flowers. Observations during the present investigations are in conformity with these reports.

### 5.2.5 Pollen studies

Pollen characters in mango are a widely studied aspect and very comprehensive. (Mukherjee, 1950; Randhwa and Damodaran, 1961 and Singh, 1961). Results from the present investigations are in general agreement with the these earlier reports. In the present studies, pollen fertility and pollen production was maximum in all the varieties during January 2011., but they were significantly lower

during the month of March 2011.When the weather data for the period was analysed it was noted that such variations showing an apparent relationship with certain climatic variables especially temperature and the values being lower during the former month.

Earlier reports show that the percentage of viable pollen is generally greater during warm weather and cool situations promoting production of abnormal non viable pollen (Shu et al., 1989 and Gunjate et al., 1983, Issrakilraila et al., 1992 and Dag et al., 1999). Observations from the present course of investigations are showing a deviation in this aspect from the earlier reports and need some further confirmatory studies.

Standardisation of optimal storage conditions for mango pollen so as to facilitate transfer of pollen from other regions and even from other states was recommended by Iyer and Schnell (1991). Accordingly pollen storage studies were undertaken during these investigations. Results showed that mango pollen can be stored without much loss in viability for about 72 hours if stored under refrigerated condition at $4^0$C.

### 5.2.6 Compatibility studies

Pollen compatibility within and between cultivars has been widely investigated in mango (Young, 1942, Randhawa and Damodaran, 1961, Gunjate et al., 1983, Robbertese et al., 1994). Complete or partial self compatibility has been reported in few cultivars (Mukherjee et al., 1961; Sharma and Singh, 1970; Ram et al; 1976; Robbertese et al., 1993).

In the present investigations controlled pollination was taken up among the different varieties in different possible combinations for a primary assessment of pollen compatibility element among these varieties. Selfing failed in setting of fruits and apparently indicating a self incompatibility element. Further confirmatory

observations employing fluorescent microscopy techniques for tracing stylar pollen tube growth are essential for arriving at final conclusions.

Crossing undertaken during the studies in different varietal combinations resulted in setting of fruits. Though the fruit drop was heavy at different stages of development, there are four successful mango hybrid progenies evolved finally from the combinations of- [Muvandan × Neelum; Muvandan × Priyur; Priyur × Banganapalli; Muvandan × Vellaikolumban]; and available for further performance evaluation.

# *Summary*

## 6. SUMMARY

The current set of investigations entitled "Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types" were undertaken at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2009-2011.These studies - a part of the departmental project on 'Hybridisation of mango varieties of Kerala'- envisaged an assessment of the biodiversity status of traditional mango types in selected villages of Thrissur and Palakkad districts by applying farmer participatory tools and studying the floral biology, pollen characters, pollination, and pollen compatibility factors in six mango types commonly grown in the homesteads with a breeder's perspective.

Salient results of the studies are presented below in a summarized format under the two major items of investigations taken up in the project.

**Component I: Biodiversity analysis of traditional mango types**

1. The primary survey for biodiversity assessment of mango types by snowball sampling method was conducted in Vallachira and Pazhayannur GPs of Thrissur district; and Kollemgode and Muthalamada GP in Palakkad district.

2. Survey indicated Muvandan as the dominating traditional variety in Pazhayannur ; and Chandrakkaran in Vallachira GP of Thrissur district. In the homesteads of Muthalamada and Kollemgode GPs of Palakkad district, Muvandan(white), Priyur, Chandrakaran and some unnamed landraces were the dominating ones .

3. Maruthampadam village in Pazhayannur GP of Thrissur and Erippadam in Muthalamada GP of Palakkad district were chosen for the final village level biodiversity assessment by applying farmer participatory tools.

4. Village level analysis was carried out by organizing farmer's interface, focal group discussions and applying 4 cell participatory techniques.

5. Discussions revealed that Maruthampadam village is richer in terms of crop diversity than Erippadam.

6. The 4- cell biodiversity analysis identified the 'common' and 'rare' mango types of the villages. Muvandan, Pulimanga and Gomanga are the common types in Maruthampadam village while the rare types included Karpuramanga, Ganapatimookan, Kilichundan, Chandrakaran, Kottamavu, Sindhuram, Marathakam and Mundappa.

7. Common mango types in Erippadam are Alphonso, Banganapalli, Kilichundan, Neelum, Sindhuram, Muvandan, Nadasala and the rare types being Chandrakaran, Kilimook, Mallika and Mundappa.

8. Diversity estimates in terms of richness and evenness values were worked out for the different mango types in both the villages.

9. Maruthampadam village recorded a varietal richness value of 17 with a range of 1-13 at homestead level while in Erippadam village the overall richness was 18 with a range of 1-15 at homestead level.

10. Muvandan recorded the highest evenness value (0.9) where as zero evenness was noted for the 'rare and vulnerable' types like Ganapatimookan, Kottamavu, Kilichundan, Marathakam, Sindhuram and Mundappa in Maruthampadam village.

11. Evenness values were lower in rare types like Mulgoa, Chandrakkaran, Mallika and Mundappa in Erippadam and it was higher in common types *viz.* Alphonso, Neelum, Sindhuram, Kilichundan etc.

12. Based on the inputs from the participatory analysis a conceptual model elucidating the strategies for conserving the biodiversity of mango types of these villages was worked out.

13. Varietal richness as related to size of gardens indicated a positive relationship in Erippadam while it was only up to a farm / homestead size range of 4-4.5 acres in Maruthampadam village.

14. Indigenous traditional knowledge on processing of mango fruits and product diversification was documented from the villagers in Maruthampadam but no such contribution evolved at Erippadam village.

**Component II- Studies on basic reproductive biology of selected mango types**

1. Studies were undertaken in six mango varieties viz., Muvandan, Neelum, Priyur, Vellaikolumban, Banganapalli and Alphonso.

2. Mango crop seasons during 2009-10 and 2010-11 in Thrissur district and Kerala as a whole were typically characterized by erratic and delayed flowering resulting in very poor crops.

3. In both the seasons, flowering pattern of the varieties exhibited much variation from the conventional mango flowering season of the state. In 2009-2010, all the varieties started flowering during the last week of December and continued till the third week of March 2010 while in 2010-2011, trees started flowering during last week of December and continued upto 2nd week of January 2011. An abnormal shift in the pattern of north east monsoon( both in terms of quantity and duration) was noted during 2009-10 and 2010-11 seasons and drastically meddling with the normal flowering process in mango plants.

4. Peak time of flower opening was noted between 7.30 am – 11 am in all the varieties.

5. Maximum anther dehiscence was noted in between 8.30 am -12 on the day of anthesis.

6. Maximum stigma receptivity was noted on the day of anthesis.

7. Time taken for complete opening of panicles was longer in Muvandan (19 days) and Priyur (17 days) where as it was shorter in other types.

8. A synchronized opening of male and hermaphrodite flowers was noted in Neelum, Priyur, Alphonso and Vellaikolumban while in Banganapalli,flower opening started with a pure male phase and thereafter a entering mixed phase.

9. Inflorescence rachis of Muvandan was dark red colour where as in Neelum and Alphonso it was light red. Light green coloured inflorescence rachis was observed in Banganapalli and Vellaikolumban while in Priyur it was with light green with red tinges.

10. The size of inflorescence was highest in Alphonso (length - 34.0 cm and breadth - 22.8 cm); and the lowest in Neelum (26.2 cm and 18.2 cm).

11. Intensity of flowering per unit area of tree canopy was highest in Alphonso where as it was lowest in variety Vellaikolumban.

12. Highest percentage of hermaphrodite flowers was recorded in Vellaikolumban (46.38 %) while it was lowest in Banganapalli (0.02%).

13. Pollen shape was round in Neelum, Priyur, Alphonso and Vellaikolumban where as oval and oblong shaped pollen was noted in Banganapalli and Muvandan respectively.

14. The pollen size ranged in between 27.29µm – 33.34µm, and the largest pollen noted in variety Muvandan.

15. Pollen fertility noted during two months in 2011 showed significant variations. It was in the range of 80.70 -93.52 per cent in January and decreased to 40.70-60.00 percent in March 2011.

16. The pollen production per anther in the months of January 2011 and March 2011 were compared and highest pollen production was noted in Vellaikolumban and Banganapalli (500) in January while in Priyur, Neelum, Alphonso, and Muvandan, the values were 400, 300, 250 and 250 respectively which declined to 188, 218, 70, 89, 223, 198 in Vellaikolumban, Banganapalli, Priyur, Neelum, Alphonso, Muvandan respectively in March 2011.

17. Storing the pollen under refrigerated conditions helped in retaining 59.0 per cent viability for 72 hours where as it was 41.3 per cent when kept over calcium chloride and in refrigerator.

18. Mango pollen failed to germinate when tried under *in vitro* conditions during the present studies.

19. Self pollination among the varieties failed in setting of fruits; but the probable involvement of incompatibility and related factors has to be confirmed by flourochromatic methods.

20. Cross pollination among the varieties resulted in successful fruit set and hence indicating the compatible nature. Due to the high rate of fruit drop during initial stages of fruit development many cross combinations did not succeed in retaining fruits to full maturity.

21. Ultimately four successful hybrid progenies obtained from the cross combinations of Muvandan×Neelum, Priyur×Banganapalli, Muvandan×Vellaikolumban and Muvandan×Priyur are available for further performance evaluation in the field.

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*Originals not seen

# *Appendices*

APPENDIX I

**INDICATORS/INFORMATION REQUIRED FOR SITE SELECTION IN THRISSUR**

Tick the correct choice where multiple option(s) are available

| Sl. No. | Parameter | Village 1 | Village 2 |
|---|---|---|---|
| 1 | Name of the village/ District/State | Pazhayannur/ Thrissur / Kerala | Vallachira/ Thrissur / Kerala |
| 2 | Number of seedling types | 5-6 based on first preliminary survey | 7-8 based on first preliminary survey |
| 3 | Number of commercial varieties | 6 | 2-3 |
| 4 | Number of households | 30 | 30 |
| 5 | Number of households with mango/Garcinia/Citrus | Almost every homestead is having one or two seedling\graft mangoes .Sampling is restricted to onlythose with conspicuous diversity | Almost every homestead is having one or two seedling\graft mangoes .Sampling is restricted to onlythose with conspicuous diversity |
| 6 | Varieties in commercial orchards ** | Muvandan[green], Priyur & unnamed local seedling pickling varieties wih vernacular names like Puliyan,Tholikaipan etc. | Chandrakaran, Muvandan,Priyor. |
| 7 | Varieties in backyards/homesteads | Muvandan, Priyur & unnamed local seedling pickling varieties with vernacular names like Puliyan,Tholikaipan etc | Pickling varieties, Tholikaiapan, Priyor, Many unnamed pickling tand juicy types with vernacular names.like chakiriyan,columb manga etc |
| 8 | Livelihood related issues with varieties | a) Fruit selling (in the orchard)<br>b) Mango Traders (after purchase from farmer)<br>c) Orchard Labourers<br>d) Transporter<br>e) Home scale processor<br>f) Farmers/ Farm labourers & other profession | a)Fruit selling (in the orchard)<br>b)Mango Traders (after purchase from farmer)<br>c)Orchard Labourers<br>d)Transporter<br>e)Home scale processor<br>f)Farmers/ Farm labourers & other profession |

APPENDIX I

| | | | |
|---|---|---|---|
| **9** | **Marketing** | | |
| 9.1 | Nearest markets and distance | Pazhayannur- 10 km, Chelakkara-15 km | Pudukkad- 5 km,Cherpu-12 km |
| 9.2 | Produce sent to market and selling channel | a) Direct<br>b) Through commission agent<br>c) Contractor<br>d) Processors | a)Direct<br>b)Through commission agent<br>c)Contractor<br>d)Processors |
| 9.3 | Type of packaging material used and availability | a) Wooden boxes,<br>b) Bamboo basket,<br>c) Open trucks/ trolley/tempo<br>d) Cardboard boxes<br>e) Any other may be mentioned<br>f) Gunny bags | a)Wooden boxes,<br>b)Bamboo basket,<br>c)Open trucks/ trolley/tempo<br>d)Cardboard boxes<br>e) Any other may be mentioned<br>f)Gunny bags |
| 9.4 | Transportation and accessibility to markets | a) Bicycle,<br>b) Open trucks<br>c) Trolley/tempo,<br>d) Tonga,<br>e) Bullock Cart,<br>f) Own vehicle<br>g) Any other | a)Bicycle,<br>b)Open trucks<br>c)Trolley/tempo,<br>d)Tonga,<br>e)Bullock Cart,<br>f)Own vehicle<br>g)Any other |
| 9.5 | Scope of selling fresh fruits in nearest market | a) Good<br>b) Medium<br>c) Less | a)Good<br>b)Medium<br>c)Less |

APPENDIX I

| | | | |
|---|---|---|---|
| 9.6 | Name of the distant market | Thrissur | Thrissur |
| 9.7 | Possibility of getting better prices at distant markets (distance and name) | a) High<br>b) Medium<br>c) Low | a)High<br>b)Medium<br>c)Low |
| 9.8 | Availability and accessibility of market | a) High<br>b) Medium<br>c) Low | a)High<br>b)Medium<br>c)Low |
| **10** | **Processing** | | |
| 10.1 | Processing capacity | a) High<br>b) Medium<br>c) Low | a)High<br>b)Medium<br>c)Low |
| 10.2 | Product locally made from the crops | a) Pickle,<br>b) Chutney,<br>c) Jam,<br>d) Leather<br>e) Drink,<br>f) Pulp,<br>g) Squash,<br>h) Amchoor<br>i) Any other product of the village | a)Pickle,<br>b)Chutney,<br>c)Jam,<br>d)Leather<br>e)Drink,<br>f)Pulp,<br>g)Squash,<br>h)Amchoor<br>i)Any other product of the village |
| 10.3 | Commercial exploitation of the products (sold in the market) | a) Pickle<br>b) Amchoor | a)Pickle<br>b)Amchoor |
| 10.4 | Whether processing factories exists or not in nearby areas | Yes/no<br>Commercial\homescale pickling units at Chelakkara,a nearby panchayath | Yes/no<br>Home scale women entreprenors active in and around mainly in pickling .kannimanga,kadumanga etc |

| | | | |
|---|---|---|---|
| 10.5 | If so, difficulties in selling produce to them and linkages | a) Transportation<br>b) Low cost by processor<br>c) Low volume of produce<br>d) Rejection of produce<br>e) Exploitation<br>f) Price fluctuation<br>g) Any other | a)Transportation<br>b)Low cost by processor<br>c)Low volume of produce<br>d)Rejection of produce<br>e)Exploitation<br>f)Price fluctuation<br>g)Any other |
| 10.6 | Have they tried commercialization of products? | Yes/no | Yes/no |
| 10.7 | If yes, list them | a) Pulp<br>b) Pickle<br>c) Amchoor | a)Pulp<br>b)Pickle<br>c)Amchoor |
| 10.8 | Whether farmers are interested in entrepreneurship as processor | Yes/no | Yes/no |
| 10.9 | If no, the reasons/constraints | a) Lack of know how<br>b) Poor quality of products<br>c) Low value of products<br>d) Competition<br>e) Remote area<br>f) Varieties unsuitable<br>g) Better price for fresh fruit<br>h) Financial constraints<br>i) Literacy constraints<br>j) If any other | a)Lack of know how<br>b)Poor quality of products<br>c)Low value of products<br>d)Competition<br>e)Remote area<br>f)Varieties unsuitable<br>g)Better price for fresh fruit<br>h)Financial constraints<br>i)Literacy constraints<br>j)If any other |
| **11** | **Yield** | | |
| 11.1 | Give average yield per tree for | 50-60 kg | 30-40 kg |

APPENDIX I

| | | | |
|---|---|---|---|
| | representative varieties of village | | |
| 11.2 | Average yield per tree (seedling types) | | 30 kg |
| 11.3 | Variation in yield –give high/medium/low yielding years | High-2008.09;very low-2009.10 | High-2008.09;very low-2009.10 |
| 11.4 | Causes for high/medium/low yields-if causes are known, describe or elucidate<br>(Tick the options) | a) Favourable condition or less/no incidence of weather hopper/powdery mildew or any disease.<br>b)Rains/Drought/Diseases/pests/cyclone /storm/temperature (high or low/) untimely flowering | a) Favourable weather condition or less/no incidence of hopper/powdery mildew or any disease.<br>b)Rains/Drought/Diseases/pests/cyclone/storm/termperature(high or low/) untimely flowering |
| **12** | **Family involvement** | | |
| 12.1 | Whether family members are involved as labourers in orchard operations? | Yes/no (to a great extend) | Yes/no ( to an extend) |
| 12.2 | If yes, family contribution to labour (average man days in a year for 5 representative families) | 150 days | 150 days |
| **13** | **Labour** | | |
| 13.1 | Whether labourers are hired for orchard operations | Yes /no | Yes /no Maintainance accomplished along with other crop in homestead/ backyard |
| 13.2 | If yes, average number of man days per year | 100 days | 100 days |
| **14** | **Miscellaneous information** | | |
| 14.1 | Average per capita income at | 20000 | 18000 |

APPENDIX I

| | | | |
|---|---|---|---|
| | panchayat or block level | | |
| 14.2 | Availability of social activity groups | Yes/no | Yes/no |
| 14.3 | If yes, mention the groups and activities | a) Self help group<br>b) Women self help groups<br>c) Growers association<br>d) Panchayat level arrangements<br>e) Any other | a)Self help group<br>b)Women self help group<br>c)Growers association<br>d)Panchayat level arrangements<br>e)Any other |
| 14.4 | Availability of training facilities of potential capacity building centres | a) State Horticulture farms<br>b) Horticulture institutes<br>c) KVKS<br>d) Agriculture /horticulture departments<br>e) NGOs<br>f) Any other Private or Public advisory services | a)State Horticulture farms<br>b)Horticulture institutes<br>c)KVKS<br>d)Agriculture /horticulture departments<br>e)NGOs<br>f)Any other Private or Public advisory services |

**** predominantly homestead mangoes .**

*** Snow ball sampling technique was resorted to for locating representative homesteads/household with appreciable variatel diversity of seedling types.**

*** Since the flowering of mango crop throughout the two districts and state is very sparse and erratic (5-10% only) during the year 2009 due to untimely showers data base related with fruiting parameters is very much limited and to be gathered later only.**

## APPENDIX II

### INDICATORS/INFORMATION REQUIRED FOR SITE SELECTION IN PALAKKAD

Tick the correct choice where multiple option(s) are available

| Sl. No. | Parameter | Village 1 | Village 2 |
|---|---|---|---|
| 1 | Name of the village/ District/State | Kollemgode/ Palakkad / Kerala | Mudalamada/ Palakkad / Kerala |
| 2 | Number of seedling types | 6-8 based on first preliminary survey | 3-4 based on first preliminary survey |
| 3 | Number of commercial varieties | 5-6 | 6-7 |
| 4 | Number of households | 30 | 30 |
| 5 | Number of households with mango/Garcinia/Citrus | Almost every homestead is having one or two seedling\graft mangoes. Sampling is restricted to only house with conspicuous diversity | This panchayath is the formost commercial mango growing tract of Kerala unlike other parts where homestead cultivation is the way here it is taken up as a very remunerative enterprise due to congenial climate conditions. |
| 6 | Varieties in commercial orchards | Kilimukh, Swarnarekha, Muloga, Neelum, Gundumanga | Sinduram, Himayuddin, Banganapalli, Alphanso, Rumania, Himampasand, Kalepad |
| 7 | Varieties in backyards | Pickling mangoes & unnamed seedling types | White Muvandan, Priyor, Chandrakaran |
| 8 | Livelihood related issues with varieties | a) Fruit selling (in the orchard)<br>b) Mango Traders (after purchase from farmer)<br>c) Orchard Labourers<br>d) Transporter<br>e) Home scale processor | a)Fruit selling (in the orchard)<br>b)Mango Traders (after purchase from farmer)<br>c)Orchard Labourers<br>d)Transporter<br>e)Home scale processor |
| **9** | **Marketing** | | |
| 9.1 | Nearest markets and distance | Palakkad- 50 Km, Pollachi- 20Km | Palakkad- 50 Km, Pollachi- 20Km |

## APPENDIX II

| | | | |
|---|---|---|---|
| 9.2 | Produce sent to market and selling channel | a) Direct<br>b) Through commission agent<br>c) Contractor<br>d) Processors | a)Direct<br>b)Through commission agent<br>c)Contractor<br>d)Processors |
| 9.3 | Type of packaging material used and availability | a) Wooden boxes,<br>b) Bamboo basket,<br>c) Open trucks/ trolley/tempo<br>d) Cardboard boxes<br>e) Any other may be mentioned<br>f) Gunny bags stuffed with green mango leaves on the top | a)Wooden boxes<br>b)Bamboo basket<br>c)Open trucks/ trolley/tempo<br>d)Cardboard boxes<br>e) Any other may be mentioned |
| 9.4 | Transportation and accessibility to markets | a) Bicycle<br>b) Open trucks<br>c) Trolley/tempo<br>d) Tonga<br>e) Bullock Cart<br>f) Own vehicle<br>g) Any other | a)Bicycle<br>b)Open trucks<br>c)Trolley/tempo<br>d)Tonga<br>e)Bullock Cart<br>f)Own vehicle<br>g)Any other |
| 9.5 | Scope of selling fresh fruits in nearest market | a) Good<br>b) Medium<br>c) Less | a)Good<br>b)Medium<br>c)Less |
| 9.6 | Name of the distant market | New Delhi, Kolkata, Mumbai | New Delhi, Kolkata, Mumbai |
| 9.7 | Possibility of getting better prices at distant markets (distance and name) | a) High<br>b) Medium<br>c) Low | a)High<br>b)Medium<br>c)Low |
| 9.8 | Availability and accessibility of | a) High | a)High |

## APPENDIX II

| | | | |
|---|---|---|---|
| | market | b) Medium<br>c) Low | b)Medium<br>c)Low |
| **10** | **Processing** | | |
| 10.1 | Processing capacity | a) High<br>b) Medium<br>c) Low | a)High<br>b)Medium<br>c)Low |
| 10.2 | Product locally made from the crops | a) Pickle<br>b) Chutney<br>c) Jam<br>d) Leather<br>e) Drink<br>f) Pulp<br>g) Squash<br>h) Amchoor<br>i) Any other product of the village | a)Pickle<br>b)Chutney<br>c)Jam<br>d)Leather<br>e)Drink<br>f)Pulp<br>g)Squash<br>h)Amchoor<br>i)Any other product of the village |
| 10.3 | Commercial exploitation of the products (sold in the market) | a) Pickle<br>b) Amchoor | a)Pickle<br>b)Amchoor |
| 10.4 | Whether processing factories exists or not in nearby areas | Yes/no | Yes/no |
| 10.5 | If so, difficulties in selling produce to them and linkages | a) Transportation<br>b) Low cost by processor<br>c) Low volume of produce<br>d) Rejection of produce<br>e) Exploitation<br>f) Price fluctuation<br>g) Any other | a)Transportation<br>b)Low cost by processor<br>c)Low volume of produce<br>d)Rejection of produce<br>e)Exploitation<br>f)Price fluctuation<br>g)Any other |
| 10.6 | Have they tried commercialization of products? | Yes/no | Yes/no |

## APPENDIX II

| | | | |
|---|---|---|---|
| 10.7 | If yes, list them | a) Pulp<br>b) Pickle<br>c) Amchoor | a)Pulp<br>b)Pickle<br>c)Amchoor |
| 10.8 | Whether farmers are interested in entrepreneurship as processor | Yes/no | Yes/no |
| 10.9 | If no, the reasons/constraints | a) Lack of know how<br>b) Poor quality of products<br>c) Low value of products<br>d) Competition<br>e) Remote area<br>f) Varieties unsuitable<br>g) Better price for fresh fruit<br>h) Financial constraints<br>i) Literacy constraints<br>j) If any other | a)Lack of know how<br>b)Poor quality of products<br>c)Low value of products<br>d)Competition<br>e)Remote area<br>f)Varieties unsuitable<br>g)Better price for fresh fruit<br>h)Financial constraints<br>i)Literacy constraints<br>j)If any other |
| **11** | **Yield** | | |
| 11.1 | Give average yield per tree for representative varieties of village | 100 kg | 95-100 kg |
| 11.2 | Average yield per tree (seedling types) | 80-90Kg | 70-80Kg |
| 11.3 | Variation in yield –give high/medium/low yielding years | High-2008.09;very low-2009.10 | High |

## APPENDIX II

| | | | |
|---|---|---|---|
| 11.4 | Causes for high/medium/low yields-if causes are known, describe or elucidate (Tick the options) | a) Favourable condition or less/no incidence of weather hopper/powdery mildew or any disease. b)Rains/Drought/Diseases/pests/cyclone /storm/temperature (high or low/) untimely flowering | a) Favourable weather condition or less/no incidence of hopper/powdery mildew or any disease. b)Rains/Drought/Diseases/pests/cyclone/storm/termperature(high or low/) untimely flowering |
| **12** | **Family involvement** | | |
| 12.1 | Whether family members are involved as labourers in orchard operations? | Yes/no (to a great extend) | Yes/no ( to an extend) |
| 12.2 | If yes, family contribution to labour (average man days in a year for 5 representative families) | 40 days | 40 days |
| **13** | **Labour** | | |
| 13.1 | Whether labourers are hired for orchard operations | Yes /no | Yes /no |
| 13.2 | If yes, average number of man days per year | 20-30 days | 20-30 days |
| **14** | **Miscellaneous information** | | |
| 14.1 | Average per capita income at panchayat or block level | 16000 | |
| 14.2 | Availability of social activity groups | Yes/no | Yes/no |

## APPENDIX II

| | | | |
|---|---|---|---|
| 14.3 | If yes, mention the groups and activities | a) Self help group<br>b) Women self help groups<br>c) Growers association<br>d) Panchayat level arrangements<br>e) Any other | a)Self help group<br>b)Women self help group<br>c)Growers association<br>d)Panchayat level arrangements<br>e)Any other |
| 14.4 | Availability of training facilities of potential capacity building centres | a) State Horticulture farms<br>b) Horticulture institutes<br>c) KVKS<br>d) Agriculture /horticulture departments<br>e) NGOs<br>f) Any other Private or Public advisory services | a)State Horticulture farms<br>b)Horticulture institutes<br>c)KVKS<br>d)Agriculture /horticulture departments<br>e)NGOs<br>f)Any other Private or Public advisory services |

**** predominantly homestead mangoes .**

*** Snow ball sampling technique was resorted to for locating representative homesteads/household with appreciable variatel diversity of seedling types.**

*** Since the flowering of mango crop throughout the two districts and state is very sparse and erratic (5-10% only) during the year 2009 due to untimely showers data base related with fruiting parameters is very much limited and to be gathered later only.**

**APPENDIX III**

## Maruthampadam – Pazhayannur Gramapanhayath

## Mango Biodiversity – Participatory Learning

| Sl. No. | Name of farmer and address | Major crops grown | Details of seedling mangoes | Processing and product diversification | Total area |
|---|---|---|---|---|---|
| 1. | Saju, P.T. Maruthampadam, Elanad | Rice, coconut, mango, rubber,arecanut, nutmeg,cocoa, vegetables, jackfruit,banana | Chandrakkaran, Muvandan, Karppooram, Kottapavalam, Pulimavu, Ganapatimookan Neelum, Priyur, Sindhooram | Pickle making, fruit bar | 7 acre |
| 2. | Vasu, T.V. Maruthampadam, Elanad | vegetables | Muvandan | - | 1 acre |
| 3. | Narayanan, T.V. Thottingal, Maruthampadam | coconut, rubber, mango, gooseberry, bilimbi, anona, jackfruit | Muvandan, Neelam, Gomanga, Pulimanga | - | 80 cent |
| 4. | Biju Ravindran Elanad, Chelakkara | Rubber, Rice, coconut, pepper, mango, banana, jackfruit, vegetables | Neelum, Muvandan | Pickle making, fruit bar, juice | 6 acre |
| 5. | Latha Manikyan Elanad, Chelakkara | Coconut, mango, vegetables, arecanut, jackfruit | Muvandan | Pickle making, fruit bar, juice | 2 acre |
| 6. | Sindhu Divakaran, Aamaloor, Elanad | Rice, coconut arecanut, Rubber, Coconut,banana, | Muvandan, Pulimanga | Pickle making, fruit bar, juice | 1.5 acre |

| | | | | | |
|---|---|---|---|---|---|
| | Cheeppara Elanad | coconut, cassava | Pulimanga, Gomanga, | | 1 acre |
| 19. | Padmanabhapilla Kongottpadam Elanad | Mango, jackfruit | Muvandan | - | 1 acre |
| 20. | Mary Mathai Kizhappalakkad Elanad | Vegetables | Muvandan, Kilimook, Pulimanga, Vellamanga, Puliyan | - | 3 acre |
| 21. | Gokuldas Puthanpurakkal Kannambra | Rice, rubber, coconut, arecanut, vegetables, banana | Muvandan,Mundapa, Kilimook, Neelum, Nadasala | Pickle making | 8 acre |

| | | | | | |
|---|---|---|---|---|---|
| | | jackfruit | | | |
| 7. | Ravindran, M. Elanad | Rice, vegetables, Rubber, arecanut | Muvandan | - | 4 acre |
| 8. | Kochu, Madhathiparambil Elanad | Vegetables, banana | Muvandan, Vellamanga | - | 3 acre |
| 9. | Preetha Amalurkalam Elanad | Rice, vegetables | Muvandan | - | 55 cent |
| 10. | Chandran, T.V Elanad | Coconut, rubber | Muvandan, Marathakam | - | 1acre |
| 11. | Pushkaran, M Trishna Elanad | coconut, mango,arecanut, rubber | Muvandan, Priyur | Pickle making | 5 acre |
| 12. | Vinod. D Venganamchira Elanad | Rice, banana, rubber | Muvandan, Pulimanga | Pickle making | 10 acre |
| 13. | Ramadas, K Vazhott Elanad | Rubber | Muvandan, Pulimanga | - | 4acre |
| 14. | Sushama Vijayan Kachamkurissi house Elanad | Vegetables, coconut, mango,arecanut | - | - | 40 cent |
| 15. | Karthyayani Velamkodu Elanad | Rubber,banana | Muvandan, Kilimook, Gomanga | - | 72 cent |
| 16. | Unni, P.V. Kanasseri Elanad | Coconut, banana, Rubber,rice, arecanut, cassava | Muvandan, Kilimookan, Nadasala, | Pickle making | 5 acre |
| 17. | Jose, R Malambathikulam, Thirumani | Banana, rice | Priyur, Nadasala, Muvandan | - | 8 acre |
| 18. | Raju | Rice, rubber, | Muvandan, | - | |

| | | | | | |
|---|---|---|---|---|---|
| | Cheeppara Elanad | coconut, cassava | Pulimanga, Gomanga, | | 1 acre |
| 19. | Padmanabhapilla Kongottpadam Elanad | Mango, jackfruit | Muvandan | - | 1 acre |
| 20. | Mary Mathai Kizhappalakkad Elanad | Vegetables | Muvandan, Kilimook, Pulimanga, Vellamanga, Puliyan | - | 3 acre |
| 21. | Gokuldas Puthanpurakkal Kannambra | Rice, rubber, coconut, arecanut, vegetables, banana | Muvandan,Mundapa, Kilimook, Neelum, Nadasala | Pickle making | 8 acre |

## APPENDIX IV

**Eripadam – Muthalamada Gramapanhayath**
**Mango Biodiversity – Participatory Learning**

| SL. No. | Name of farmer and address | Major crops grown | Details of seedling mangoes | Processing and product diversification | Area | Area under mango crop |
|---|---|---|---|---|---|---|
| 1. | N. Sahadevan, Nenmeni, Kollankodu | Rice, coconut, mango | Sindhooram, Alphonso, Natashala, Kilimukh, Priyur, Muvandan, Gomanga,BanganapalliKalepad, Nadanmanga, Kilichundan, Neelum | - | 10 acre | 5 acre |
| 2. | B. Sachidanandan, Erippaddam, Muthalamada | Rice, coconut, arecanut, mango | Sindhooram, Kalepad | - | 1.80 acre | 50 cent |
| 3. | Sukumaran, Erippadam | Coconut, mango, vegetables | Sindhooram, Priyur | - | 1acre 10 cent | 3 cent |
| 4. | A. Chamy, Kattupadam, Muthalamada | Rice, coconut arecanut | Kalepad, Banganapilli, Alphonso, Gudadth, Mulgoa, Chandrakaran | - | 2.5 acre | 40 cent |
| 5. | K. Bharathan, Manali House, Muthalamada | Rice | Kilichundan, Neelum, Nadanmanga | Pickle making | 2 acre 80 cent | 2 cent |
| 6. | Ummer Koya, Kattupadam, Muthalamada | Rice, coconut, mango | Neelum. Kilichundan, Sindhooram, Nadasala, Nadanmanga, | Export | 4 acre 50 cent | 50 cent |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Gudadth, Mulgoa | | | |
| 7. | P.K. Shivaraman, Parakolumbu, Muthalamada | Rice, mango | Sindhooram,Karineelum, Banganapalli, Neelum | - | 1 acre | 10 cent |
| 8. | Shad S., Kattupadam House, Muthalamada | Rice, coconut, mango | Neelum, Kilimukh, Kilichundan, Nadasala,Kalepad,Nadanmanga, Alphonso, Banganapalli, Mulgoa, Gudadth | - | 2 acre 50 cent | 1 acre |
| 9. | P.C. Muthuravuthar, Thottathil House, Erippadam | Mango | Nadasala, Gudadth, Sindhooram, Neelum, Mundappa, Kilichundan, Nadanmanga, Mulgoa,Muvandan, Kalepad | - | 4 acre | 4 acre |
| 10. | K. Jayakrishnan, Navukkodu House, Pattancheri | Coconut, Mango | Kilichundan, Neelum, Sindhooram, Nadanmanga, Mulgoa | - | 1.5 acre | 1 acre |
| 11. | M.P. Badarudeen, Manippuram, Kuttippadam | Rice, coconut, mango | Banganapilly, Sindhooram | - | 6 acre | 25 cent |
| 12. | Basheer, Parakolumbu, Muthalamada | Coconut, mango | Kilichundan, Alphonso, Neelum, | - | 40 cent | 15 cent |
| 13. | Vasu, Kuttippadam, Muthalamada | Rice, coconut, mango, banana, vegetables | Kilimukh, Sindhooram, Kilichundan, Muvandan, Banganapalli | - | 2.75 acre | 25 cent |
| 14. | S. Suresh, Kanakalathalayam, Muthalamada | Coconut, mango | Muvandan, Kalapady, Neelum, Kilimukh, Sindhooram, Alphonso, | Pickle making | 7 acre | 4 acre |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Nadanmanga, Gudadth, Mulgoa | | | |
| 21. | Ibrahim, Erippadam, Muthalamada | Rice, mango | Kilimukh, Neelum, Gomanga | - | 10 cent | 3 cent |
| 22. | Hakim K., Muthalamada | Coconut, mango | Sindhooram, Alphonso, Banganapalli, Muvandan | - | 1.20 acre | 1 acre |
| 23. | C. Mohan, Kalathil farm, Kattupadam, Muthalamada | Rice, coconut, arecanut, cocoa | Muvandan, Kalepad, Sindhooram, Alphonso Kilichundan, Nadanmanga, Banganapalli, Himampasanth, Gudadth, Mulgoa, Chandrakaran | - | 5 acre | 1 acre |
| 24. | Sundaran, Erippadam, Muthalamada | Coconut | Neelum, Muvandan | - | 1.20 acre | 10 cent |
| 25. | K. Shivaraman, Anakkadu house, Pttancheri | Coconut, mango | Banganapalli, Sindhooram, Neelum | Pickle making | 40 cent | 10 cent |
| 26. | C.M. Shankaranarayanan, Kizhakkeveedu, Chettithara | Mango | Kilichundan, Sindhooram | - | 1.5 acre | 75 cent |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Chandrakaran Banganapalli, Himapasanth, Kilichundan, Nadasala, Nadamanga, Gudadth, Mulgoa | | | |
| 15. | K.V. Madhusoodanan, Kuttippadam, Muthalamada | Rice, coconut, mango | Mulgoa, Gudadth, Neelum, Muvandan, Banganapalli, Nadasala, Alphonso, Priyur, Kalepad, Kilichundan, Nadanmanga, Gomanga, Gudadth, Mulgoa | - | 8 acre | 3 acre |
| 16. | A. Gangadharan, Hillview, Erippadam | Rice, coconut, arecanut, banana, aroids | Kilichundan, Nadasala, Neelum, Nadanmanga, Sindhooram, Banganapalli, | - | 4.30 acre | 3 cent |
| 17. | P.A. Chandappa, Parakolumbu, Muthalamada | Rice, banana, aroids, mango | Sindhooram, Muvandan, Alphonso, Gudadth, | - | 2.5 acre | 1 acre |
| 18. | Muhammed Moosa, Parakolumbu, Muthalamada | Rice, coconut, mango | Sindhooram, Banganapilly, Alphonso, Neelum, Kilichundan, Muvandan, Nadasala, Nadanmanga | - | 3.5 acre | 1 acre |
| 19. | Shashikumar P., Manali, Kuttippadam, Muthalamada | Rice, coconut, mango, vegetables | Neelum, Kilimukh Kilichundan | - | 5 acre | 3 cent |
| 20. | K. Ramesh, Kanakalathalayam, Muthalamada | Coconut, mango | Kilichundan, Neelum,Alphonso, Sindhooram, Priyur, Himampasanth, Muvandan, Nadasala, Kalepad, | - | 7 acre | 4 acre |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Nadanmanga, Gudadth, Mulgoa | | | |
| 21. | Ibrahim, Erippadam, Muthalamada | Rice, mango | Kilimukh, Neelum, Gomanga | - | 10 cent | 3 cent |
| 22. | Hakim K., Muthalamada | Coconut, mango | Sindhooram, Alphonso, Banganapalli, Muvandan | - | 1.20 acre | 1 acre |
| 23. | C. Mohan, Kalathil farm, Kattupadam, Muthalamada | Rice, coconut, arecanut, cocoa | Muvandan, Kalepad, Sindhooram, Alphonso Kilichundan, Nadanmanga, Banganapalli, Himampasanth, Gudadth, Mulgoa, Chandrakaran | - | 5 acre | 1 acre |
| 24. | Sundaran, Erippadam, Muthalamada | Coconut | Neelum, Muvandan | - | 1.20 acre | 10 cent |
| 25. | K. Shivaraman, Anakkadu house, Pttancheri | Coconut, mango | Banganapalli, Sindhooram, Neelum | Pickle making | 40 cent | 10 cent |
| 26. | C.M. Shankaranarayanan, Kizhakkeveedu, Chettithara | Mango | Kilichundan, Sindhooram | - | 1.5 acre | 75 cent |

## APPENDIX V

### Weather parameters from October 2009- March 2010

### October 2009

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/10/09 | 28.8 | 23.5 | 92 | 86 | 0.6 | 50.9 |
| 2 | 02/10/09 | 26.4 | 21.2 | 98 | 89 | 0.0 | 55.9 |
| 3 | 03/10/09 | 29.5 | 21.3 | 95 | 74 | 3.3 | 27.0 |
| 4 | 04/10/09 | 29.9 | 22.1 | 95 | 76 | 5.7 | 5.8 |
| 5 | 05/10/09 | 30.2 | 23.5 | 95 | 65 | 8.6 | 0.0 |
| 6 | 06/10/09 | 30.5 | 22.8 | 92 | 68 | 8.9 | 0.0 |
| 7 | 07/10/09 | 30.9 | 23.0 | 95 | 64 | 8.5 | 0.4 |
| 8 | 08/10/09 | 31.8 | 22.7 | 95 | 59 | 9.6 | 0.0 |
| 9 | 09/10/09 | 31.4 | 22.3 | 95 | 61 | 10.1 | 0.0 |
| 10 | 10/10/09 | 31.8 | 21.9 | 95 | 55 | 9.7 | 0.0 |
| 11 | 11/10/09 | 32.5 | 22.3 | 95 | 58 | 9.3 | 0.0 |
| 12 | 12/10/09 | 32.4 | 22.8 | 95 | 56 | 3.1 | 0.2 |
| 13 | 13/10/09 | 32.9 | 22.9 | 88 | 59 | 4.8 | 26.0 |
| 14 | 14/10/09 | 32.1 | 22.5 | 93 | 66 | 6.1 | 0.0 |
| 15 | 15/10/09 | 28.5 | 22.7 | 91 | 77 | 0.0 | 0.6 |
| 16 | 16/10/09 | 32.1 | 22.2 | 96 | 66 | 8.7 | 0.0 |
| 17 | 17/10/09 | 32.9 | 22.9 | 95 | 67 | 9.1 | 0.0 |
| 18 | 18/10/09 | 33.8 | 23.2 | 95 | 56 | 8.8 | 0.0 |
| 19 | 19/10/09 | 33.5 | 23.2 | 95 | 55 | 7.0 | 0.0 |
| 20 | 20/10/09 | 33.5 | 23.7 | 97 | 60 | 8.0 | 0.0 |
| 21 | 21/10/09 | 34.7 | 23.2 | 95 | 44 | 9.1 | 0.0 |
| 22 | 22/10/09 | 34.0 | 23.8 | 90 | 46 | 8.1 | 0.0 |
| 23 | 23/10/09 | 34.5 | 23.4 | 92 | 36 | 8.1 | 0.0 |
| 24 | 24/10/09 | 33.3 | 23.3 | 90 | 51 | 6.8 | 0.0 |
| 25 | 25/10/09 | 32.6 | 23.8 | 96 | 62 | 6.2 | 0.0 |
| 26 | 26/10/09 | 34.1 | 23.7 | 85 | 55 | 7.1 | 0.0 |
| 27 | 27/10/09 | 32.5 | 24.7 | 92 | 69 | 4.6 | 0.0 |
| 28 | 28/10/09 | 34.0 | 24.3 | 90 | 49 | 9.4 | 0.0 |
| 29 | 29/10/09 | 32.0 | 25.8 | 74 | 62 | 3.5 | 0.0 |
| 30 | 30/10/09 | 33.2 | 25.8 | 74 | 50 | 8.8 | 0.0 |
| 31 | 31/10/09 | 33.2 | 24.2 | 81 | 56 | 7.5 | 0.0 |

**November 2009**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/11/09 | 31.6 | 25.0 | 78 | 63 | 5.1 | 0.0 |
| 2 | 02/11/09 | 33.0 | 25.2 | 71 | 50 | 9.3 | 0.0 |
| 3 | 03/11/09 | 32.0 | 25.1 | 70 | 55 | 5.7 | 0.0 |
| 4 | 04/11/09 | 33.2 | 25.6 | 72 | 55 | 6.6 | 0.0 |
| 5 | 05/11/09 | 32.0 | 25.3 | 79 | 57 | 5.1 | 0.0 |
| 6 | 06/11/09 | 30.1 | 25.5 | 75 | 66 | 0.0 | 0.0 |
| 7 | 07/11/09 | 30.7 | 24.8 | 84 | 89 | 0.0 | 55.3 |
| 8 | 08/11/09 | 27.9 | 23.7 | 96 | 90 | 0.0 | 16.0 |
| 9 | 09/11/09 | 29.0 | 24.2 | 88 | 95 | 1.3 | 12.1 |
| 10 | 10/11/09 | 29.6 | 22.5 | 93 | 95 | 0.7 | 42.9 |
| 11 | 11/11/09 | 28.6 | 22.3 | 95 | 87 | 1.1 | 9.4 |
| 12 | 12/11/09 | 33.1 | 23.1 | 93 | 70 | 7.3 | 0.0 |
| 13 | 13/11/09 | 33.1 | 24.1 | 92 | 64 | 6.9 | 0.0 |
| 14 | 14/11/09 | 32.0 | 25.7 | 80 | 78 | 4.0 | 0.5 |
| 15 | 15/11/09 | 31.0 | 23.7 | 84 | 63 | 0.4 | 4.4 |
| 16 | 16/11/09 | 31.9 | 22.8 | 95 | 63 | 5.6 | 0.0 |
| 17 | 17/11/09 | 31.5 | 23.2 | 95 | 61 | 9.9 | 0.0 |
| 18 | 18/11/09 | 31.2 | 23.8 | 93 | 62 | 5.7 | 0.0 |
| 19 | 19/11/09 | 31.8 | 23.8 | 93 | 70 | 5.3 | 4.3 |
| 20 | 20/11/09 | 32.7 | 24.4 | 97 | 71 | 4.6 | 16.2 |
| 21 | 21/11/09 | 32.0 | 22.8 | 93 | 59 | 7.6 | 0.0 |
| 22 | 22/11/09 | 31.0 | 23.8 | 87 | 66 | 4.6 | 19.5 |
| 23 | 23/11/09 | 32.0 | 23.2 | 87 | 58 | 9.0 | 0.0 |
| 24 | 24/11/09 | 32.4 | 23.9 | 92 | 56 | 8.9 | 0.0 |
| 25 | 25/11/09 | 32.7 | 23.7 | 84 | 54 | 9.9 | 0.0 |
| 26 | 26/11/09 | 32.6 | 24.3 | 88 | 49 | 9.9 | 0.0 |
| 27 | 27/11/09 | 31.6 | 23.4 | 82 | 50 | 8.2 | 0.0 |
| 28 | 28/11/09 | 31.2 | 21.3 | 81 | 45 | 9.9 | 0.0 |
| 29 | 29/11/09 | 31.4 | 19.4 | 71 | 51 | 10.0 | 0.0 |
| 30 | 30/11/09 | 31.5 | 22.3 | 88 | 56 | 8.8 | 0.0 |

**December 2009**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/12/09 | 31.5 | 23.2 | 78 | 60 | 9.3 | 0.0 |
| 2 | 02/12/09 | 30.2 | 24.6 | 69 | 67 | 8.9 | 0.0 |
| 3 | 03/12/09 | 32.5 | 24.5 | 79 | 56 | 8.9 | 0.0 |
| 4 | 04/12/09 | 33.0 | 24.7 | 84 | 57 | 6.7 | 0.0 |
| 5 | 05/12/09 | 31.6 | 23.4 | 84 | 56 | 5.6 | 0.0 |
| 6 | 06/12/09 | 30.4 | 23.3 | 69 | 55 | 6.0 | 0.0 |
| 7 | 07/12/09 | 31.5 | 22.5 | 83 | 54 | 10.0 | 0.0 |
| 8 | 08/12/09 | 31.5 | 22.5 | 83 | 54 | 9.8 | 0.0 |
| 9 | 09/12/09 | 31.9 | 22.4 | 67 | 47 | 10.0 | 0.0 |
| 10 | 10/12/09 | 31.4 | 23.7 | 61 | 35 | 10.1 | 0.0 |
| 11 | 11/12/09 | 31.5 | 23.7 | 60 | 44 | 9.9 | 0.0 |
| 12 | 12/12/09 | 32.3 | 21.5 | 80 | 51 | 9.4 | 0.0 |
| 13 | 13/12/09 | 32.3 | 24.3 | 71 | 56 | 7.0 | 0.0 |
| 14 | 14/12/09 | 32.9 | 23.9 | 72 | 47 | 10.2 | 0.0 |
| 15 | 15/12/09 | 32.4 | 24.7 | 70 | 52 | 8.8 | 0.0 |
| 16 | 16/12/09 | 32.1 | 24.8 | 78 | 59 | 8.0 | 0.0 |
| 17 | 17/12/09 | 33.0 | 23.9 | 78 | 53 | 9.3 | 0.0 |
| 18 | 18/12/09 | 33.2 | 24.0 | 76 | 50 | 10.0 | 0.0 |
| 19 | 19/12/09 | 32.3 | 24.6 | 70 | 49 | 9.5 | 0.0 |
| 20 | 20/12/09 | 32.2 | 26.0 | 71 | 50 | 9.9 | 0.0 |
| 21 | 21/12/09 | 32.2 | 25.5 | 72 | 52 | 8.6 | 0.0 |
| 22 | 22/12/09 | 30.5 | 25.8 | 69 | 60 | 3.6 | 0.0 |
| 23 | 23/12/09 | 31.7 | 25.3 | 66 | 53 | 7.2 | 0.0 |
| 24 | 24/12/09 | 31.7 | 25.8 | 62 | 45 | 7.0 | 0.0 |
| 25 | 25/12/09 | 31.3 | 24.6 | 70 | 52 | 5.2 | 0.0 |
| 26 | 26/12/09 | 32.4 | 24.2 | 68 | 48 | 7.9 | 0.0 |
| 27 | 27/12/09 | 32.1 | 23.8 | 80 | 53 | 3.8 | 42.7 |
| 28 | 28/12/09 | 30.5 | 22.5 | 68 | 58 | 7.1 | 0.0 |
| 29 | 29/12/09 | 30.9 | 23.7 | 80 | 57 | 3.3 | 0.0 |
| 30 | 30/12/09 | 30.2 | 23.3 | 72 | 53 | 3.3 | 0.0 |
| 31 | 31/12/09 | 32.2 | 22.8 | 72 | 60 | 7.3 | 0.0 |

**January 2010**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/01/2010 | 32.5 | 23.9 | 74 | 45 | 9.9 | 0.0 |
| 2 | 02/01/2010 | 31.8 | 23.4 | 64 | 43 | 9.7 | 0.0 |
| 3 | 03/01/2010 | 31.8 | 23.4 | 66 | 44 | 9.3 | 0.0 |
| 4 | 04/01/2010 | 32.7 | 21.3 | 83 | 43 | 9.1 | 0.0 |
| 5 | 05/01/2010 | 32.5 | 21.9 | 69 | 46 | 9.4 | 0.0 |
| 6 | 06/01/2010 | 32.0 | 20.9 | 75 | 36 | 9.7 | 0.0 |
| 7 | 07/01/2010 | 31.8 | 22.9 | 63 | 39 | 9.3 | 0.0 |
| 8 | 08/01/2010 | 32.3 | 23.8 | 85 | 52 | 8.1 | 0.0 |
| 9 | 09/01/2010 | 33.1 | 22.8 | 73 | 52 | 8.5 | 0.0 |
| 10 | 10/01/2010 | 30.1 | 25.2 | 81 | 52 | 0.1 | 0.0 |
| 11 | 11/01/2010 | 33.8 | 22.2 | 86 | 44 | 10.0 | 0.0 |
| 12 | 12/01/2010 | 33.5 | 22.9 | 86 | 51 | 9.3 | 0.0 |
| 13 | 13/01/2010 | 33.3 | 24.0 | 95 | 54 | 6.4 | 0.0 |
| 14 | 14/01/2010 | 32.9 | 23.7 | 85 | 53 | 6.9 | 0.0 |
| 15 | 15/01/2010 | 31.5 | 23.6 | 82 | 51 | 9.4 | 0.0 |
| 16 | 16/01/2010 | 31.7 | 23.8 | 63 | 46 | 8.9 | 0.0 |
| 17 | 17/01/2010 | 32.2 | 24.2 | 71 | 40 | 10.1 | 0.0 |
| 18 | 18/01/2010 | 33.4 | 22.4 | 66 | 44 | 10.0 | 0.0 |
| 19 | 19/01/2010 | 33.4 | 21.1 | 78 | 55 | 9.6 | 0.0 |
| 20 | 20/01/2010 | 32.5 | 22.2 | 78 | 63 | 8.9 | 0.0 |
| 21 | 21/01/2010 | 32.2 | 22.8 | 71 | 44 | 9.1 | 0.0 |
| 22 | 22/01/2010 | 32.6 | 22.2 | 63 | 42 | 9.9 | 0.0 |
| 23 | 23/01/2010 | 32.1 | 21.1 | 73 | 60 | 9.9 | 0.0 |
| 24 | 24/01/2010 | 32.2 | 20.8 | 73 | 60 | 9.7 | 0.0 |
| 25 | 25/01/2010 | 32.4 | 21.7 | 78 | 38 | 9.9 | 0.0 |
| 26 | 26/01/2010 | 33.0 | 21.7 | 78 | 42 | 9.6 | 0.0 |
| 27 | 27/01/2010 | 33.3 | 22.3 | 74 | 38 | 9.0 | 0.0 |
| 28 | 28/01/2010 | 32.2 | 22.5 | 77 | 44 | 10.0 | 0.0 |
| 29 | 29/01/2010 | 32.9 | 23.8 | 72 | 41 | 10.3 | 0.0 |
| 30 | 30/01/2010 | 33.9 | 23.9 | 55 | 37 | 10.3 | 0.0 |
| 31 | 31/01/2010 | 32.4 | 22.8 | 75 | 43 | 9.7 | 0.0 |

**February 2010**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/02/2010 | 33.5 | 23.3 | 55 | 45 | 8.2 | 0.0 |
| 2 | 02/02/2010 | 33.0 | 23.6 | 60 | 37 | 9.8 | 0.0 |
| 3 | 03/02/2010 | 33.4 | 22.9 | 61 | 31 | 9.9 | 0.0 |
| 4 | 04/02/2010 | 33.4 | 22.6 | 62 | 37 | 10.2 | 0.0 |
| 5 | 05/02/2010 | 32.9 | 22.1 | 67 | 36 | 10.0 | 0.0 |
| 6 | 06/02/2010 | 33.0 | 23.1 | 74 | 34 | 10.4 | 0.0 |
| 7 | 07/02/2010 | 33.0 | 23.8 | 52 | 31 | 10.4 | 0.0 |
| 8 | 08/02/2010 | 33.7 | 23.7 | 53 | 36 | 9.9 | 0.0 |
| 9 | 09/02/2010 | 34.4 | 22.5 | 65 | 48 | 10.0 | 0.0 |
| 10 | 10/02/2010 | 34.4 | 22.3 | 78 | 41 | 9.2 | 0.0 |
| 11 | 11/02/2010 | 33.4 | 24.1 | 75 | 36 | 1.6 | 0.0 |
| 12 | 12/02/2010 | 36.2 | 24.1 | 74 | 36 | 9.8 | 0.0 |
| 13 | 13/02/2010 | 34.5 | 23.1 | 79 | 45 | 8.0 | 0.0 |
| 14 | 14/02/2010 | 36.9 | 23.6 | 87 | 37 | 9.9 | 0.0 |
| 15 | 15/02/2010 | 35.6 | 24.0 | 90 | 42 | 9.0 | 0.0 |
| 16 | 16/02/2010 | 36.2 | 23.9 | 80 | 32 | 10.1 | 0.0 |
| 17 | 17/02/2010 | 35.9 | 22.7 | 76 | 41 | 10.1 | 0.0 |
| 18 | 18/02/2010 | 34.9 | 23.8 | 90 | 49 | 6.8 | 0.0 |
| 19 | 19/02/2010 | 36.1 | 25.2 | 93 | 39 | 7.1 | 0.0 |
| 20 | 20/02/2010 | 37.0 | 23.6 | 80 | 27 | 10.3 | 0.0 |
| 21 | 21/02/2010 | 36.6 | 23.9 | 90 | 33 | 10.1 | 0.0 |
| 22 | 22/02/2010 | 37.3 | 24.3 | 92 | 34 | 9.8 | 0.0 |
| 23 | 23/02/2010 | 34.5 | 25.3 | 92 | 58 | 9.5 | 0.0 |
| 24 | 24/02/2010 | 34.5 | 24.5 | 95 | 55 | 8.6 | 0.0 |
| 25 | 25/02/2010 | 34.2 | 24.0 | 92 | 53 | 8.7 | 0.0 |
| 26 | 26/02/2010 | 34.6 | 24.2 | 91 | 59 | 6.5 | 0.0 |
| 27 | 27/02/2010 | 36.9 | 24.4 | 92 | 47 | 9.7 | 0.0 |
| 28 | 28/02/2010 | 37.4 | 24.4 | 90 | 24 | 10.0 | 0.0 |

**March 2010**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/03/2010 | 37.1 | 23.9 | 93 | 23 | 9.3 | 0.0 |
| 2 | 02/03/2010 | 37.3 | 23.3 | 90 | 15 | 9.6 | 0.0 |
| 3 | 03/03/2010 | 37.2 | 23.3 | 93 | 38 | 9.1 | 0.0 |
| 4 | 04/03/2010 | 33.8 | 25.2 | 92 | 54 | 6.0 | 0.0 |
| 5 | 05/03/2010 | 34.4 | 24.6 | 93 | 51 | 8.3 | 0.0 |
| 6 | 06/03/2010 | 34.4 | 25.0 | 90 | 53 | 8.4 | 0.0 |
| 7 | 07/03/2010 | 35.0 | 24.0 | 91 | 49 | 8.7 | 0.0 |
| 8 | 08/03/2010 | 36.3 | 25.7 | 89 | 47 | 8.0 | 0.0 |
| 9 | 09/03/2010 | 38.9 | 26.6 | 90 | 33 | 8.9 | 0.0 |
| 10 | 10/03/2010 | 37.9 | 25.3 | 87 | 32 | 9.3 | 0.0 |
| 11 | 11/03/2010 | 37.6 | 25.0 | 70 | 30 | 8.3 | 0.0 |
| 12 | 12/03/2010 | 36.6 | 25.4 | 74 | 31 | 9.8 | 0.0 |
| 13 | 13/03/2010 | 37.5 | 24.9 | 68 | 33 | 8.4 | 0.0 |
| 14 | 14/03/2010 | 37.0 | 24.7 | 92 | 52 | 8.7 | 0.0 |
| 15 | 15/03/2010 | 36.3 | 25.3 | 92 | 61 | 7.3 | 0.0 |
| 16 | 16/03/2010 | 36.4 | 26.3 | 92 | 57 | 6.8 | 12.9 |
| 17 | 17/03/2010 | 37.3 | 22.1 | 87 | 45 | 8.6 | 0.0 |
| 18 | 18/03/2010 | 37.1 | 25.0 | 79 | 28 | 9.5 | 0.0 |
| 19 | 19/03/2010 | 37.0 | 22.8 | 71 | 34 | 9.9 | 0.0 |
| 20 | 20/03/2010 | 37.7 | 23.8 | 88 | 47 | 9.0 | 0.0 |
| 21 | 21/03/2010 | 37.4 | 25.2 | 92 | 50 | 8.8 | 0.0 |
| 22 | 22/03/2010 | 36.0 | 25.4 | 95 | 53 | 7.9 | 0.0 |
| 23 | 23/03/2010 | 35.1 | 25.2 | 92 | 56 | 8.5 | 0.0 |
| 24 | 24/03/2010 | 34.9 | 25.1 | 92 | 51 | 8.4 | 0.0 |
| 25 | 25/03/2010 | 35.0 | 24.8 | 92 | 56 | 8.0 | 0.0 |
| 26 | 26/03/2010 | 34.6 | 25.7 | 92 | 58 | 7.0 | 0.0 |
| 27 | 27/03/2010 | 34.5 | 24.8 | 90 | 58 | 7.2 | 0.0 |
| 28 | 28/03/2010 | 36.0 | 25.2 | 90 | 53 | 8.0 | 0.0 |
| 29 | 29/03/2010 | 34.5 | 25.3 | 89 | 56 | 7.9 | 0.0 |
| 30 | 30/03/2010 | 35.2 | 25.8 | 90 | 53 | 7.4 | 0.0 |
| 31 | 31/03/2010 | 35.2 | 24.8 | 86 | 53 | 7.9 | 0.0 |

## APPENDIX VI

### Weather parameters from October 2010- March 2011

### October 2010

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 1/10/2010 | 33.6 | 22.7 | 92 | 64 | 7.6 | 10.1 |
| 2 | 2/10/2010 | 30.8 | 22.6 | 96 | 75 | 2.7 | 70.4 |
| 3 | 3/10/2010 | 31.6 | 22.3 | 95 | 68 | 6.8 | 28.8 |
| 4 | 4/10/2010 | 31.6 | 22.5 | 93 | 67 | 8.8 | 0.4 |
| 5 | 5/10/2010 | 29.0 | 23.5 | 95 | 86 | 0.5 | 42.8 |
| 6 | 6/10/2010 | 25.4 | 22.9 | 97 | 96 | 0 | 136.8 |
| 7 | 7/10/2010 | 26.5 | 22.4 | 96 | 93 | 0 | 33.2 |
| 8 | 8/10/2010 | 30.4 | 23.0 | 97 | 71 | 4.5 | 0 |
| 9 | 9/10/2010 | 26.4 | 24.4 | 97 | 84 | 0 | 2.4 |
| 10 | 10/10/2010 | 30.6 | 23.0 | 95 | 70 | 4 | 0 |
| 11 | 11/10/2010 | 31.0 | 23.7 | 92 | 68 | 8 | 0 |
| 12 | 12/10/2010 | 31.4 | 22.8 | 93 | 63 | 6 | 0 |
| 13 | 13/10/2010 | 30.4 | 23.5 | 94 | 64 | 4 | 0 |
| 14 | 14/10/2010 | 30.6 | 23.0 | 92 | 69 | 6.6 | 11.3 |
| 15 | 15/10/2010 | 26.0 | 21.6 | 93 | 94 | 0.9 | 88.7 |
| 16 | 16/10/2010 | 30.2 | 21.3 | 96 | 61 | 7.8 | 0 |
| 17 | 17/10/2010 | 30.2 | 22.0 | 95 | 68 | 7.9 | 0 |
| 18 | 18/10/2010 | 30.5 | 21.6 | 95 | 73 | 5.3 | 5.2 |
| 19 | 19/10/2010 | 28.1 | 21.8 | 95 | 92 | 0.8 | 24.1 |
| 20 | 20/10/2010 | 30.0 | 22.4 | 96 | 71 | 3.7 | 1.1 |
| 21 | 21/10/2010 | 28.5 | 22.3 | 96 | 90 | 0 | 12.8 |
| 22 | 22/10/2010 | 27.0 | 22.5 | 95 | 87 | 0 | 46.8 |
| 23 | 23/10/2010 | 28.6 | 22.9 | 96 | 81 | 4.6 | 0.4 |
| 24 | 24/10/2010 | 30.6 | 22.0 | 96 | 63 | 10.2 | 0 |
| 25 | 25/10/2010 | 31.0 | 22.0 | 93 | 66 | 10.1 | 0 |
| 26 | 26/10/2010 | 30.9 | 22.7 | 93 | 69 | 6.5 | 3.5 |
| 27 | 27/10/2010 | 28.4 | 22.9 | 92 | 96 | 0 | 30.4 |
| 28 | 28/10/2010 | 31.2 | 21.4 | 96 | 69 | 5 | 10.2 |
| 29 | 29/10/2010 | 31.0 | 21.0 | 95 | 68 | 1.9 | 29.4 |
| 30 | 30/10/2010 | 30.0 | 21.8 | 95 | 71 | 0.7 | 73.4 |
| 31 | 31/10/2010 | 30.0 | 21.4 | 96 | 71 | 4.6 | 5.4 |

**November 2010**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/11/2010 | 30.1 | 23.5 | 96 | 75 | 0.4 | 35.5 |
| 2 | 02/11/2010 | 30.2 | 21.5 | 96 | 71 | 7.2 | 0 |
| 3 | 03/11/2010 | 31.8 | 22.3 | 92 | 70 | 8.8 | 0 |
| 4 | 04/11/2010 | 31.1 | 23.8 | 95 | 68 | 6.4 | 4 |
| 5 | 05/11/2010 | 30.0 | 23.6 | 93 | 68 | 3.9 | 16.2 |
| 6 | 06/11/2010 | 28.4 | 21.5 | 96 | 72 | 0 | 0 |
| 7 | 07/11/2010 | 28.2 | 22.7 | 97 | 80 | 0 | 0 |
| 8 | 08/11/2010 | 31.8 | 22.0 | 95 | 58 | 9.7 | 0 |
| 9 | 09/11/2010 | 30.9 | 22.3 | 95 | 70 | 5.2 | 32.9 |
| 10 | 10/11/2010 | 32.1 | 22.5 | 96 | 66 | 6.8 | 66.1 |
| 11 | 11/11/2010 | 28.8 | 21.5 | 98 | 98 | 0.3 | 26.1 |
| 12 | 12/11/2010 | 31.4 | 20.9 | 96 | 65 | 9.2 | 0 |
| 13 | 13/11/2010 | 30.6 | 23.3 | 95 | 74 | 4.4 | 0 |
| 14 | 14/11/2010 | 32.6 | 23.2 | 95 | 56 | 9.3 | 0 |
| 15 | 15/11/2010 | 32.7 | 22.8 | 88 | 58 | 8.6 | 0 |
| 16 | 16/11/2010 | 32.7 | 22.5 | 92 | 66 | 3 | 2.8 |
| 17 | 17/11/2010 | 30.2 | 22.5 | 96 | 79 | 1.8 | 30.4 |
| 18 | 18/11/2010 | 31.4 | 22.2 | 85 | 71 | 6.1 | 2.1 |
| 19 | 19/11/2010 | 31.4 | 23.0 | 84 | 70 | 2.7 | 0 |
| 20 | 20/11/2010 | 32.2 | 22.4 | 90 | 64 | 6.8 | 1 |
| 21 | 21/11/2010 | 30.0 | 22.8 | 96 | 68 | 0.9 | 47.6 |
| 22 | 22/11/2010 | 30.3 | 22.1 | 87 | 75 | 3.9 | 9.1 |
| 23 | 23/11/2010 | 31.0 | 21.8 | 96 | 63 | 5.1 | 0 |
| 24 | 24/11/2010 | 28.9 | 23.0 | 90 | 76 | 0 | 1.2 |
| 25 | 25/11/2010 | 27.8 | 22.5 | 96 | 79 | 0 | 0 |
| 26 | 26/11/2010 | 27.5 | 21.7 | 85 | 72 | 0.1 | 1.4 |
| 27 | 27/11/2010 | 28.4 | 21.5 | 91 | 71 | 0.3 | 0 |
| 28 | 28/11/2010 | 28.8 | 22.5 | 87 | 88 | 0.1 | 6.4 |
| 29 | 29/11/2010 | 30.0 | 22.8 | 79 | 63 | 2.8 | 0 |
| 30 | 30/11/2010 | 31.2 | 24.0 | 73 | 54 | 8.7 | 0 |

**December 2010**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/12/2010 | 27.9 | 23.7 | 82 | 81 | 0 | 0.7 |
| 2 | 02/12/2010 | 30.7 | 23.5 | 85 | 65 | 3 | 2.4 |
| 3 | 03/12/2010 | 29.3 | 22.5 | 93 | 67 | 0.8 | 0 |
| 4 | 04/12/2010 | 31.0 | 21.5 | 86 | 64 | 3.9 | 0 |
| 5 | 05/12/2010 | 30.6 | 21.3 | 80 | 51 | 4.3 | 0 |
| 6 | 06/12/2010 | 31.9 | 20.5 | 94 | 54 | 5.9 | 0 |
| 7 | 07/12/2010 | 33.2 | 20.0 | 86 | 53 | 8.5 | 0 |
| 8 | 08/12/2010 | 30.6 | 21.5 | 93 | 65 | 1.7 | 0 |
| 9 | 09/12/2010 | 31.4 | 21.5 | 93 | 56 | 5.8 | 0 |
| 10 | 10/12/2010 | 31.2 | 21.5 | 95 | 65 | 5.8 | 0 |
| 11 | 11/12/2010 | 31.1 | 21.2 | 95 | 67 | 3.5 | 0 |
| 12 | 12/12/2010 | 30.8 | 22.1 | 88 | 54 | 10 | 0 |
| 13 | 13/12/2010 | 31.9 | 19.4 | 94 | 52 | 9.1 | 0 |
| 14 | 14/12/2010 | 31.6 | 20.9 | 91 | 54 | 9.1 | 0 |
| 15 | 15/12/2010 | 31.9 | 21.8 | 91 | 61 | 6.4 | 3 |
| 16 | 16/12/2010 | 30.4 | 23.4 | 83 | 63 | 4.6 | 16 |
| 17 | 17/12/2010 | 30.9 | 23.0 | 83 | 56 | 8.8 | 0 |
| 18 | 18/12/2010 | 30.9 | 23.7 | 80 | 58 | 5.7 | 0 |
| 19 | 19/12/2010 | 30.5 | 23.1 | 75 | 42 | 9.5 | 0 |
| 20 | 20/12/2010 | 31.1 | 23.5 | 78 | 55 | 10 | 2.4 |
| 21 | 21/12/2010 | 30.6 | 23.2 | 73 | 57 | 9.9 | 0 |
| 22 | 22/12/2010 | 31.6 | 22.2 | 73 | 69 | 10.1 | 0 |
| 23 | 23/12/2010 | 30.6 | 21.2 | 77 | 47 | 9.8 | 0 |
| 24 | 24/12/2010 | 30.0 | 20.7 | 77 | 47 | 9.5 | 0 |
| 25 | 25/12/2010 | 30.1 | 20.4 | 75 | 49 | 6.6 | 0 |
| 26 | 26/12/2010 | 31.1 | 20.5 | 76 | 53 | 9.8 | 0 |
| 27 | 27/12/2010 | 31.2 | 21.3 | 76 | 51 | 9.8 | 0 |
| 28 | 28/12/2010 | 31.3 | 21.7 | 74 | 47 | 6.9 | 0 |
| 29 | 29/12/2010 | 30.2 | 24.2 | 67 | 56 | 2.8 | 0 |
| 30 | 30/12/2010 | 31.1 | 23.3 | 75 | 53 | 8 | 0 |
| 31 | 31/12/2010 | 31.4 | 22.3 | 85 | 54 | 7.1 | 0 |

**February 2011**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/02/11 | 34.6 | 23.9 | 61 | 23 | 9.1 | 0.0 |
| 2 | 02/02/11 | 32.0 | 22.8 | 51 | 26 | 7.0 | 0.0 |
| 3 | 03/02/11 | 33.1 | 23.2 | 54 | 25 | 9.8 | 0.0 |
| 4 | 04/02/11 | 33.4 | 20.4 | 63 | 35 | 9.8 | 0.0 |
| 5 | 05/02/11 | 34.1 | 18.3 | 50 | 23 | 10.4 | 0.0 |
| 6 | 06/02/11 | 33.8 | 21.9 | 64 | 24 | 10.4 | 0.0 |
| 7 | 07/02/11 | 34.1 | 19.7 | 65 | 37 | 7.7 | 0.0 |
| 8 | 08/02/11 | 34.5 | 22.6 | 86 | 38 | 8.9 | 0.0 |
| 9 | 09/02/11 | 34.5 | 22.4 | 73 | 37 | 8.7 | 0.0 |
| 10 | 10/02/11 | 35.0 | 21.3 | 69 | 16 | 10.5 | 0.0 |
| 11 | 11/02/11 | 34.4 | 20.9 | 66 | 16 | 10.5 | 0.0 |
| 12 | 12/02/11 | 33.6 | 23.6 | 48 | 17 | 10.4 | 0.0 |
| 13 | 13/02/11 | 34.7 | 20.8 | 45 | 17 | 10.3 | 0.0 |
| 14 | 14/02/11 | 35.0 | 19.3 | 74 | 26 | 10.3 | 0.0 |
| 15 | 15/02/11 | 32.7 | 21.5 | 78 | 46 | 9.2 | 0.0 |
| 16 | 16/02/11 | 32.9 | 21.2 | 89 | 42 | 9.1 | 0.0 |
| 17 | 17/02/11 | 34.0 | 20.7 | 94 | 50 | 9.8 | 0.0 |
| 18 | 18/02/11 | 32.9 | 21.0 | 94 | 45 | 9.7 | 0.0 |
| 19 | 19/02/11 | 33.7 | 19.7 | 93 | 50 | 9.8 | 0.0 |
| 20 | 20/02/11 | 33.6 | 21.9 | 91 | 59 | 5.0 | 0.0 |
| 21 | 21/02/11 | 32.4 | 23.6 | 87 | 57 | 5.9 | 0.0 |
| 22 | 22/02/11 | 34.7 | 23.7 | 91 | 52 | 7.8 | 59.6 |
| 23 | 23/02/11 | 33.9 | 23.1 | 91 | 46 | 5.6 | 5.5 |
| 24 | 24/02/11 | 33.2 | 23.1 | 91 | 50 | 3.4 | 0.8 |
| 25 | 25/02/11 | 32.9 | 23.8 | 83 | 52 | 7.6 | 0.0 |
| 26 | 26/02/11 | 32.6 | 23.8 | 93 | 55 | 5.6 | 11.6 |
| 27 | 27/02/11 | 33.4 | 22.6 | 91 | 48 | 6.8 | 0.0 |
| 28 | 28/02/11 | 33.7 | 24.2 | 72 | 39 | 10.0 | 0.0 |

**January 2011**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/01/11 | 32.3 | 22.7 | 90 | 50 | 7.3 | 0.0 |
| 2 | 02/01/11 | 31.2 | 22.5 | 90 | 57 | 7.1 | 0.0 |
| 3 | 03/01/11 | 31.0 | 21.1 | 91 | 63 | 4.2 | 0.0 |
| 4 | 04/01/11 | 32.5 | 20.7 | 89 | 39 | 9.8 | 0.0 |
| 5 | 05/01/11 | 31.6 | 23.1 | 75 | 50 | 6.7 | 0.0 |
| 6 | 06/01/11 | 32.3 | 22.5 | 75 | 47 | 8.8 | 0.0 |
| 7 | 07/01/11 | 33.1 | 23.7 | 75 | 49 | 7.6 | 0.0 |
| 8 | 08/01/11 | 32.9 | 22.7 | 95 | 52 | 6.1 | 0.0 |
| 9 | 09/01/11 | 33.9 | 23.3 | 91 | 45 | 5.1 | 0.0 |
| 10 | 10/01/11 | 33.5 | 23.8 | 93 | 52 | 5.5 | 0.0 |
| 11 | 11/01/11 | 33.6 | 24.0 | 95 | 48 | 6.3 | 0.0 |
| 12 | 12/01/11 | 33.8 | 22.1 | 78 | 40 | 6.9 | 0.0 |
| 13 | 13/01/11 | 31.8 | 20.5 | 79 | 32 | 4.6 | 0.0 |
| 14 | 14/01/11 | 32.2 | 19.8 | 65 | 25 | 9.0 | 0.0 |
| 15 | 15/01/11 | 32.2 | 18.2 | 67 | 35 | 10.0 | 0.0 |
| 16 | 16/01/11 | 32.6 | 23.8 | 76 | 48 | 8.9 | 0.0 |
| 17 | 17/01/11 | 32.9 | 22.8 | 83 | 47 | 9.8 | 0.0 |
| 18 | 18/01/11 | 33.4 | 22.3 | 78 | 35 | 9.8 | 0.0 |
| 19 | 19/01/11 | 33.4 | 21.7 | 63 | 30 | 10.2 | 0.0 |
| 20 | 20/01/11 | 33.6 | 18.8 | 72 | 23 | 10.1 | 0.0 |
| 21 | 21/01/11 | 32.8 | 19.0 | 72 | 34 | 9.9 | 0.0 |
| 22 | 22/01/11 | 31.8 | 21.9 | 67 | 38 | 9.9 | 0.0 |
| 23 | 23/01/11 | 32.0 | 21.0 | 64 | 32 | 9.9 | 0.0 |
| 24 | 24/01/11 | 32.0 | 23.2 | 64 | 33 | 9.9 | 0.0 |
| 25 | 25/01/11 | 31.5 | 22.7 | 70 | 39 | 9.8 | 0.0 |
| 26 | 26/01/11 | 32.1 | 23.3 | 67 | 41 | 9.8 | 0.0 |
| 27 | 27/01/11 | 32.8 | 24.9 | 68 | 46 | 9.8 | 0.0 |
| 28 | 28/01/11 | 32.8 | 23.0 | 70 | 35 | 9.5 | 0.0 |
| 29 | 29/01/11 | 33.7 | 22.1 | 77 | 35 | 10.0 | 0.0 |
| 30 | 30/01/11 | 34.0 | 23.5 | 66 | 35 | 10.1 | 0.0 |
| 31 | 31/01/11 | 34.1 | 24.4 | 57 | 23 | 10.6 | 0.0 |

**February 2011**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/02/11 | 34.6 | 23.9 | 61 | 23 | 9.1 | 0.0 |
| 2 | 02/02/11 | 32.0 | 22.8 | 51 | 26 | 7.0 | 0.0 |
| 3 | 03/02/11 | 33.1 | 23.2 | 54 | 25 | 9.8 | 0.0 |
| 4 | 04/02/11 | 33.4 | 20.4 | 63 | 35 | 9.8 | 0.0 |
| 5 | 05/02/11 | 34.1 | 18.3 | 50 | 23 | 10.4 | 0.0 |
| 6 | 06/02/11 | 33.8 | 21.9 | 64 | 24 | 10.4 | 0.0 |
| 7 | 07/02/11 | 34.1 | 19.7 | 65 | 37 | 7.7 | 0.0 |
| 8 | 08/02/11 | 34.5 | 22.6 | 86 | 38 | 8.9 | 0.0 |
| 9 | 09/02/11 | 34.5 | 22.4 | 73 | 37 | 8.7 | 0.0 |
| 10 | 10/02/11 | 35.0 | 21.3 | 69 | 16 | 10.5 | 0.0 |
| 11 | 11/02/11 | 34.4 | 20.9 | 66 | 16 | 10.5 | 0.0 |
| 12 | 12/02/11 | 33.6 | 23.6 | 48 | 17 | 10.4 | 0.0 |
| 13 | 13/02/11 | 34.7 | 20.8 | 45 | 17 | 10.3 | 0.0 |
| 14 | 14/02/11 | 35.0 | 19.3 | 74 | 26 | 10.3 | 0.0 |
| 15 | 15/02/11 | 32.7 | 21.5 | 78 | 46 | 9.2 | 0.0 |
| 16 | 16/02/11 | 32.9 | 21.2 | 89 | 42 | 9.1 | 0.0 |
| 17 | 17/02/11 | 34.0 | 20.7 | 94 | 50 | 9.8 | 0.0 |
| 18 | 18/02/11 | 32.9 | 21.0 | 94 | 45 | 9.7 | 0.0 |
| 19 | 19/02/11 | 33.7 | 19.7 | 93 | 50 | 9.8 | 0.0 |
| 20 | 20/02/11 | 33.6 | 21.9 | 91 | 59 | 5.0 | 0.0 |
| 21 | 21/02/11 | 32.4 | 23.6 | 87 | 57 | 5.9 | 0.0 |
| 22 | 22/02/11 | 34.7 | 23.7 | 91 | 52 | 7.8 | 59.6 |
| 23 | 23/02/11 | 33.9 | 23.1 | 91 | 46 | 5.6 | 5.5 |
| 24 | 24/02/11 | 33.2 | 23.1 | 91 | 50 | 3.4 | 0.8 |
| 25 | 25/02/11 | 32.9 | 23.8 | 83 | 52 | 7.6 | 0.0 |
| 26 | 26/02/11 | 32.6 | 23.8 | 93 | 55 | 5.6 | 11.6 |
| 27 | 27/02/11 | 33.4 | 22.6 | 91 | 48 | 6.8 | 0.0 |
| 28 | 28/02/11 | 33.7 | 24.2 | 72 | 39 | 10.0 | 0.0 |

**March 2011**

| Sl no. | Date | Maximum temperature | Minimum temperature | RH morning | RH evening | SSH (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 01/03/11 | 33.7 | 23.3 | 77 | 31 | 10.1 | 0.0 |
| 2 | 02/03/11 | 34.2 | 23.1 | 54 | 27 | 10.5 | 0.0 |
| 3 | 03/03/11 | 35.5 | 22.8 | 51 | 17 | 10.3 | 0.0 |
| 4 | 04/03/11 | 35.6 | 21.3 | 75 | 32 | 10.0 | 0.0 |
| 5 | 05/03/11 | 34.7 | 22.9 | 90 | 43 | 9.3 | 0.0 |
| 6 | 06/03/11 | 36.5 | 24.1 | 93 | 29 | 9.7 | 0.0 |
| 7 | 07/03/11 | 36.6 | 23.3 | 91 | 20 | 10.1 | 0.0 |
| 8 | 08/03/11 | 37.4 | 23.3 | 91 | 20 | 9.8 | 0.0 |
| 9 | 09/03/11 | 35.0 | 24.3 | 91 | 49 | 9.0 | 0.0 |
| 10 | 10/03/11 | 34.2 | 22.9 | 90 | 59 | 8.8 | 0.0 |
| 11 | 11/03/11 | 34.6 | 24.1 | 95 | 54 | 8.6 | 0.0 |
| 12 | 12/03/11 | 36.0 | 23.7 | 92 | 23 | 9.3 | 5.8 |
| 13 | 13/03/11 | 36.0 | 23.2 | 90 | 35 | 9.4 | 4.2 |
| 14 | 14/03/11 | 34.0 | 23.0 | 93 | 61 | 9.8 | 0.0 |
| 15 | 15/03/11 | 36.2 | 23.7 | 92 | 28 | 9.7 | 0.0 |
| 16 | 16/03/11 | 36.5 | 24.3 | 85 | 26 | 9.7 | 0.0 |
| 17 | 17/03/11 | 35.0 | 24.7 | 67 | 27 | 9.6 | 0.0 |
| 18 | 18/03/11 | 34.5 | 23.1 | 69 | 29 | 9.9 | 0.0 |
| 19 | 19/03/11 | 34.2 | 21.9 | 74 | 39 | 9.5 | 0.0 |
| 20 | 20/03/11 | 33.2 | 23.3 | 85 | 55 | 7.1 | 0.0 |
| 21 | 21/03/11 | 34.5 | 24.7 | 92 | 56 | 7.7 | 0.0 |
| 22 | 22/03/11 | 34.0 | 24.3 | 92 | 58 | 7.4 | 0.0 |
| 23 | 23/03/11 | 34.6 | 24.9 | 90 | 55 | 8.8 | 0.0 |
| 24 | 24/03/11 | 33.3 | 25.7 | 92 | 59 | 6.7 | 0.0 |
| 25 | 25/03/11 | 33.0 | 24.4 | 93 | 57 | 7.7 | 0.0 |
| 26 | 26/03/11 | 33.8 | 25.7 | 79 | 63 | 3.1 | 0.0 |
| 27 | 27/03/11 | 34.6 | 24.3 | 86 | 59 | 7.4 | 0.0 |
| 28 | 28/03/11 | 33.7 | 26.2 | 92 | 58 | 5.3 | 0.0 |
| 29 | 29/03/11 | 33.7 | 25.3 | 88 | 58 | 7.7 | 0.0 |
| 30 | 30/03/11 | 34.8 | 24.2 | 93 | 57 | 8.7 | 0.0 |
| 31 | 31/03/11 | 34.8 | 24.0 | 92 | 56 | 8.2 | 0.0 |

## APPENDIX VII

**Fruit quality assessment of parental mango varieties**

| Variety | TSS (° brix) | Acidity (%) | Total sugar (%) |
|---|---|---|---|
| Banganapalli | 19.0 | 0.3 | 9.4 |
| Muvandan | 15.1 | 0.3 | 8.5 |
| Priyur | 10.1 | 0.2 | 8.4 |
| Vellaikolumban | 16.3 | 0.1 | 10.1 |
| Alphonso | 18.0 | 0.4 | 12.4 |
| Neelum | 11.5 | 0.2 | 10.2 |

# BIODIVERSITY ANALYSIS OF TRADITIONAL MANGO TYPES OF KERALA AND STUDIES ON THE REPRODUCTIVE BIOLOGY OF SELECTED POPULAR TYPES

By

**MANNAMBETH RENISHA JAYARAJAN**

## ABSTRACT OF THE THESIS

*submitted in partial fulfillment of the*

*requirement for the degree of*

*Master of Science in Horticulture*

**Faculty of Agriculture**

**Kerala Agricultural University**

**DEPARTMENT OF POMOLOGY AND FLORICULTURE**

**COLLEGE OF HORTICULTURE**

**VELLANIKKARA, THRISSUR-680 656**
**KERALA, INDIA**

**2011**

## ABSTRACT

The present investigations entitled "Biodiversity analysis of traditional mango types of Kerala and studies on the reproductive biology of selected popular types" were undertaken at the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2009-2011. Major objectives of the study were to assess the biodiversity status of traditional mango types in selected villages of Thrissur and Palakkad districts of Kerala by applying participatory tools and studying the floral biology, pollen characters, pollination and self and cross compatibility factors in six mango varieties commonly grown in the homesteads of Kerala.

These studies formed a part of the departmental project entitled "Hybridization of mango varieties of Kerala" and were taken up under two broad components during implementation.

**Component I:**

Primary assessment of indigenous mango types was initiated by surveying homesteads in Vallachira and Pazhayannur GP's of Thrissur district and Kollemgode and Muthalamada GP'S of Palakkad district. Homesteads were selected by snowball sampling. Dominant local types in these homesteads were Muvandan in Pazhayannur and Chandrakkaran in Vallachira GP of Thrissur whereas Muvandan, Priyur, Chandrakaran and some unnamed landraces in Kollemgode and Muthalamada GPs of Palakkad district. Final village level biodiversity assessment was done in Maruthampadam in Pazhayannur GP (Thrissur Dt) and Erippadam in Muthalamada GP (Palakkad Dt.). Farmer participatory 4- cell analysis (FCA) and focus group discussions (FGD) were made by organizing farmers interface in these villages. Data recorded showed that Maruthampadam village was richer in crop diversity than Erippadam. Based on the FCA, Muvandan, Pulimanga and Gomanga could be

grouped as the 'common' types of the Maruthampadam village while the 'rare' types included Karpuramanga, Ganapatimookan, Kilichundan, Chandrakaran, Kottamavu, Sindhuram, Marathakam and Mundappa . 'Common' mango types in Erippadam village were Alphonso, Banganapalli, Kilichundan, Neelum, Sindhuram, Muvandan, Nadasala and the 'rare' types being Chandrakaran, Kilimook, Mallika and Mundappa. The varietal richness of Erippadam was higher than Maruthampadam village. In Maruthampadam village, recorded evenness value was highest for Muvandan while it was zero for the 'rare' and 'vulnerable' types. In Eripaddam, 'common' types registered higher evenness values than 'rare' types. Varietal richness as related to size of gardens indicated positive relationship in Erippadam village. ITK documentation from the villages provided some useful information on the traditional processing and product diversification of mango fruits practiced by the villagers in Maruthampadam.

**Component II:**

The varieties involved in the study were Muvandan, Neelum, Priyur, Vellaikolumban, Banganapalli and Alphonso. Mango flowering in both the seasons during 2009-10 and 2010-11 were of much erratic, poor and belated nature. A definite influence of the shift in north east monsoon pattern experienced during these periods could be attributed as the major contributory factor to the above. Peak anthesis was noted between 7.30 and 11.00am in all varieties and anther dehiscence between 8.30 am and 12 noon. Highest stigma receptivity was on the day of anthesis. Panicles of Muvandan and Priyur were longer than the other varieties. The varieties Neelum, Priyur, Alphonso, Vellaikolumban, and Muvandan exhibited a mixed phase while opening out but in Banganapalli, flower opening started with a pure male phase and thereafter entered mixed phase. Inflorescence rachis of Muvandan was dark red in colour where as in Neelum and Alphonso it was light red. Light green coloured inflorescence rachis was observed in Banganapalli and Vellaikolumban while in

Priyur it was light green with reddish tinge. Size of inflorescence was highest in Muvandan while it was lowest in Neelum. Intensity of flowering per unit area of tree canopy was highest in Alphonso where as it was lowest in Vellaikolumban. Highest percentage of hermaphrodite flowers was recorded in Vellaikolumban (46.38%) while it was lowest in Banganapalli (0.02 %). The varieties Neelum, Priyur, Alphonso and Vellaikolumban showed round shaped pollen whereas oval and oblong shaped pollen was noted in Banganapalli and Muvandan, respectively. The size of the pollen ranged in between 27.29µm and 33.34µm. Pollen production and viabiliy were related to climatic variations. Pollen storage in refrigerated conditions retained viability for 72 hours. Selfing did not result in fruit setting and apparently indicating the involvement of incompatibility factors. It has to be further confirmed by flourimetric methods. Crossing among the varieties affected fruit setting obviating the involvement of incompatibility factors. Four successful hybrid mango progeny seedlings are available finally for performance evaluation.