FLORAL BIOLOGY ANTHESIS AND FRUIT DEVELOPMENT IN DRUMSTICK (*Moringa oleifera* Lam.)

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DECLARATION

I hereby declare that this thesis entitled "**Floral biology, anthesis and fruit development in drumstick (*Moringa oleifera* Lam.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled "**Floral biology, anthesis and fruit development in drumstick (*Moringa oleifera* Lam.)**" is a record of research work done independently by Ms. Sindhu. K. Mathew 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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Dedicated to

Appachan and Amma

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CONTENTS

LIST OF TABLES

LIST OF TABLES continued

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	per cent
@	At the rate of
^{0}C	Degree Celsius
µm	Micro metre
cm	Centimetre
et al.	And others
F.I.B.	Farm Information Bureau
Fig.	Figure
g	Gram
h	Hour
ha	Hectare
i.e.	That is
KAU	Kerala Agricultural University
mm	Millimetre
N-E	North East
No.	Number
ppm	Parts per million
t	Tonnes
viz.	Namely

INTRODUCTION

1. INTRODUCTION

Drumstick or moringa (*Moringa oleifera* Lam.) is a vitamin rich, mineral packed perennial vegetable belonging to the family Moringaceae. It's a native of North West India and is widely distributed in India, Sri Lanka, Pakistan, Singapore, Malaysia, Cuba, Jamaica and Egypt (Ochse, 1977; Ramachandran *et al.*, 1980).

The variety of products that can be obtained and the number of uses for which drumstick can be put to, have pushed this plant to the fore-front of rural development. The leaves, fruits and flowers are used as nutritious vegetable. They are rich source of proteins, amino acids vitamins and minerals (Rajkumar *et al.*, 1973). Roots are good substitute for horseradish. Seeds yield 'ben oil' which is much valued in perfumery and pharmaceuticals (Delaveav, 1980). Seeds are also used for water purification (Manickam and Ghosh, 1986). The bark fibre is used for making mats, paper and cordage (Seemanthini, 1964; Aykroyd, 1966; Verma *et al.* 1976; Ochse, 1977; Peter, 1978 and 1979). Fruits have been used against diabetes and some compounds from the roots act to reduce the fertility in mice (Mossa, 1985; Shukla *et al.*, 1988). Considering these remarkable attributes, the crop has been identified as the important one both in dry land agriculture as well as in agri-horti-silvi programme (Sundarraj *et al.*, 1970; Morton, 1991).

In Kerala, the humid tropics of India, drumstick is grown in most of the homesteads and the total area is estimated as 19838 ha with a production of 21.162 t (F.I.B., 2000). Despite its nutritional, economical and medicinal importance, the crop still remains neglected and not much work has been done on its improvement.

Kerala, being a state with tremendous variability, it is high time to characterise and exploit drumstick in terms of crop improvement. Annual

moringa released from Tamil Nadu Agricultural University is getting popularity among the farmers of Kerala. Drumstick clones with earliness, high yield, superior quality and even dwarf stature are the needs of the hour.

Floral biology is of great importance for execution of any breeding programme. Such information is virtually lacking in most of the tropical crops in general and moringa in specific (Bawa, 1976). So it needs greater attention and research to collect such information to improve this crop. Keeping this aspect in view, the present study was formulated with the following objectives.

1. To study the trend in flowering and fruiting
2. To gather basic information on anthesis, anther dehiscence and stigma receptivity
3. To know about the system of pollination, pollinators, fruit set and fruit development.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Drumstick (*Moringa oleifera* Lam.) is one of the most popular multipurpose perennial vegetables of South India. Despite its nutritional, medicinal and economic importance, very little work has been done on its improvement. The information on floral biology, fruit set and fruit development in drumstick is scanty. The available literature is reviewed under the following heads.

1. Phenology of flowering and fruiting
2. Emergence of flower bud
3. Anthesis
4. Anther dehiscence
5. Stigma receptivity
6. Pollen morphology
7. Estimation of pollen production
8. *In vitro* germination, pollen tube growth and pollen viability
9. Pollen storage
10. Pollination
11. Fruit development

2.1 PHENOLOGY OF FLOWERING AND FRUITING

Drumstick (*Moringa oleifera* Lam.) is an evergreen plant in most of the places in India. Muthuswamy (1954) reported two main flowering seasons *viz.*, March–April and July–September under Coimbatore condition.

Under Lucknow and Punjab conditions there was only one flowering season during February–March (Singh 1962; Nair and Singh, 1974).

Ochse (1977) reported that in West Indies there were moringa types which rarely flower and were principally cultivated for their foliage.

Duke (1978) reported that moringa thrived well in tropical and subtropical climate with free and continuous flowering and fruiting. Fruit production peaked in March and April in Sri Lanka.

Ramachandran *et al.* (1980) reported that 'Chemmuringa' flowered throughout with heavy yield.

Under Bangalore conditions, flowering was observed in two seasons i.e., March-May and July–September. Profused and prolonged flowering was seen in March–May (Devar *et al.*, 1981).

Annual drumstick had precocious flowering and bearing tendencies (Mohideen and Shanmugavelu, 1983).

Indira and Peter (1988) reported that under North Indian conditions plant remained dormant in December–January. Flowering and fruiting occurred in February. In South India there were two crops, one in March-April and second in July- September. Chemmuringa flowered throughout the year.

Jyothi *et al.* (1990) reported that in Visakhapatanam, *Moringa oleifera* flowered twice a year, February to May and September to November.

Pushpangathan *et al.* (1996) reported that in N-E part of India, moringa flowered during February and gave mature fruits during March–April. In South India, moringa flowered several times in a year depending upon the weather conditions. In Jamaica and Florida, moringa flowered throughout the year.

Annual drumstick had early flowering habit commencing from August–September with a peak period of blossoming during December–January in Thrissur. Even though it flowered early, fruit set occurred only in December–January blooms (Babu and Rajan, 1996).

Veeraragavathatham *et al.* (1998) evaluated the local drumstick plants available in Tamil Nadu and identified two annual types, KM 1 and PKM 1 based on the flowering habit.

Studies conducted at the College of Horticulture, Vellanikkara revealed that most of the perennial drumstick clones flowered late in the season (KAU, 1999).

2.2 EMERGENCE OF FLOWER BUD

Devar *et al.* (1981) studied the flower bud development in moringa and reported ten distinctive stages in the development. Flower bud took 24.4 days at Bangalore for its complete development from visible initiation to the opening. The mature buds were described as elongated bulged at the centre and roundish at the apex. The average length and diameter were 1.2 and 0.6 cm respectively. The flower colour was yellowish white with greenish calyx

2.3 ANTHESIS

Devar *et al.* (1981) reported that under Bangalore conditions anthesis in moringa commenced as early as 4.30 am and continued till 6.30 am. Anthesis peak was at 5.30 am. After 6.30 am there was no anthesis.

Under Visakhapatanam conditions flowers opened from 03 to 19 h (Jyothi *et al.*, 1990).

Babu and Rajan (1996) reported that in annual moringa, the flower opening commenced from 2.30 pm and completed by next day around 9 am.

At Coimbatore, anthesis in moringa commenced from 4.30 am with a peak at 5.30 am. At the Horticultural College and Research Institute, Periyakulam, anthesis commenced as early as 2.30 am and continued upto 7.00 am with a peak at 5.30 am (Subramanion *et al.*, 1997).

2.4 ANTHER DEHISCENCE

Devar *et al.* (1981) reported that the anther of the longest stamen dehisced first followed by the rest of the stamen in the descending order of filamental length. The anther dehisced after anthesis. The anther dehiscence was 0, 16, 80 and 4 per cent at 3.30, 4.30, 5.30 and 6.30 am. After 6.30 am there was no anther dehiscence.

Drumstick anthers dehisced at anthesis by longitudinal splits. Overcast sky or rainy weather delayed the process for 30 minutes (Jyothi *et al.*, 1990).

Babu and Rajan (1996) reported that in annual moringa, flower opening and anther dehiscence was in a phased manner. Anthers were of closed type at the time of flower opening and dehisced next day between 9.00 and 9.30 am.

Subramanion *et al.* (1997) reported that anther of the longest stamen dehisced first.

2.5 STIGMA RECEPTIVITY

Stigma was receptive a day prior to opening of flowers and continued upto the day of opening of flowers with maximum receptivity on the day of opening. The stigma was non-receptive one day after the opening (Devar *et al.*, 1981).

Jyothi *et al.* (1990) reported that stigma became receptive after 24 h of anthesis continued to be so for 48 h and then turned light brown. Hand pollination of freshly receptive stigma gave 100 per cent fruit set, those of 24 h old ones gave 72 per cent and 48 h old ones 36 per cent.

Stigmatic receptivity was 24, 72 and 4 per cent respectively one day before anthesis, on the day of anthesis and one day after anthesis. Two days after anthesis stigma became non-receptive (Hanchinamani *et al.*, 1994).

In annual moringa, stigma was introvert and non receptive at the time of anthesis in Thrissur. Stigma got exerted out in the next day morning between 8 and 8.30 am and became receptive (Babu and Rajan, 1996).

2.6 POLLEN MORPHOLOGY

Nair and Singh (1974) reported that the average diameter of fertile pollen grains was 54 µm.

Pollens were creamy white with spheroidal shape. It was tricalporate and smooth walled. The average diameter of fertile and sterile pollen grains were 46.5µm and 34.3 µm respectively (Devar *et al.*, 1981).

Pollen viability and storage studies revealed that fertile pollen grains were of size 32.33 to 41.65 µm where as the size of sterile pollen grains ranged from 22.99 to 32.33 µm. (Singh *et al.*, 1983; Ferguson, 1985).

The drumstick pollen grains had 35 µm diameter and were spheroid with oily and sticky surface (Jyothi *et al.*, 1990).

Babu and Rajan (1996) reported that in annual moringa, fertile pollen had a diameter of 33.3 µm where as sterile one had 22.1 µm.

2.7 ESTIMATION OF POLLEN PRODUCTION

Nair and Singh (1974) reported that under Lucknow conditions, the average number of pollen grains per anther was 7400. However, Devar *et al.* (1981) reported that the average pollen production per anther was 7800. According to Jyothi *et al.* (1990) the average pollen grains per anther ranged from 4720-5600.

2.8 *IN VITRO* GERMINATION, GROWTH OF POLLEN TUBE AND POLLEN VIABILITY

Pollen germination was 89 per cent in 5 per cent sucrose medium while the stainability was 97.41 per cent (Devar *et al.*, 1981).

Viability reading by the germination method was lower than those of staining method in various crops viz., cocoa (Rajamony, 1981), Lovi-lovi (George *et al.*, 2000) and tuberose (Seetharama *et al.*, 2000).

Singh *et al.* (1983) reported that pollen germination was highest for fresh pollen on a media containing 6 per cent sucrose and 15 ppm boric acid. Similarly, in annual moringa, just dehisced pollen had 92.5 per cent stainability. (Babu and Rajan ,1996).

2.9 POLLEN STORAGE

Johri and Vasil (1961) reported that *Arachis hypogea* pollen required 10 per cent sucrose for optimal germination whereas those stored for 7-15 days required 12 per cent sucrose.

Jyothi *et al.* (1990) revealed that 24 h old drumstick pollen gave 72 per cent germination in 100 per cent sucrose while 72 h old gave 30 per cent and afterwards zero.

2.10 POLLINATION

Grant (1950) listed drumstick flowers as bird pollinated.

Moringa flowers were good source of nectar and pollen and flowers were predominantly pollinated by honey bees (Singh, 1962; Nair and Singh, 1974).

Ramachandran *et al.* (1980) reported that flowers were fragrant and bisexual.

Devar *et al.* (1981) reported that drumstick was highly cross-pollinated and the honeybees were the active flower visitors. Assisted crossing resulted in 66 per cent fruit set whereas natural pollination and natural selfing resulted in 56 per cent and 20 per cent fruit set respectively.

Jyothi *et al.* (1990) reported that drumstick flowers were visited by diurnally active insects like *Xylocopa* spp. *Trigona* sp. and *Apis* spp. The

insect activity was low at 8.00 h, increased to a peak at 10.00 to 12.00 h and then declined and ceased around 18.00 h.

Watson and Dallwitz (1992) reported that moringa plants were hermaphrodite.

Hanchinamani *et al.* (1994) reported that local cultivars preferred cross pollination while improved cultivars preferred self pollination. Hand pollination resulted in 48 per cent fruit set while open pollination resulted in 72 per cent fruit set.

Pushpangathan *et al.* (1996) reported that moringa flowers were visited by bumble bees and honey bees.

Babu and Rajan (1996) reported the involvement of ants and flea beetle in the pollination of moringa. They also found that assisted pollination on the exerted stigma between 8 and 8.30 am resulted in better fruit set.

Subramanion *et al.* (1997) reported that moringa plant was cross pollinated. Similarly Peter (1998) opined that the bisexual flowers were highly cross pollinated due to heteromorphism and was entomophilous. Bees were the major pollinator.

Rakhee (2000) reported that drumstick flowers were visited predominantly by *Trigona* sp.

2.11 FRUIT DEVELOPMENT

Iyer (1980) reported that in moringa fruits, the levels of cytokinin and gibberellins were high at the initial stages and the auxin activity peaked later.

Iyer *et al.* (1981) divided the fruit development in drumstick into three stages, namely, initial stage (5-10 cm) developing stage (25-30 cm) and the mature stage (45-50 cm). Fruits elongated rapidly during the developing stage. Auxin activity was low at the initial stage, rose to peak when they were 25-30 cm and fall to low level at maturity.

Nagar *et al.* (1982) identified zeatin and zeatin riboside from immature fruit of 30-40 cm long and the concentration peaked when fruits were 40 cm long.

In annual moringa, the maximum fruit length was attained on the 85th day of anthesis and there after a slight and gradual decrease was noticed. Fruits took 100 days for physiological maturity (Palanisami *et al.*, 1985).

Drumstick of Jaffna type grown in parts of South India produced fruits of 60 to 90 cm length. 'Chavakacheri murunga' produced fruits of length 90-120 cm and 'Kodikal murungai' produced very short fruits (Indira and Peter, 1988).

Jyothi *et al.* (1990) reported that flower buds prematurely drop off in two seasons, about 30 per cent during February-May and 40 per cent during September-November and the natural fruit set during this periods were 15 per cent and 11 per cent respectively.

Hanchinamani (1992) reported that fruits took 60 days for horticultural maturity in rainy season where as 30 days were enough during summer season. .But the heat unit requirement was almost same in both seasons and the average value was 590.34.

Under Dharwad condition local cultivars had 72 per cent fruit set under open pollination. Flower shedding was 18.4 per cent and maturity per cent was only 0.2 per cent. On an average 19 pods were produced per plant (Hanchinamani *et al.*, 1994).

Pushpangathan *et al.* (1996) reported that moringa fruits were about 60-100cm long, green and splitted longitudinally on ripening.

Chadha (2001) reported that more the flower clustering on the tree, the less will be the yield. On an average, an inflorescence consisted fifty three flowers and only 1 to 2.8 per cent of fruits came to maturity.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study was conducted during a calendar year starting from the rainy season June 2001 to the summer season, May 2002 at the College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. Sixty bearing moringa plants of local variety maintained in the Instructional Farm of the College of Agriculture were used for the study. The plants were maintained with uniform management practices.

The weather parameters during the period of study are presented in Table3.1 and illustrated in Fig.1 and 2.

3.1 PHENOLOGY OF FLOWERING AND FRUITING

Ten bearing plants were selected and marked for the study. Monthly count of total inflorescence and fruits produced were recorded on the last day of each month. This was continued for one calendar year. Average flower production per day was also recorded. For this, one branch was selected in each plant. The total number of flowers opened per day in that branch was precisely counted. That number was multiplied with the number of branches to get the total number of flowers opened per day. The study was repeated in five consecutive days and the average was taken. Average flower production per month and the non-flowering months were also recorded.

3.2 EMERGENCE OF FLOWER BUD

3.2.1 Number of Days From Initiation to Anthesis

Ten inflorescence were marked at the time of initiation. The days taken form the date of initiation to the opening of first flower in that panicle was recorded. The degree-day requirement was also worked out using the following formula suggested by Gupta (1975).

Table 3.1 Weather parameters during the period of June 2001to May 2002

Months	Average maximum temperature, °C	Average minimum temperature, °C	Total rainfall, mm	Total sun shine hours	Average relative humidity, %
June	30.42	21.15	182.50	150.20	79.98
July	30.34	20.30	297.50	140.30	82.70
August	29.60	21.20	189.50	191.80	84.20
September	30.10	23.80	558.20	207.30	80.90
October	30.00	24.00	256.90	203.90	83.19
November	30.39	23.48	238.10	185.00	77.00
December	30.85	23.10	20.60	227.30	79.90
January	31.05	22.19	0.00	248.50	78.69
February	30.50	22.26	15.00	237.60	75.80
March	32.95	23.50	16.70	264.10	74.95
April	33.10	24.80	50.60	236.90	76.97
May	31.50	25.00	200.10	177.40	80.08

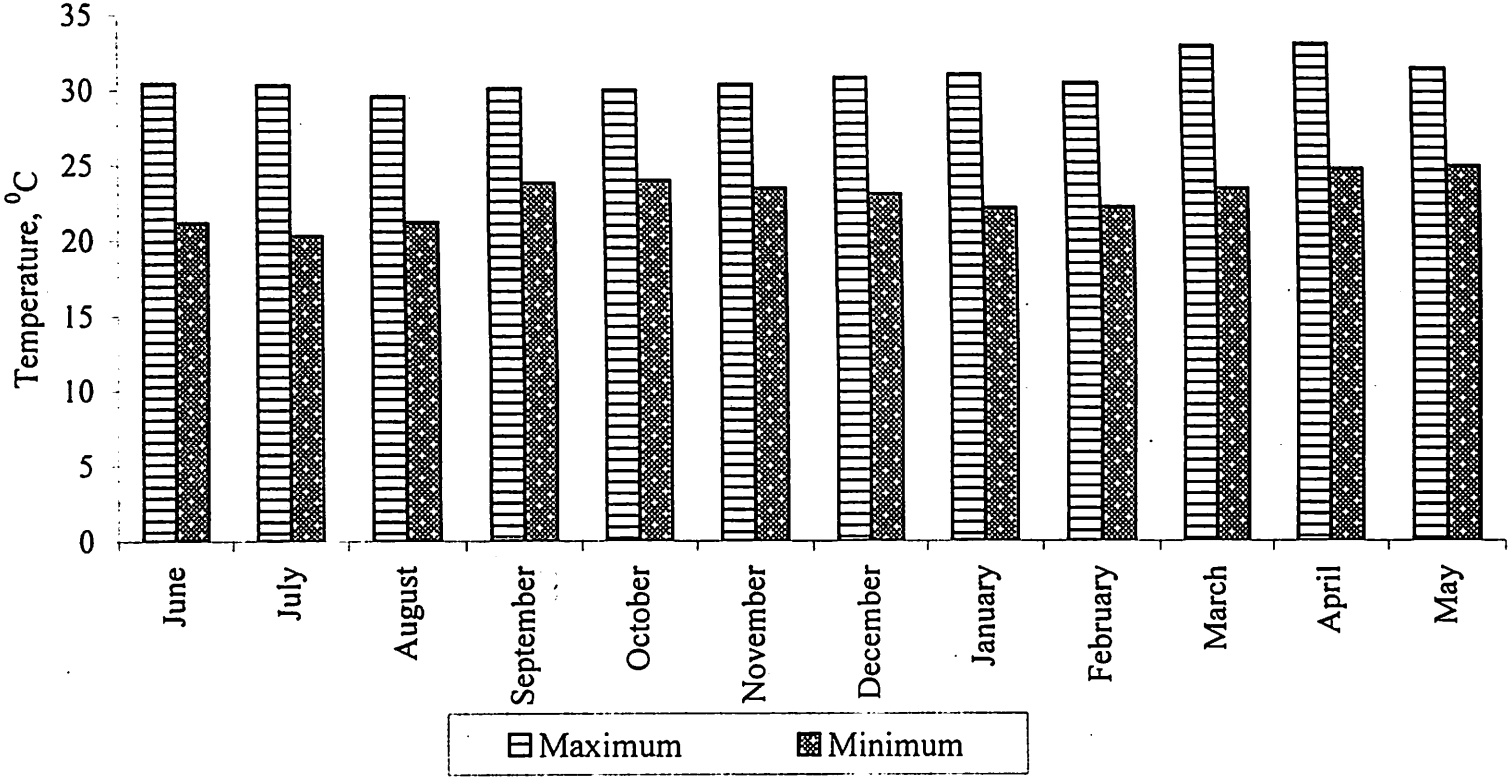

Fig. 1. Maximum and minimum temperature during the period from June 2001 to May 2002

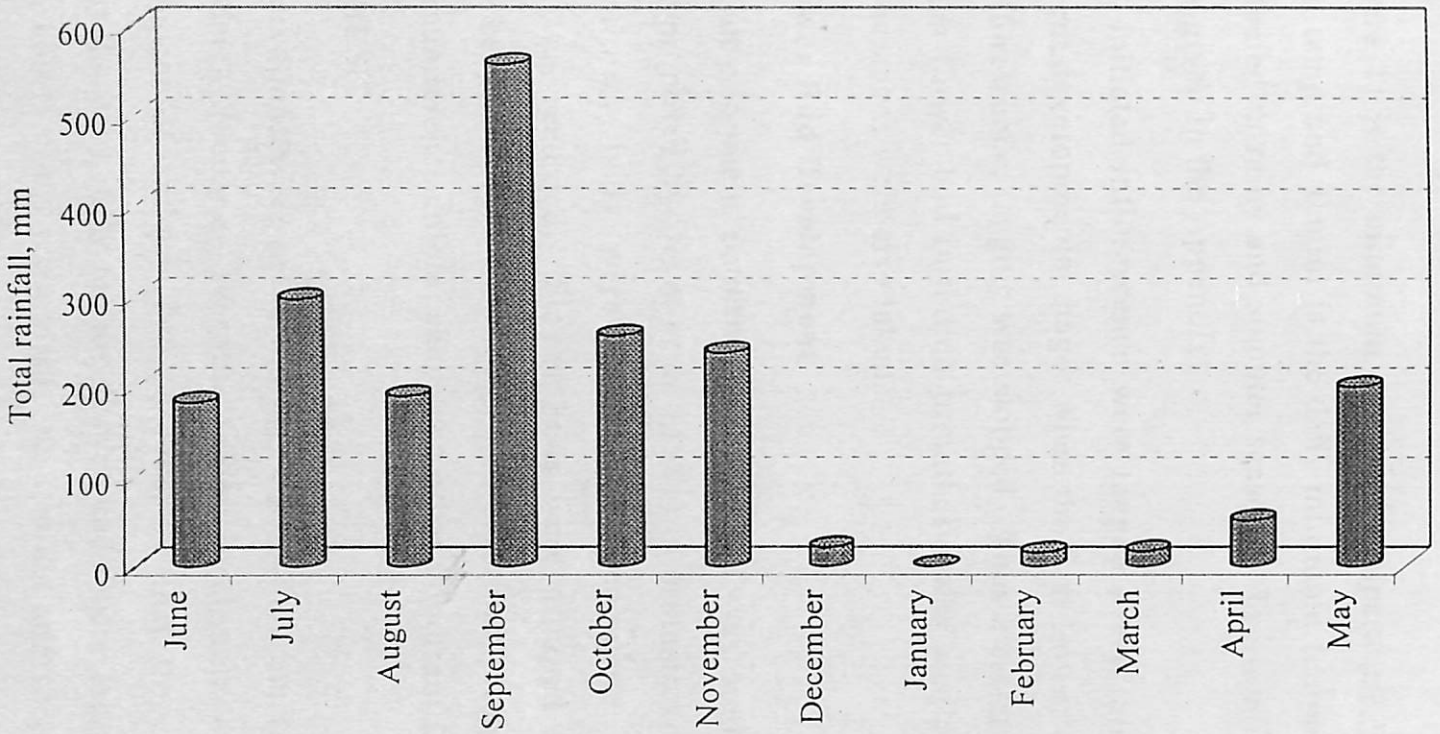

Fig. 2. Rainfall distribution during June 2001 to May 2002

$$\text{Growing degree days (GDD)} = \sum_{T=1}^{n} \frac{\text{Tmax} + \text{Tmini}}{2} - \text{Tt}$$

Where Tt is the minimum threshold temperature, Tmax is the daily maximum temp and T mini is the daily minimum temperature. The study was conducted in rainy and summer seasons. The temperature during the study was given in the Appendix1.

Just initiated inflorescence were tagged every third day for tracing the different developmental stages when the first flower opened in the first tagged inflorescence, tagging was stopped. Thus a series of developmental stages from flower bud initiation to anthesis was available. Photographs of different stages were also taken.

3.2.2 Flower Bud Development

The development pattern of flower bud was studied, adopting the procedure proposed by Devar *et al.* (1981) in drumstick. Twenty five just emerged flower buds were marked and complete development till blooming was recorded. Flower buds were grouped into seven stages arbitrarily based on size. Each stage was described properly indicating the length, circumference colour, shape and other important features.

3.3 ANTHESIS

Observations were made during July- September (rainy season) and January–March (summer season). After preliminary observations on commencement of anthesis (which revealed that flowers were opening throughout the day), fifty mature flower buds were tagged at 6 pm. each day. Two observations were made one at 6 am and second at 6 pm. The first one was reckoned as the number of flowers opened at night and the second one as the number opened in day time. From these observations the percentage of flowers opened during day and night was worked out

separately. Later, precise observations were made in day and night. Fifty flower buds were marked and observations were made from 6 pm of the day to 6 pm in the next day at two hour intervals.

3.4 ANTHER DEHISCENCE

Flower buds were tagged in groups of ten at the time of anthesis. There were twelve lots based on the time of flower opening (from 6 pm to 6 pm, in the next day). They were observed with a hand lens at two hour interval for anther dehiscence. Appearance of longitudinal split in the pollen sac indicated the commencement of anther dehiscence. When more than three anthers in a flower liberated pollen grains, it was reckoned as having completed anther dehiscence. The observations were repeated for three days with another group of flowers and the average worked out. Study was conducted both during July–August and February–March.

3.5 STIGMA RECEPTIVITY

Stigma receptivity was assessed based on the following methods.

Adherence of pollen grains to stigma as suggested by Rajamony (1981) in cocoa and fruit set after controlled pollination as adopted by Devar *et al.* (1981) in moringa.

In the first method, anthers from freshly opened flowers were rubbed on to the stigmatic surface. The stigmatic surface was then viewed through a hand lens (4 X) to see whether the transfer of pollen has been effected or not. For this purpose seventy-five flower buds were marked and divided into three lots of twenty-five each. The first lot was collected one day prior to opening and the stickiness of pollen to stigmatic surface was tested. The next lot was collected on the day of opening and the third lot one day after opening.

In the second method, seventy five mature flower buds were marked, emasculated and bagged. Emasculation was done with care to avoid any damage to stigma. The flowers were divided into three lots of twenty five

each. The first lot was pollinated a day prior to opening, the second lot on the day of opening and the third lot next day of opening. The flowers were observed for one week for fruit set. The percent of fruit set in each case was recorded. The study was conducted during February –March.

3.6 POLLEN MORPHOLOGY

Pollen morphology was studied by aceto carmine staining methods and the Pollen size was measured using ocular stage micrometer as adopted by Thakur and Singh (1965) in annona.

In the staining methods, pollen grains from mature flower buds were taken and a slide was prepared using aceto carmine glycerine ester (aceto carmine 50 % + glycerine 50%). The pollen grains were observed through the high power (10x45 X) of the microscope.

Pollen size measurement was done using ocular micrometer. Ocular micrometer was calibrated using stage micrometer. Separate calibration was done for low power (10x10 X) and high power (10x45 X). The calibrated ocular micrometer was used for recording the measurements. Diameter of twenty five pollen grains was measured and the average worked out. The size of both fertile and sterile pollen grains was recorded.

3.7 ESTIMATION OF POLLEN PRODUCTION

Pollen production per flower was estimated using a haemocytometer as suggested by Rao and Khader (1962).

Mature flower buds were collected just before opening. One or two anthers crushed in one ml distilled water. One drop was placed on the haemocytometer using a micropipette and observed through the low power (10x10 X) of the compound microscope. Every time, the first large square with 16 small squares was observed for the presence of pollen grains. Total number of pollens in that square was recorded. Repeated the

observation and the total pollen grains per flower were worked out using the formula.

$$\text{Total pollen grains / anther} = \frac{X \times Y \times \text{constant}}{\text{No. of small squares} \times \text{No. of anthers crushed}}$$

Constant for 1st square = 1.6 lakh

X = total no of pollen grains in the first square

Y= dilution factor (here one)

From the average number of pollen grains per anther, total pollen grains per flower was worked out.

Total pollen grains/ flower = Average pollen grains per anther x Number of anthers.

3.8 *IN VITRO* GERMINATION AND POLLEN TUBE GROWTH

Germination of pollen grains was observed in media containing five different concentrations of sucrose. The sucrose concentrations used were one, five, ten, fifteen and twenty per cent .0.1, 0.5, 1.0, 1.5 and 2 g each of sucrose was dissolved in 10 ml distilled water to prepare the above mentioned concentrations. The media were poured into clean and sterilized petri dishes and kept over night.

Fresh flowers were collected at 6 am and the pollen grains were dusted in the medium on a slide and kept undisturbed for one hour. After one hour, the slide was stained with aceto carmine and the cover slip was placed. This was observed through the low power (10x10 X) and high power (10x45 X) of the microscope. Germination percentage and pollen tube growth was recorded in each medium. The medium which gave higher germination and pollen tube growth was taken as the standard one for further studies.

3.9 POLLEN VIABILITY

Viability of pollen grains was tested by two methods *viz.*, aceto carmine staining method and germination method as adopted by Rajamony (1981) in cocoa.

3.9.1 Acetocarmine Staining Method

Stainability was assessed in 0.5 per cent acetocarmine. Hundred pollen grains were observed at random. Total number of fertile and sterile pollen grains was recorded separately.

3.9.2 Germination Method

Germination was carried out in sucrose medium which was found best in the *in vitro* pollen germination test.

3.10 POLLEN STORAGE

Loss in viability of pollen on storage was estimated as described below. Fresh flowers were collected in a petridish at 6 am. The anthers were put in a tissue paper packet and inserted in a glass specimen tube as suggested by Patel (1938) in coconut. The tubes were sealed with paraffin wax. One lot was kept at room temperature and another was stored in a refrigerator at 5-10 ^{0}C. Anthers collected from freshly opened flowers kept on wet filter paper inside a petridish at room temperature served as the control. Viability based on germination and pollen tube growth was tested daily till no germination was found or germination declined to a negligible level.

3.11 POLLINATION STUDY

Pollination study was carried out as per the method adopted by Devar, *et al.* (1981) in moringa.

3.11.1 Mode of Pollination

One hundred and twenty five fully developed flower buds were marked and divided into five lots of twenty five each. Out of these, first

lot was merely tagged to assess the percentage of natural pollination second lot was not emasculated but bagged to assess the extent of selfing. Third lot was emasculated and kept open for assessing the extent of natural crossing. The fourth lot was emasculated crossed and bagged to assess the percentage of fruit set from assisted crossing. The last lot was emasculated and bagged to prove the involvement of insects in pollination. The flowers were observed for one week and the percentage of fruit set was worked out in each case.

3.11.2 Natural Pollination and the Time of Maximum Insect Activity

In order to assess the extent of natural pollination and the time of maximum insect activity, twenty five fully opened flowers were collected at random at two hour interval in day time. The stigma was observed with a hand lens (4 X) for the presence of pollen. The percentage of pollinated stigma was recorded. The experiment was done in five consecutive days and the average was taken. Insect collection was also done in two hour interval to assess the time of maximum insect activity. The study was conducted both in rainy and summer seasons.

3.11.3 Natural Pollination Over Different Months

The study was conducted in the 5^{th}, 10^{th}, 15^{th}, 20^{th} and 25^{th} day of each month. Fifty fresh flowers were collected at random at 6 pm. The stigma was examined with the help of hand lens (4x) for the presence of pollen. The average value of five observations was used for calculating the natural pollination in each month.

3.11.4 Pollinators

The insects visiting the flowers were collected and identified. The insect collection was done in five different days. Out of the total insects collected, different groups were separated and counted separately. The most efficient pollinator was also identified from that count. The photographs of the pollinators were taken.

3.12 FRUIT DEVELOPMENT

The study included the calculation of the number of days from fertilization to fruit set, fertilization to harvest (horticultural maturity), fertilization to physiological maturity, rate of fruit growth, fruit set per cent, maturity per cent and the flower shedding per cent.

3.12.1 Days from Fertilization to Fruit Set

Twenty five flowers were tagged just after fertilization (assessed by the swelling of ovary and the exertion of style). The time taken for the development of a small fruit was recorded in each case and the average was worked out. The length of fruit at fruit set was also recorded. The study was conducted during rainy and summer seasons.

3.12.2 Days from Fertilization to Maturity

Twenty five flowers were tagged just after fertilization. The developing fruits were observed for length and circumference at weekly intervals till horticultural maturity is reached. Observations were continued till they attained physiological maturity. The measurements were made using a metre scale and a twine.

3.12.3 Flower Shedding and Fruit Set

The study was conducted during two peak flowering periods (July-August and February- March). For this purpose inflorescences were marked after counting the total number of flower buds. The number of flowers which set fruit and number of fruits reaching maturity were recorded. From this, per cent of fruit set, per cent of flower shedding, per cent of fruit drop and per cent of mature fruits were worked out.

3.13 INCIDENCE OF HAIRY CATERPILLAR (*Eupterote* spp.)

Total number of observational plants which were attacked by the caterpillar and the symptoms of attack were recorded every month. Percentage of incidence in each month was worked out accordingly.

RESULTS

4. RESULTS

A study on floral biology, anthesis and fruit development in drumstick (*Moringa oleifera* Lam.) was conducted at the Department of Olericulture, College of Agriculture, Vellayani during a calendar year starting from the rainy season (June 2001) to the summer season (May 2002). The results obtained during the course of investigation are presented below.

4.1 PHENOLOGY OF FLOWERING AND FRUITING

Data on flowering and fruiting pattern are presented in Table 4.1 and illustrated in Fig. 3.

Flower production was seen throughout the year except in the month of November and December. Two peaks in flowering were observed *viz.*, July- August and February-March. Out of this, flower production was maximum in February- March. Mean number of flowers per plant per day varied from 86 in June to 376 in March.

Peak of fruit production was during July –August and March- April. Maximum fruit production was observed during March.

4.2 EMERGENCE OF FLOWER BUD

The description of the flower bud is presented in Table 4.2 and the stages of development are shown in Plates 1 to 5. The flower buds were grouped into seven stages based on size (Plate 3). The data on normal days and degree days requirement from flower bud initiation to anthesis are presented in Table 4.3 and 4.4.

The results revealed that the bud took an average of 29.8 days or 472.25 degree days for its complete development during rainy season. In summer season it was 24.8 days or 471.18 degree days.

Table 4.1 Phenology of flowering and fruiting in drumstick

Month	Total number of inflorescence in ten plants	Mean number of flowers/ day/ plant	Total number of flowers/ month/ plant	Total number of fruits produced in ten plants
June	61	86	2580	10
July	308	336	10416	89
August	264	314	9420	72
September	158	180	5580	63
October	81	94	2820	46
November	-	-	-	-
December	-	-	-	-
January	206	110	3410	25
February	379	318	8904	151
March	390	376	11656	170
April	242	258	7740	165
May	142	164	5084	24

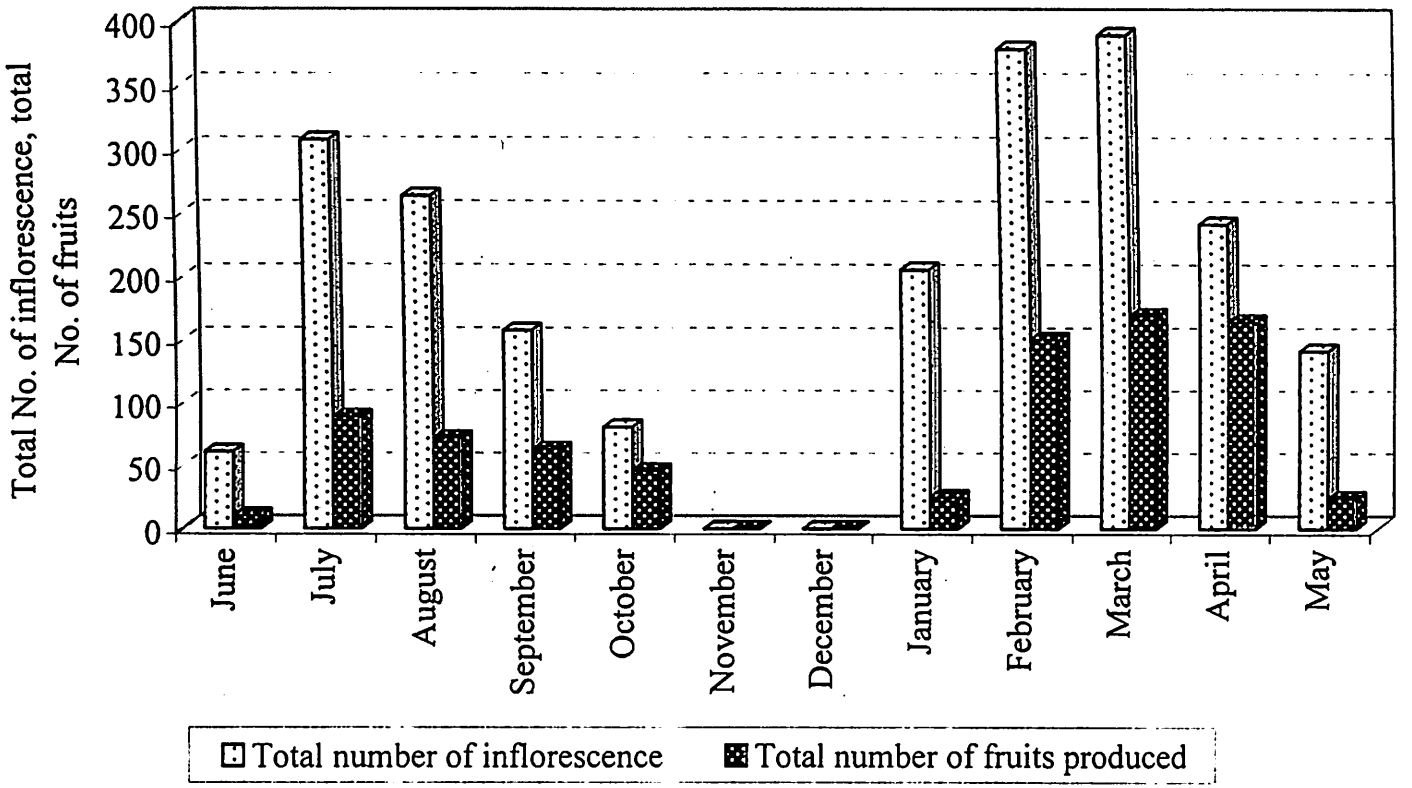

Fig. 3 Flowering and fruiting pattern in drumstick during a calendar year

Table 4.2 Stages of flower bud development in drumstick

Stage	Shape	Size		Description
		Length, cm	Circumference, cm	
1	Globular	0.1	0.1	Buds were greenish and inconspicuous
2	Slightly globular	0.4	0.4	The colour changed to light green and the bud was bulged. Ridges and furrows visible.
3	Elongated	0.9	0.5	Colour became greenish white. The bud enlarged and ridges and furrows more prominent. Tip of the bud became creamy white.
4	Little bit elongated	1.3	0.7	Colour creamy white. The bud was enlarged.
5	Much elongated	1.5	1.1	Colour yellowish white all over, calyx green. Centre portion bulged out, both ends tapering.
6	Elongated, upper portion roundish	1.6	1.3	Yellowish white colour. One side of the bud split opened and one of the petals exposed. The smallest petal exposed first.
7	The flower bud had fully opened	1.7	1.6	Sepals and petals five, yellowish white. Anthers yellow, dorsifixed, filaments were of different length, style creamy white and pitted stigma.

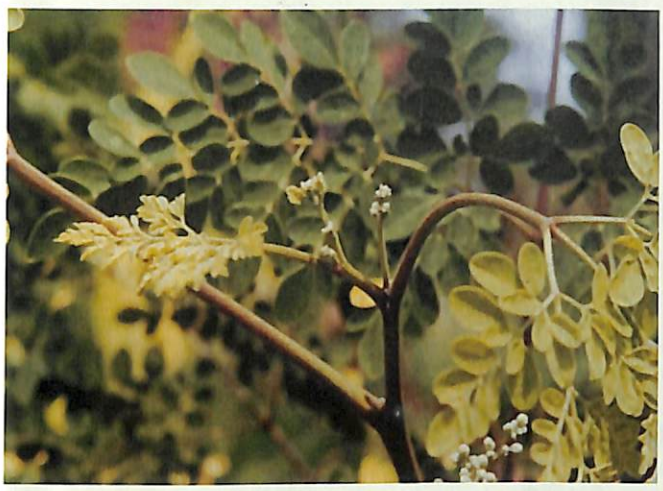

Plate. 1. Flower bud initiation

Plate. 2. Flower bud initiation to first flower

Plate. 3. Stages of development of flower bud

Plate. 4. Flower

Plate. 5. Inflorescence

Table 4.3 Normal days and degree days from flower bud initiation to anthesis in drumstick during rainy season

Date of flower bud initiation	Date of first flower opening	Number of days taken	Degree days
25/07	27/08	33.00	494.40
27/07	28/08	31.00	482.05
29/07	28/08	30.00	454.80
30/07	30/08	31.00	475.20
2/08	1/09	30.00	469.55
5/08	4/09	30.00	481.50
7/08	5/09	29.00	468.10
11/08	9/09	29.00	474.35
12/08	9/09	28.00	457.85
15/08	12/09	27.00	464.75
Average		29.80	472.25

*Minimum threshold temperature for moringa is 10°C

Table 4.4 Normal days and degree days from initiation to anthesis in drumstick during summer season

Date of flower bud initiation	Date of first flower opening	Number of days taken	Degree days
20/03	15/04	26.00	490.90
22/03	15/04	24.00	454.20
25/03	20/04	26.00	492.80
28/03	22/04	25.00	473.05
29/03	24/04	26.00	492.60
29/03	22/04	24.00	453.40
30/03	23/04	24.00	452.60
05/04	30/05	25.00	472.73
15/04	9/05	24.00	455.83
18/04	13/05	24.00	473.78
Average		24.80	471.18

4.3 ANTHESIS

Observations on anthesis are presented in Table 4.5, 4.6 and 4.7 and illustrated in Fig.4. Anthesis did not show any regular pattern and the same continued throughout the day. In rainy season, 48.26 per cent flower buds opened during day time and 51.74 per cent during night. In summer season it was 49.6 and 50.4 per cent respectively. In day time maximum flowers opened around 14 h and in night it was around 04 h.

4.4 ANTHER DEHISCENCE

The data on anther dehiscence are presented in Table 4.8 and illustrated in the Fig.5. The results revealed that, the anthers were of closed type at the time of anthesis and the anther of the longest stamen dehisced first. In the forenoon, the mean time taken for anther dehiscence was 3 h 48 minute in rainy season and 3 h 18 minute in summer season. In the afternoon it was 1 h 18 minute and 1 h 06 minute respectively. Anthers of the flowers opened in night period dehisced only at day time and the mean time taken was 8 h 30minute in both seasons.

4.5 STIGMA RECEPTIVITY

The data on the receptivity of stigma are presented in Table 4.9, 4.10 The percentage of adherence of pollen grains was 56, 88 and 12, one day prior to opening, on the day of opening and one day after opening respectively. The percentage of fruit set on these days was 40, 72 and 4 respectively. It's evident from the results that stigma was receptive a day prior to opening and continued up to the day of opening with maximum receptivity on the day of opening. A sudden decline occurred in the receptivity of stigma in the next day of opening.

Table 4.5 Anthesis in drumstick during the rainy season

Month	Total flower buds observed	No. of buds opened	
		Day	Night
July	250	125	125
August	250	120	130
September	250	117	133
Grand total	750	362	388

Table 4.6 Anthesis in drumstick during the summer season

Month	Total flower buds observed	No. of buds opened	
		Day	Night
January	250	115	135
February	250	136	124
March	250	121	139
Grand total	750	372	378

Table 4.7 Anthesis in drumstick during day and night hours

Season		Day Time						Night					
		08	10	12	14	16	18	20	22	24	02	04	06
Number of flowers opened	Rainy	16	22	4	30	9	19	10	6	5	16	35	28
	Summer	1	16	13	35	6	14	13	9	5	15	39	28

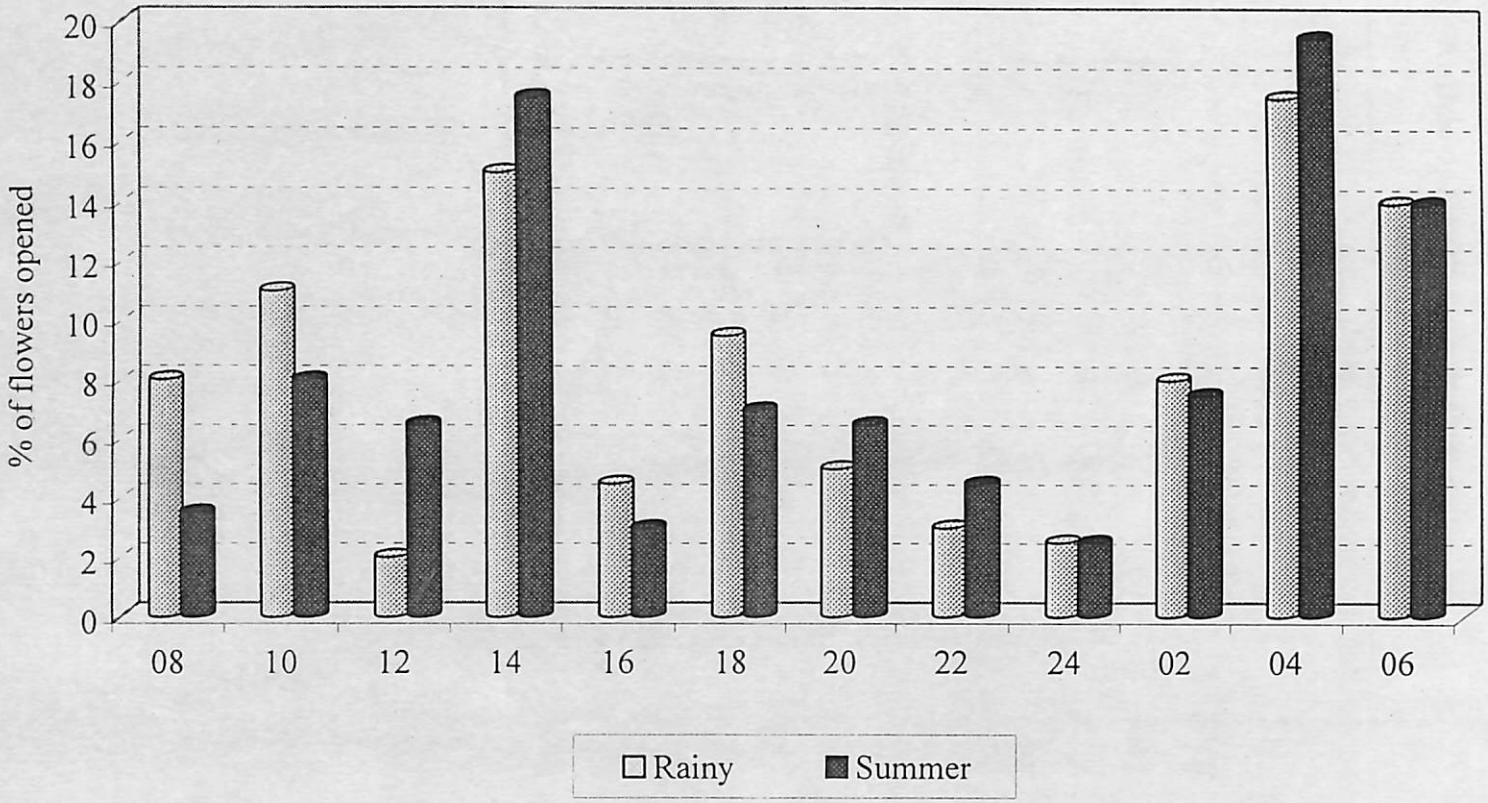

Fig. 4. Anthesis in drumstick for a period of 24 hours

Table 4.8 Anther dehiscence in drumstick

Time		Mean time for anther dehiscence, h : minute			
		Rainy season		Summer season	
04-06	Forenoon	5:00	Mean 3:48	4:18	Mean 3:18
06-08		4:00		3:42	
08-10		3:24		2:54	
10-12		2:48		2:18	
12-14	Afternoon	1:18	Mean 1:18	1:00	Mean 1:06
14-16		1:12		1:06	
16-18		1:30		1:24	
18-20	Night	10:36	Mean 8.56	10:42	Mean 8:30
20-22		9:48		9:30	
22-24		8:54		9 :00	
24-02		7:48		7:56	
02-04		5:42		5:48	

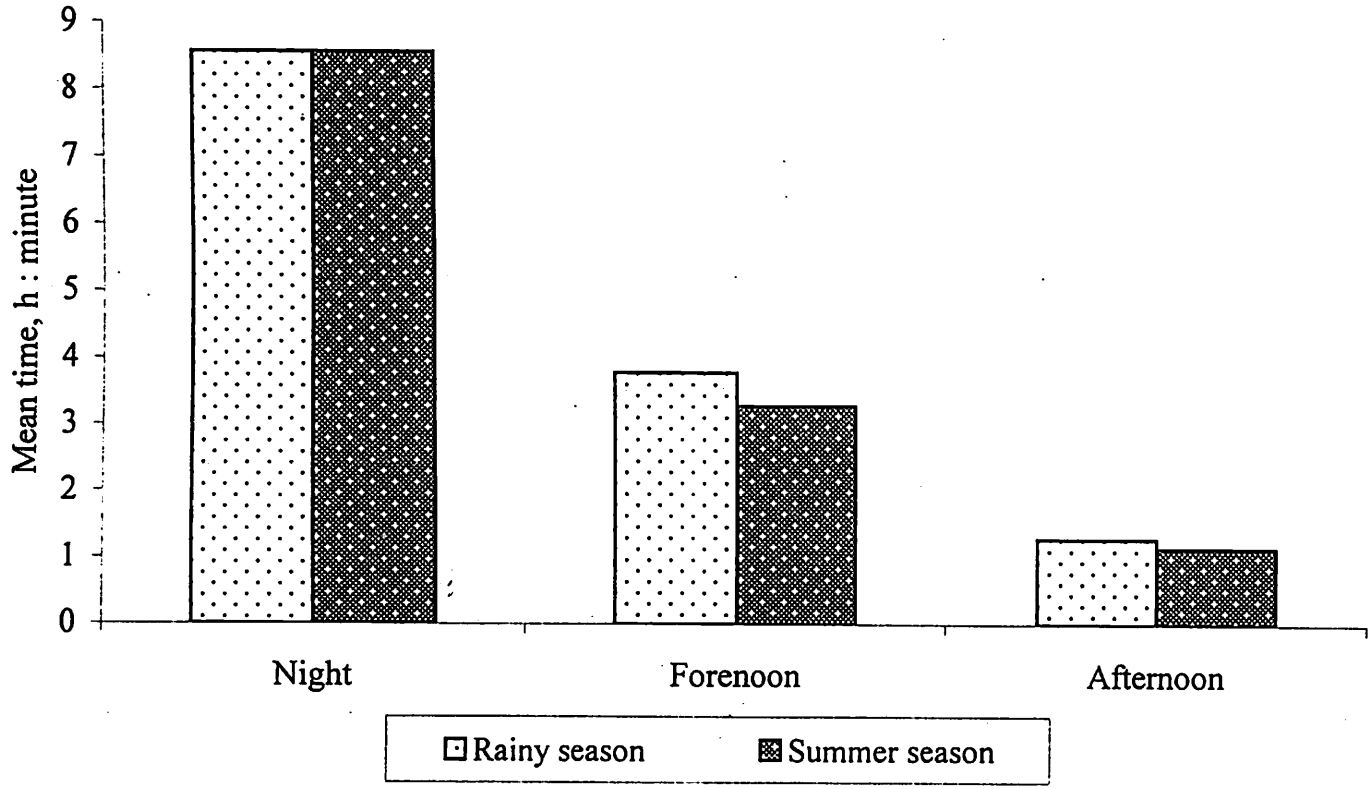

Fig. 5. Anther dehiscence in drumstick during rainy season and summer season

Table 4.9 Stigma receptivity in drumstick based on the pollen grain adherence

Stage of flower	Total number observed	Number of sticky surface	Per cent
One day prior to opening	25	14	56
On the day of opening	25	22	88
One day after opening	25	3	12

Table 4.10 Stigma receptivity in drumstick based on fruit set after controlled pollination

Stage of flower	Total Number	Fruit set	Per cent
One day prior to opening	25	10	40
On the day of opening	25	18	72
One day after opening	25	1	4

4.6 POLLEN MORPHOLOGY

The pollen grains were spherical with smooth exine. Pollens had three germ pores (Plate 6 and 7). The palynological descriptions are furnished in the Table 4.11. The average diameter of fertile pollen was 43.5 µm under low power (10x10 X) and 414 µm under high power (10x45 X). For sterile pollen it was 33 and 319.45 µm respectively.

4.7 ESTIMATION OF POLLEN PRODUCTION

The data on pollen production are given in the Table 4.12. The average pollen count per anther in rainy season was 7250 and the total pollen production per flower was 36250 in rainy season. In summer it was 7500 and 37500 respectively.

4.8 *IN VITRO* GERMINATION AND POLLEN TUBE GROWTH

Pollen grains germinated in 1, 5, 15 and 20 percent sucrose media. Pollen exhibited good tube growth in 5, 10, 15 and 20 per cent sucrose (Table 4.13). Pollen germination and tube growth was least in 1.0 per cent sucrose and highest in 15.0 per cent sucrose (Plate.8).

4.9 POLLEN VIABILITY

Viability was assessed both by staining and germination methods (Table 4.14). Viability reading in the germination method was lower than in the staining method. The mean viability values on staining and germination in 15 per cent sucrose media were 97 and 88 per cent respectively.

4.10 POLLEN STORAGE

The data on pollen storage studies are given in the Table 4.15. Under refrigerated condition, the viability declined only to a negligible level with seven days. However, under room temperature, pollen viability lost within three days.

Table 4.11 Morphology of fertile and sterile pollen grains of drumstick

Pollen grains	Number of pollen grains	Average size, µm	
		Low power (10x10 X)	High power (10x45 X)
Fertile	25·00	43.50	414·00
Sterile	25·00	33·00	319.45

Table 4.12 Pollen count in drumstick flowers in different seasons

Season	Rainy season		Average	Summer season		Average
	June-July	August-September		January-February	March-April	
Pollen/ anther	7500	7000	7250	7500	7500	7500
Pollens / flower	37500	35000	36250	37500	37500	37500

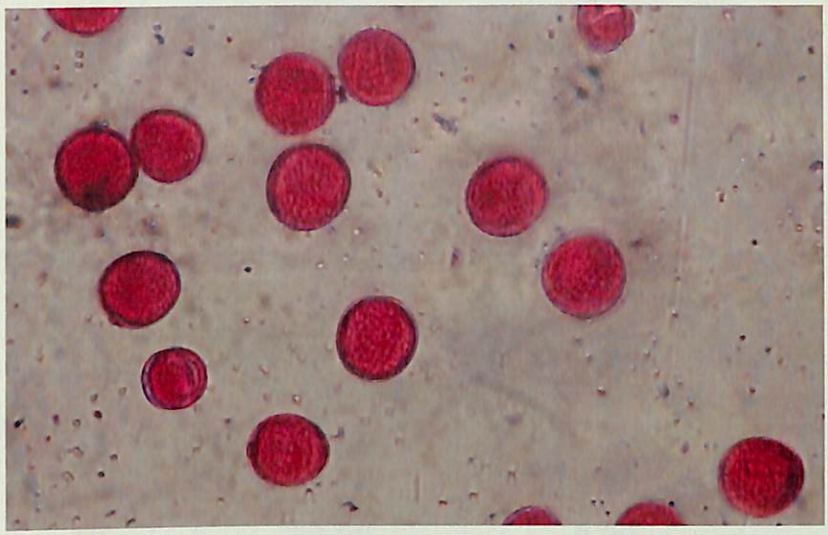

Plate. 6. Fertile pollen

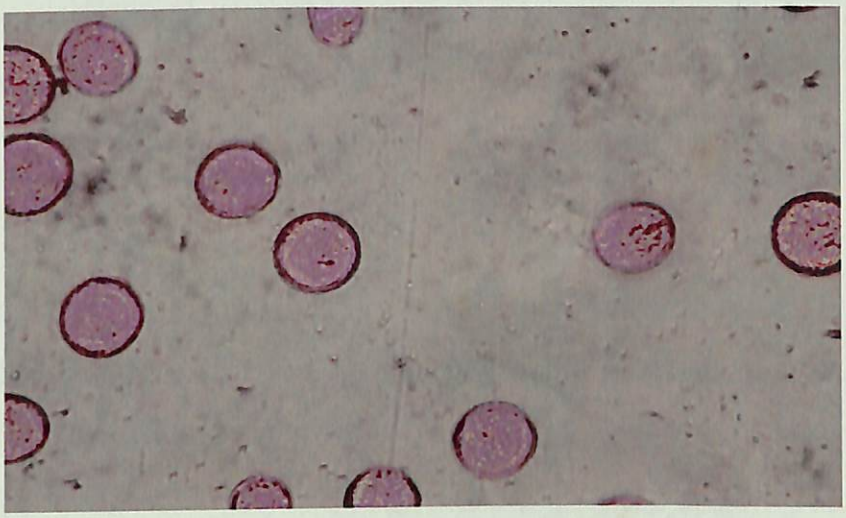

Plate. 7. Sterile pollen

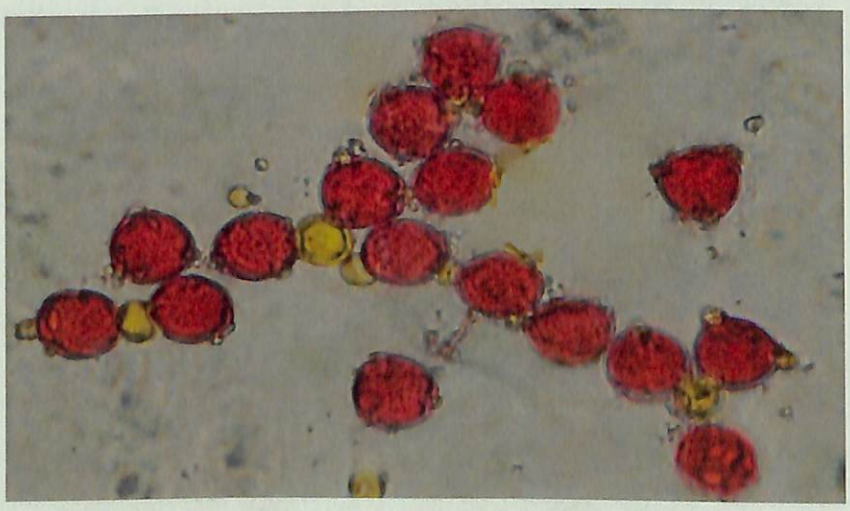

Plate. 8. Germinated pollen

Table 4.13 *In vitro* germination of pollen and tube growth in drumstick

Medium	Germination per cent	Pollen tube growth	
		Low (10x10 X), µm	High (10x45 X), µm
1 per cent sucrose	70.00	0.00	92.40
5 per cent sucrose	87.00	24.90	177.24
10 per cent sucrose	88.00	28.20	247.32
15 per cent sucrose	88.00	32.70	277.20
20 per cent sucrose	87.00	27.00	180.33

Table 4.14 Pollen viability in drumstick using acetocarmine staining and germination method

Total no. of pollen	Fertile pollen	Sterile pollen	Per cent of fertility	Per cent of sterility	Germination per cent				
					1% sucrose	5% sucrose	10% sucrose	15% sucrose	20% sucrose
200	194	6	97	3	70	87	88	88	87

Table 4.15 Loss in pollen viability of drumstick on storage under refrigeration and room temperature

Days of storage	Refrigerated storage			room temperature storage		
	Staining %	Germination %	Pollen tube growth (10x45 X), µm	Staining %	Germination %	Pollen tube growth (10x45 X), µm
1	96.00	86.00	277.20	95.00	85.00	96.32
2	88.00	77.00	240.45	54.50	14.00	-
3	83.00	67.00	144.27	23.00	6.00	-
4	80.00	58.60	134.16	-	-	-
5	63.80	43.00	68.80	-	-	-
6	60.00	37.50	44.02	-	-	-
7	42.00	12.00	-	-	-	-

4.11 POLLINATION

4.11.1 Mode of Pollination

The data on pollination are presented in Table 4.16. The fruit set percentage was 40, 8, 28 and 56 in natural pollination, natural selfing, natural crossing and assisted crossing respectively. Fruit set was maximum in assisted crossing. The flower buds which were emasculated and bagged did not set any fruit (Plate 9).

4.11.2 Natural Pollination and the Time of Maximum Insect Activity

Pollination per cent was maximum between 10 h and 14 h in both seasons (Table 4.17 and Fig.6 and 7). The insect activity was also high at that time.

4.11.3 Extent of Natural Pollination Over Different Months

The data are presented in the Table 4.18 and illustrated in the Fig.8. Natural pollination percent was maximum in March (41.6%) followed by April (39.2%) and minimum in September (23.2%).

4.11.4 Pollinators

Five different groups of insects visited the flowers (Table 4.19 and Plates 10 to 14). Among these, honeybees were the most efficient pollinator. Other flower visitors included Nitidulid beetles, bumble bees, sirphyd flies and ants.

4.12 FRUIT DEVELOPMENT STUDIES

4.12.1 Days from Fertilization to Fruit Set

The mean days for fruit set was 5.55 in rainy season and 5 in summer season (Table 4.20 and Plate 15). The fruit length at fruit set was 7.0 and 7.21 cm respectively in rainy and summer seasons.

Table 4.16 Fruit set in drumstick flowers under different methods of pollination

Method of pollination	Fruit set	Per cent	Remarks
Flower buds merely tagged	10	40	Natural pollination
Not emasculated but bagged	2	8	Natural selfing
Flower buds emasculated and kept open	7	28	Natural crossing
Emasculated crossed and bagged	14	56	Assisted crossing
Emasculated and bagged	-	-	No pollination

*Total 125 flower buds were marked @ 25 each

Table 4.17 Rate of natural pollination and insect activity in drumstick

Time	Rainy season						Summer season					
	06-08	08-10	10-12	12-14	14-16	16-18	06-08	08-10	10-12	12-14	14-16	16-18
Total flowers	25	25	25	25	25	25	25	25	25	25	25	25
Pollinated flowers	1	2	5	6	4	1	1	3	10	9	5	2
Per cent	4	8	20	24	16	4	4	12	40	36	20	8
Total no. of insects	-	1	4	5	2	1	1	3	8	7	3	2

Table 4.18 Rate of natural pollination in drumstick over different months

Month	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb	Mar.	Apr.	May
% of natural pollination	33.6	27.2	25.6	23.2	31.2	-	-	33.6	40·0	41.6	39.2	25·0

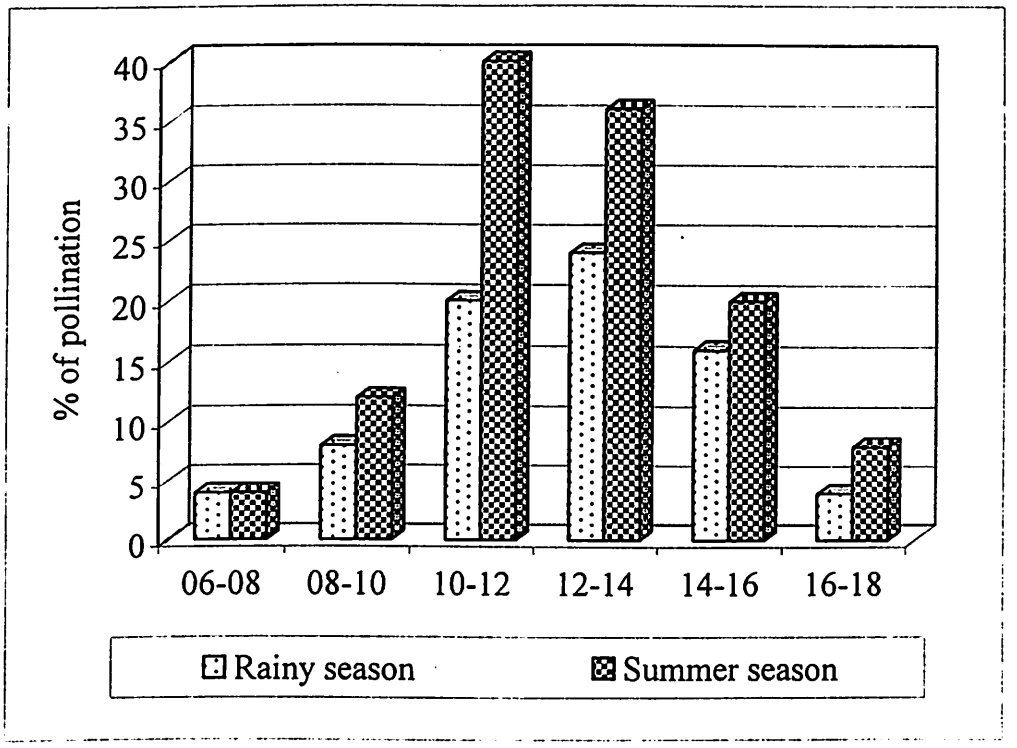

Fig. 6. Rate of natural pollination in drumstick during different periods of a day

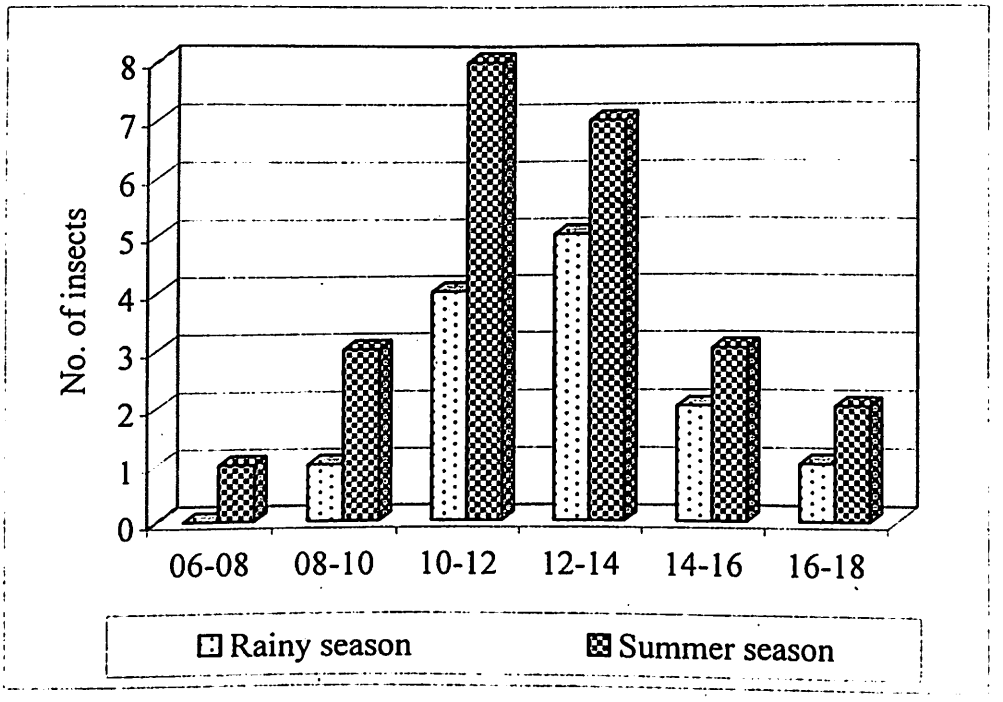

Fig. 7. Insect activity in drumstick during different periods of a day

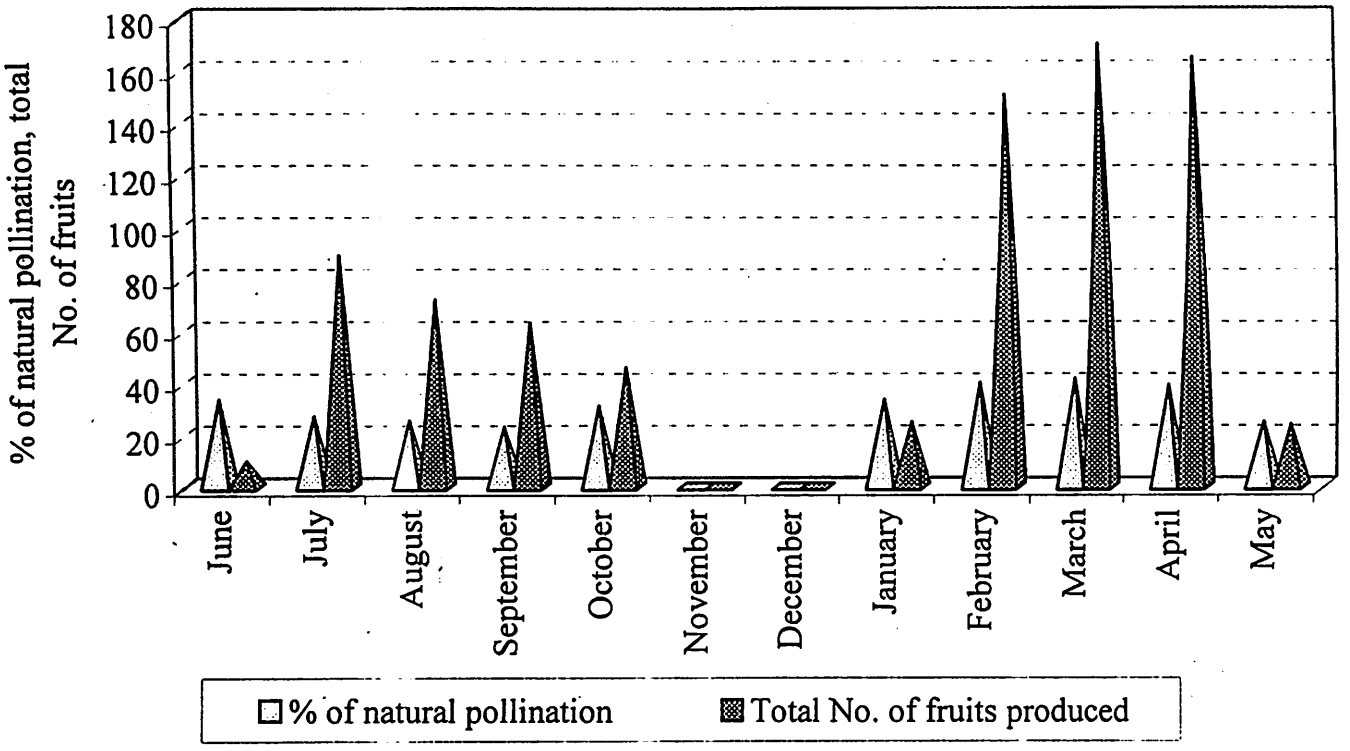

Fig. 8. Natural pollination and fruit production in drumstick over different months

Table 4.19 Insects identified as the pollinators of drumstick flowers

Name of the pollinator	Total number
Honey bees (*Apis mellifera*, *Apis cerana indica* and *Trigona* sp.)	19
Nitidulid beetles	10
Bumble bees (*Xylocopa* spp.)	4
Sirphyd flies	4
Ants	3

*Collection done on five consecutive days and the total number was taken

Table 4.20 Days from fertilization to fruit set and length at fruit set

Season	Rainy season			Average	Summer season			Average
	July	August	Sept		January	February	March	
Mean no. of days for fruit set	5.33	6·00	5.33	5.55	5.25	5·00	4.75	5.00
Mean length of fruit at fruit set, cm	6.83	7·00	7.16	7.00	7.37	7·00	7.25	7.21

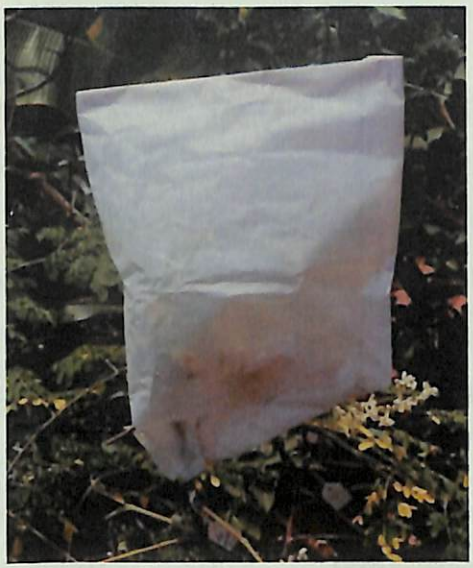

Plate. 9. Bagged inflorescence

Plate. 10. *Apis cerana indica*

Plate. 11. *Apis mellifera*

Plate. 12. Ant

Plate. 13. Sirphyd fly

Plate. 14. Nitidulid beetle

4.12.2 Fruit Development

The data regarding the fruit development are presented in Tables 4.21, 4.22 and 4.23. During the initial period of development, fruits elongated rapidly. Thereafter the developmental process slowed down. After the horticultural maturity (Plate 16), a gradual decrease in length was noticed. The mean fruit length at horticultural maturity was 46.2 and 48.4 cm respectively in rainy and summer seasons. At physiological maturity it was 45.6 and 47.9 cm respectively in rainy and summer seasons. The fruits took an average of 42 days for horticultural maturity and 70 days for physiological maturity in rainy season. In summer season it took only 34 and 59 days respectively for horticultural and physiological maturity. The mean degree days requirement for horticultural and physiological maturity was 635 and 1112.15 in rainy season, while it was 634.65 and 1111.68 in summer season.

4.12.3 Flower Shedding and Fruit Set

The data on flower shedding fruit set and fruit maturity are presented in Table4.24. The per cent of fruit set and fruit maturity was 7.2 and 2.7 in rainy season and 11.39 and 3.70 in summer season. The percent of fruit drop was 61.5 and 66.6 respectively in rainy and summer seasons. Flower shedding percentage was 92.73 and 88.60 in rainy and summer seasons.

4.13 INCIDENCE OF HAIRY CATERPILLAR (*Eupterote* spp.)

The caterpillar was a serious menace during the crop period. It was a voracious feeder and once occurred completely defoliated the tree. The percentage of incidence was illustrated in Fig. 9.

Table 4.21 Fruit development in drumstick during rainy season

Particulars	Number of days after fertilization									
	7	14	21	28	35	42*	49	56	63	70
Mean length, cm	7.16	25.60	45.28	45.70	46.20	46.40	46.10	45.80	45.76	45.60
Mean circumference, cm	0.93	1.50	2.42	3.02	3.96	4.70	5.88	6.24	6.74	6.96
Mean pedicel length, cm	2.08	2.33	2.4.00	2.4.00	2.4.00	2.4.00	2.4.00	2.40	2.40	2.40

*Attained horticultural maturity

Table 4.22 Fruit development in drumstick during summer season

Particulars	Number of days after fertilization								
	7	14	21	28	34*	42	49	56	59
Mean length, cm	7.3	26.5	47.0	47.7	48.4	48.3	48.2	48	47.9
Mean circumference, cm	0.9	1.7	2.5	3.4	4.3	4.9	5.6	6.3	6.8
Mean pedicel length, cm	2.1	2.2	2.5	2.5	2.5	2.5	2.5	2.5	2.5

*Attained horticultural maturity

Table 4.23 Fruit maturity in drumstick in terms of normal days and degree days

Season	Number of days for		Degree days for	
	Horticultural maturity	Physiological maturity	Horticultural maturity	Physiological maturity
Rainy	42	70	635.00	1112.15
Summer	34	59	634.65	1111.68

Plate. 15. Fertilization to fruit set

Plate. 16. Fruit set to horticultural maturity

Table 4.24 Rate of flower drop, fruit set and fruit maturity in drumstick during rainy and summer seasons

Sl. No.	July (rainy)			March (summer)		
	Total no. of flowers / inflorescence	No. which set fruit	Fruit reaching maturity	Total no. of flowers/ inflorescence	No which set fruit	Fruits reaching maturity
1	18	2	-	46	1	-
2	60	2	1	47	2	-
3	14	2	2	20	3	1
4	32	1	1	25	4	1
5	19	3	1	10	2	2
6	36	3	-	20	6	2
Grand Total	179	13	5	158	18	6

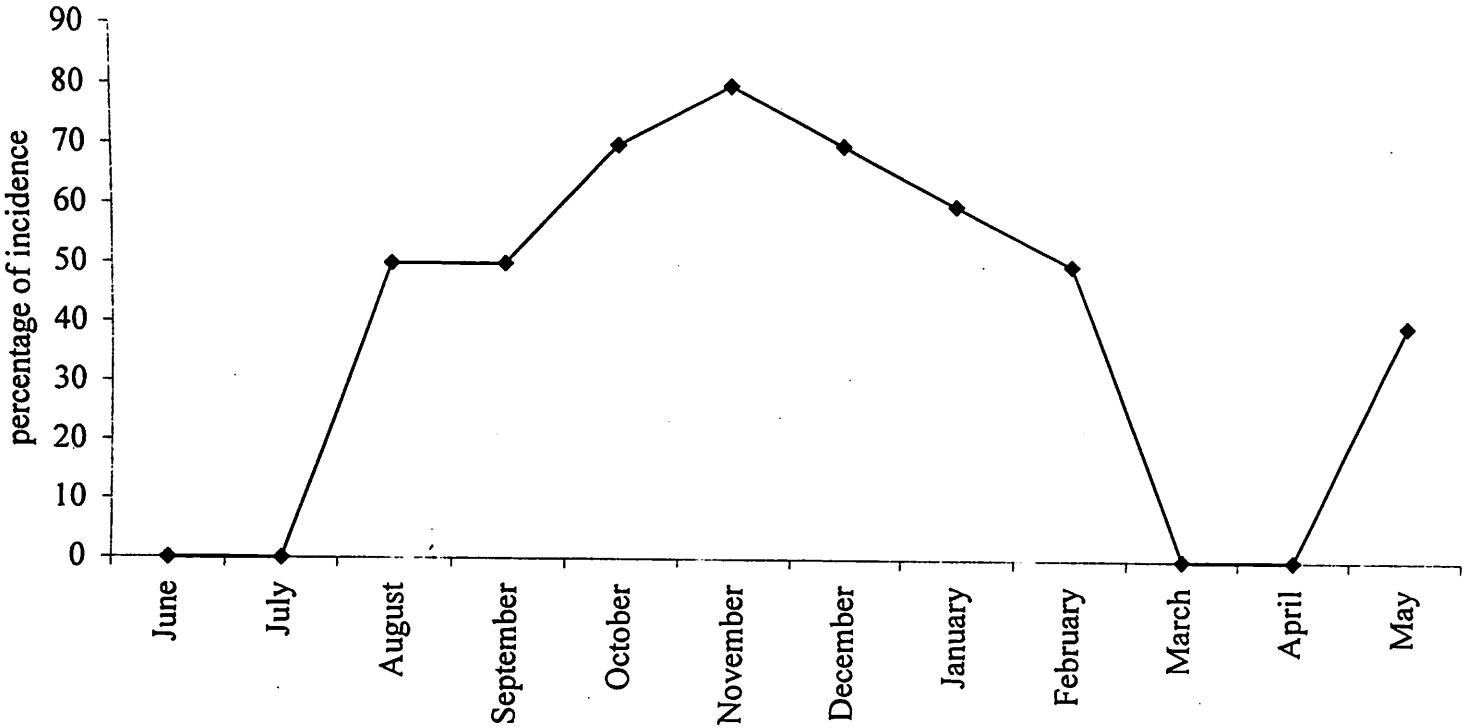

Fig. 9. Incidence of hairy caterpillar in drumstick

DISCUSSION

5. DISCUSSION

Drumstick or moringa (*Moringa oleifera* Lam.) is one of the most popular vegetables in South India and is highly valued for its nutritive, medicinal and economic importance. Moringa is a very rich source of proteins, minerals and vitamins and is able to provide nutritional security for our ever-growing population. Despite its potential food value, the crop still remains under exploited and very little work has been done on its improvement.

The information on floral biology fruit set and fruit development is the prerequisite for any breeding programme. Such informations are virtually lacking in this crop. In this context, sixty bearing plants were observed for one calendar year starting from June2001 to May 2002 to gather information on floral biology anthesis and fruit development. The results of the study are discussed below.

5.1 FLOWERING AND FRUITING

Flowering in plants may be continuous, seasonal or gregarious. Climatic variables such as wind, rain, relative humidity, temperature, light intensity and spectral quality are the triggers for the time of flowering in plants. Continuity of flowering can be due to constancy of environmental conditions or insensitivity to environmental fluctuation.

The present study revealed that under South Kerala condition, drumstick flowered throughout the year except in the months of November and December. The continuous flowering may be due to the equitable climate prevailing in this region. There were two peaks of flowering *viz.*, July – August and February – March. Flower production was maximum in February – March. Corresponding to the peak flowering periods there were two fruiting peaks, during July – August and March – April.

Continuous flowering and fruiting in moringa was reported by several workers in different locations (Duke, 1978; Ramachandran *et al.*, 1980; Pushpangathan *et al.*, 1996). However, Muthuswamy (1954) reported the prevalence of two flowering seasons *viz.*, March – April and July – August under Coimbatore condition. Only one flowering season during February – March was recorded both in Lucknow and Punjab (Singh, 1962; Nair and Singh, 1974). According to Indira and Peter (1988), in South India there were two crops, one in March-April and second in July-September.

The non-flowering during November – December in the present study may be due to the comparatively colder climate during these months and the plant might be experiencing a slight dormancy. The mean flower production was maximum during March and minimum in June. It may be attributed to the sunny and rainy weather during these months

5.2 FLOWER BUD DEVELOPMENT

The floral initiation and the modification of floral structure take place in a phased manner. The floral meristem passes through an irreversible sequence of phases resulting in the formation of floral bud (Frankel, 1977).

The results obtained in the present study revealed that moringa bud took 29.8 days or 472.25 degree days for its complete development during rainy season. In summer season it was 24.8 days or 471.18 degree days. The number of days is almost in conformity with the 24.4 days reported by Devar *et al.* (1981). The degree day requirement for both seasons was almost equal. But in summer season, the required degree day was attained in a shorter span of time due to the higher mean daily temperature.

5.3 ANTHESIS

Anthesis refers to the flower opening, which brings about exposure of anthers and stigmas to pollen vectors. Diurnal timing of anthesis may

be synchronized with the pollinator's activity or it may be affected by weather conditions or even by the age of flower bud (Synge, 1947).

In drumstick, anthesis continued through out the day. Almost equal number of flowers opened in day and night. Not much seasonal variation observed in this case. In moringa, flower opening mainly depend on the age of flower bud. Whenever the buds attained the required maturity, it got opened. There were two anthesis peaks one at 14 h and second around 04 h. These peaks coincided with the highest and lowest temperature in a day. But the result was contrary to those obtained by Devar *et al.* (1981) and Subramanion *et al.* (1997). According to them, no anthesis occurred after 7 am. However, combining the anthesis time of 3.00 to 19 h reported by Jyothi *et al.* (1990) and 2.30 pm to 9 am reported by Babu and Rajan (1996) the result of the present study can be substantiated.

5.4 ANTHER DEHISCENCE

Anthers in individual flowers may all dehisce simultaneously in the closed bud or at the time of anthesis or dehisce successively. Pollen is released through openings such as splits, transverse cracks or pores. Temperature and relative humidity regulate the duration of pollen discharge (Meinders and Jones, 1950).

In the present study, anthers were of closed type at the time of anthesis. This is in line with the report of Babu and Rajan (1996) in annual moringa. The anthers of the flowers opened at night dehisced only at day time and took a mean time of 8 h 30 minute for dehiscence. This may be due to the low temperature prevailing in the night, whereas in the day time, as the temperature increased, the mean time for anther dehiscence also found decreasing. In the forenoon session, the mean time taken was 3 h 48 minute and 3 h 18 minute respectively in rainy and summer seasons. In the afternoon, it was 1 h 18 minute and 1 h 6 minute respectively. These agree with the findings of Swarnapriya *et al.* (1995)

in *Gloriosa superba*, where the increased temperature caused earlier dehiscence of anthers.

Similar to anthesis, the anther dehiscence was also found to be continued throughout the day disagreeing completely with the report of Devar *et al.* (1981). According to them, there was no anthesis and anther dehiscence after 6.30 am.

Jyothi *et al.* (1990) reported that anthers dehisced at anthesis (03 to 19 h) by longitudinal splits. The study conducted by Babu and Rajan (1996) revealed that anthers got dehisced in the next day between 9.00 and 9.30 am, in that case the anthesis was from 2.30 pm to 9.00 am. The present study partly support their findings.

The anther of the longest stamen dehisced first in the present study followed by the rest of the stamen in the descending order of filamental length. This is in conformity with the earlier report of Devar *et al.* (1981) and Subramanion *et al.* (1997).

5.5 STIGMA RECEPTIVITY

The chronological sequence of anther dehiscence, pollinator activity and stigma receptivity is necessary for effective pollination.

In the present study, the stigma was receptive one day prior to opening and continued with maximum receptivity on the day of opening and a sudden decline in receptivity thereafter. This is in agreement with the findings of Devar *et al.* (1981) and Hanchinamani *et al.* (1994). However, this is not in line with the findings of Jyothi *et al.* (1990) and Babu and Rajan (1996). According to them, the stigma became receptive only one day after opening and the receptivity retained for one more day.

5.6 POLLEN STUDIES

The pollen grains were spherical, the exine was smooth and had three germ pores. The average diameter under low power (10x10 X) was 43.5 μm and 33 μm respectively for fertile and sterile pollen. This

confirms the earlier findings of Devar *et al.* (1981), Singh *et al.* (1983) and Ferguson (1985). Under Lucknow conditions, the average diameter of fertile pollen was 54 µm (Nair and Singh, 1974). A diameter of 35 µm was reported by Jyothi *et al.* (1990). In the study conducted by Babu and Rajan (1996) the fertile and sterile pollens were found to have 33.1 µm and 22.1 µm diameter respectively.

The results of the estimation of pollen production revealed that the average pollen count per anther in rainy season was 7250 and the total per flower was 36250. In summer season, the count was 7500 and 37500 respectively. Higher pollen production in summer might have contributed to the better fruit set and higher fruit production in summer. Lower count in the rainy season can be attributed to the frequent rainfall. This result almost agrees with the findings of Nair and Singh (1974) who reported 7400 pollens per anther. But Jyothi *et al.* (1990) reported a lower count of 4720 per anther and 24600 per flower under Visakhapatanam conditions.

Pollen grains failed to germinate in water in the *in vitro* germination study. Good pollen germination and tube growth was obtained in five to twenty per cent sucrose media. Germination per cent and tube growth was poor in one per cent sucrose. Highest germination and tube growth was observed in fifteen per cent sucrose and thereafter a slight decline was noticed.

Sucrose was helpful as an artificial medium for germination of pollen grains as it served as a nutrient during pollen tube growth (Singh *et al.*, 1961). The low germination per cent and tube growth in one per cent sucrose may be due to inadequate nutrient availability.

Pollen viability reading in the germination method in the present study was found to be lower than that of staining per cent. Similar result was obtained in various crops *viz.*, cocoa (Rajamony, 1981), lovi-lovi (George *et al.*, 2000) and tuberose (Seetharama *et al.*, 2000).

The mean viability values obtained on staining and germination were 97 and 88 per cent respectively. This result is in conformity with that obtained by Devar *et al.* (1981). According to Singh *et al.* (1983), pollen viability was highest on a medium containing six per cent sucrose and 15 ppm boric acid. Similarly, Babu and Rajan (1996) got a high stainability per cent of 92.5 in annual moringa.

Pollen collection and storage means induction of waiting period for anther dehiscence and gathering of the pollen before it's dispersed. Temperature above optimum decreases pollen longevity, while decreasing temperature extends viability. Pollen grains of many crops can be stored viable at 4-5°C (Frankel, 1977).

In the present study, under refrigerated condition, viability declined to a negligible level within seven days, while under room temperature, viability lost within three days. Refrigeration has been reported to extent the viability in cocoa (Simmons, 1976). Rapid loss in viability under room temperature is mainly due to the higher temperature.

Studies of Jyothi *et al.* (1990) revealed that 24 h old pollen grains have 72 per cent germination in 100 per cent sucrose while 72 h old gave 30 per cent and thereafter zero. The present study partly agrees with the finding of Jyothi *et al.* (1990). In both cases, under room temperature, viability lost completely after three days of storage.

5.7 POLLINATION

Drumstick in the present study was found more to be a cross pollinated crop rather than a highly cross pollinated crop, as eight per cent natural selfing was recorded. Highly cross pollinated crop means there is no chance of selfing where the natural breeding mechanisms *viz.*, male sterility, self incompatibility or sex mechanism acts as the barrier for selfing (Vishnuswarup, 1991). Hence the present study conforms partly the reports of Devar *et al.* (1981), Subramanion *et al.* (1997) and Peter

(1998) who reported that drumstick is highly cross pollinated. The fruit set percentage was 40, 8, 28 and 56 in natural pollination, natural selfing, natural crossing and assisted crossing respectively. Maximum fruit set was obtained in assisted crossing. The flowers which were emasculated and bagged did not set any fruit revealing the entomophilous nature of the crop. The results fully agree with the findings of Devar *et al.* (1981).

Pollination per cent as well as the insect activity were consistent in the present study and both reached at the peak rate between 10 h and 14 h. Similar peaks have been reported in the pollination activity by the honey bee species *viz.*, *Apis* spp. and *Trigona* sp (Lazari *et al.*, 1998).

Natural pollination per cent in the present study was maximum in March (41.6 per cent). The sunny weather and higher insect activity may be the reason. That in turn resulted in the highest fruit production in the same month. Minimum natural pollination was noticed in September (23.2 per cent). Unusually high rainfall during that month might have reduced the insect activity.

Pollination is the process of transferring pollen to the stigmatic surface. The flower specificities of the species must be supported the activity of most efficient pollen dispersal agent. The biotic pollen dispersal agents will undergo parallel evolutionary adaptations based on the structural, spectral and olfactorial flower specificities (Baker and Hurd, 1968).

Five different groups of insects visited moringa flowers in the present study. Among these, honeybees topped in number and were identified as the most efficient pollinators. The pollinating activity of honeybees in moringa was already reported by Singh (1962), Nair and Singh (1974), Devar *et al.* (1980), Peter (1998) and Rakhee (2000). The flower visitors also included *Xylocopa* spp., ants, Nitidulid beetles and sirphyd flies. The pollinating activity of *Xylocopa* spp. was earlier

reported by Jyothi *et al.* (1990) and Pushpangathan *et al.* (1996). Ant was also reported as a pollinator in moringa by Babu and Rajan (1996).

5.8 FRUIT DEVELOPMENT

The mean number of days for fruit set was 5.55 and 5 in rainy and summer seasons respectively. The fruit length at fruit set was 7 and 7.27 cm respectively in rainy and summer seasons. The slight seasonal difference can be attributed to the higher temperature in summer, which might have caused the rapid fruit development process.

In drumstick, fruits are harvested when they are nonfibrous and young (horticultural maturity). If not harvested at that stage fruit becomes fibrous, thick and unsuitable for consumption. On attaining physiological maturity fruit will split longitudinally.

In the present study during the initial period the fruit development was faster and thereafter the process slowed down. Iyer (1980) reported that in moringa fruits cytokinin and gibberellins were high at the initial stage. This can be attributed as its reason. After the attainment of horticultural maturity a slight and gradual reduction in length was observed. This finding is in corroboration with that of Palanisami *et al.* (1985). The circumference of the fruit increased through out the development. Pedicel length showed a slight increase during the first two weeks and thereafter remained the same. The heat units exerted profound effect on fruit development irrespective of the calendar date of fruit set. The one that set in rainy season took more number of days for fruit maturity than those set in summer months owing to the fact that the summer months had higher temperature. But the degree day requirement was almost equal in both seasons. This finding fully agrees with that of Hanchinamani (1992).

The total flower production, flower shedding per cent, fruit set and fruit drop per cent determines the ultimate yield in a crop like moringa.

The results obtained in the present study revealed that in moringa, the flower shedding per cent was very high. It was 92.73 per cent in rainy season and 88.60 per cent in summer season. This led to a poor fruit set per cent of 7.20 and 11.39 respectively in rainy and summer seasons. Again, immature fruits drop off heavily i.e., 61.5 and 66.6 per cent respectively in rainy and summer season giving a very low maturity per cent of 2.7 in rainy season and 3.7 in summer season. Whenever the flower clustering was more in an inflorescence, the ultimate fruit yield from that inflorescence was less. Higher flower shedding in rainy season was mainly due to the rainy and windy weather.

The present findings agree with the reports of Jyothi *et al.* (1990) under Vishakapattanam condition and Hanchinamani (1994) under Dharwad conditions. The present finding also agree with that of Chadda (2000), who reported a fruit maturity per cent of 1 to 2.8 and opined that higher flower clustering resulted in lower fruit set and yield.

SUMMARY

6. SUMMARY

A study on floral biology, anthesis and fruit development in drumstick (*Moringa oleifera* Lam.) was conducted at the Department of Olericulture, College of Agriculture, Vellayani during the period June 2001 to May 2002. Sixty bearing plants were used for various observations and experimentation.

Drumstick flowered throughout the year except in the month of November and December. Flowering peaked during July – August and February – March. The peak fruit production was during July – August and March – April.

Flower buds took 29.8 days or 472.25 degree days from initiation to complete development during rainy season. In summer season it was 24.8 days or 471.18 degree days.

Anthesis was observed throughout the day with maximum around 14 h and 04 h. Anthers remained closed at the time of anthesis. The mean time for anther dehiscence varied with temperature. As the temperature increased, the time for anther dehiscence found decreased.

The stigma was receptive one day prior to the opening of flower. The maximum receptivity was on the day of opening. After 24 h, the stigma receptivity showed a sharp decline.

The palynological studies revealed that pollen grains were spherical with three germpores. The size of fertile and sterile pollen was 43:5 µm and 33 µm respectively. The mean pollen count per anther was 7250 in rainy season and 7500 in summer season. Pollen grains showed good germination and tube growth in 15 per cent sucrose medium. Pollen viability per cent assessed by staining and germination methods were 97

and 88 respectively. Pollen stored in refrigerator lost viability within seven days and under room temperature within three days.

Among different methods of pollination, the assisted crossing resulted in maximum fruit set. The study also proved that drumstick was cross pollinated and entomophilous. Among the insect pollinators, honeybees predominantly visited the flowers and the insect activity was maximum between 10 and 14 h. Natural pollination per cent was highest in March and lowest in September.

The natural fruit set and fruit maturity per cent was very low in drumstick. It was 7.2 and 2.7 in rainy season and 11.39 and 3.7 in summer season. Flower shedding per cent was obviously as high as 92.73 in rainy season and 88.60 in summer season. The fruit development was dependent on heat units and an average of 42 days or 635 degree days were needed for horticultural maturity during rainy season. In summer season it was 34 days or 634.65 degree days. The requirement for physiological maturity was 70 days or 1112.15 degree days during rainy season and 59 days or 1111.68 degree days during summer season.

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*Original not seen

FLORAL BIOLOGY ANTHESIS AND FRUIT DEVELOPMENT IN DRUMSTICK (*Moringa oleifera* Lam.)

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Abstract of the
thesis submitted in partial fulfilment of the requirement
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8. ABSTRACT

A study was conducted at College of Agriculture, Vellayani during 2001-2002 to gather information on floral biology, anthesis and fruit development in drumstick (*Moringa oleifera* Lam.). Sixty bearing plants were utilized for the experiments carried out during June 2001 to May 2002.

Flowering was observed throughout the year except in the month of November and December. Two flowering peaks *viz.*, July – August and February – March were recorded. The fruit production peaked during July – August and March – April.

Flower buds took an average of 29.8 days or 472.25 degree days for its complete development during rainy season and 24.8 days and 471.18 degree days during summer season. Anthesis continued throughout the day with two peaks at 14 h and 04 h. Anthers were of closed type at the time of anthesis and they dehisced later.

Stigma was receptive a day prior to opening and continued upto the day of opening with maximum receptivity.

The pollen grains were spherical with smooth exine and had three germpores. The average diameter of fertile and sterile pollen grains was 43.5 µm and 33 µm respectively. The average pollen production per anther in rainy and summer seasons was 7250 and 7500 respectively. Pollen grains exhibited highest germination and tube growth in 15 per cent sucrose medium. Viability on acetocarmine staining and germination was 97 and 88 per cent respectively. The pollen grains stored under refrigerator lost their viability within seven days while under room temperature pollen lost viability within three days.

The drumstick was found cross pollinated and entomophilous. Honeybees were the chief pollinators. Insect activity was maximum

between 10 and 14 h. Natural pollination per cent was maximum in March and minimum in September.

An average of 5.55 and 5.00 days were taken for fruit set in rainy and summer seasons respectively. Flower shedding percentage was 92.73 and 88. 60 in rainy and summer seasons. The fruit maturity per cent was 2.7 and 3.7 during these periods.

During rainy season, fruits took an average of 42 days or 635 degree days for horticultural maturity whereas 70 days or 1112.15 degree days required for physiological maturity. In summer season, fruits attained horticultural maturity in 34 days and physiological maturity in 59 days. Degree days requirement for these was 634.65 and 1111.68 respectively.

APPENDICES

APPENDIX – 1

Average daily temperature used for the calculation of heat unit

Sl. No.	July	August	September	March	April	May
1	25.55	22.40	27.30	27.05	29.30	30.30
2	24.50	22.75	27.75	27.65	29.65	30.30
3	23.10	23.40	27.50	27.40	29.80	28.25
4	24.40	23.00	27.35	27.60	28.80	25.20
5	24.30	24.25	27.00	27.80	28.75	28.20
6	24.85	25.15	27.65	27.30	28.50	29.10
7	24.25	25.25	27.25	28.25	28.50	28.85
8	24.35	25.50	27.75	28.50	28.50	29.00
9	24.00	25.80	27.30	28.25	28.90	29.60
10	24.00	25.80	27.25	28.30	29.30	29.55
11	25.15	26.60	28.00	27.05	29.90	29.25
12	25.50	26.50	28.70	28.10	28.40	29.75
13	25.75	25.40	27.60	27.30	28.20	26.70
14	26.95	26.40	28.20	28.25	27.70	28.50
15	25.25	25.25	29.00	28.70	27.60	28.85
16	25.00	25.30	28.40	28.30	29.50	28.85
17	25.30	25.75	27.80	27.90	29.00	29.00
18	25.15	26.30	28.50	28.60	29.40	26.10
19	25.00	26.00	27.00	27.15	29.10	25.00
20	25.70	25.00	26.20	27.00	29.30	27.30
21	25.70	26.30	26.80	28.10	28.70	28.25
22	25.35	25.55	24.25	28.60	27.95	27.85
23	25.35	25.85	25.30	28.80	29.20	28.50
24	25.70	25.70	24.40	29.05	29.25	28.45
25	25.85	25.50	24.20	29.85	30.15	28.85
26	25.50	23.65	25.25	28.95	29.50	27.25
27	23.60	25.00	26.80	28.75	28.15	27.80
28	23.75	26.75	26.45	28.90	28.28	28.45
29	23.50	27.00	26.40	29.65	29.40	27.25
30	23.35	26.75	26.65	30.00	30.75	27.40
31	24.95	27.15		29.05		28.45

APPENDIX – II

HABIT OF FLOWERING AND FLORAL DESCRIPTION OF DRUMSTICK

Habit of Flowering

Inflorescence was a hairy axillary panicle – Monochasial cyme. Inflorescence was produced on current season growth. Panicles were erect and many flowered.

Floral Description

Flowers were yellowish or creamy white, sweet smelling and nectarous. Individual flowers were bisexual, zygomorphic and pedicellate.

Calyx : Consisted of five sepals deeply five partite and were unequal. Sepals were connate at the base and formed a calyx tube. Sepals were green in colour and slightly pubescent.

Corolla : Consisted of five creamy white petals which were unequal and were born on a small disc present in the calyx tube. Out of the five petals upper two petals were small and the lower three were large. Latteral petals were reflexed.

Androecium : It had five stamens alternating with five staminodes. Staminodes were filiform. Filaments were unequal and were enlarged at the base. The hind most stamen was the longest one. Anthers were one celled and dorsifixed and dehisced longitudinally. Anthes were light yellow at first when it neared to dehiscence it became deep yellow. Nector accumulation at the base of staminal column.

Gynoecium : Ovary superior, one celled, three carpelled and covered with hairs. Contain many ovules on parietal placentation, style one, slender, white and was shortly pubescent, stigma one and truncate.

Fruit : was an elongated silique like capsule, three valved, seeds many, large, three winged and nonendospermous.