STUDIES ON GROWTH, FLOWERING, FRUIT SET AND FRUIT DEVELOPMENT IN NUTMEG (*Myristica fragrans* Hout.)

BY

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THESIS

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VELLANIKKARA, TRICHUR.

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DECLARATION

I, hereby declare that this thesis entitled "Studies on growth, flowering, fruit set and fruit development in nutmeg (*Myristica fragrans* Hout.)" is a bonafide record of research work done by me during the course of research work 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.

Vellanikkara,
14/15 November, 1979

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CERTIFICATE

Certified that this thesis entitled "Studies on growth, flowering, fruit set and fruit development in nutmeg (*Myristica fragrans* Hout.)" is a record of research work done independantly by Smt. Nazeem, P.A. 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.

Vellanikkara,
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We, the undersigned members of the Advisory Committee of Smt. Nazeem, P.A., a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Studies on growth, flowering, fruit set and fruit development in nutmeg (*Myristica fragrans* Hout.)" may be submitted by Smt. Nazeem, P.A. in partial fulfilment of the requirement for the degree.

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INTRODUCTION

INTRODUCTION

The trade in Indian spices dates back to the dawn of civilization. It played an important role in shaping the history of India and the West. In olden days, pepper- the king of spices had to travel long distance on land to reach the countries in Europe. Indian spices now travel to all the nooks and corners of the world to flavour foods and beverages and sooth and heal through medicinal preparations. Thus they are indeed the ambassadors of taste and good living from India.

During 1977-'78 India exported 81,227.7 tonnes of spices valued at Rs.1,418.85 million. This included 6.3 tonnes of nutmeg valued at 25.1 thousand rupees. Nutmeg and mace are the ingredients of curry powder, the export of which is increasing year by year. During 1977-'78, 1,929.9 tonnes of curry powder valued at Rs.19.5 million was exported as against 1,552 tonnes valued at 13.4 million rupees during the previous year*. The annual world production is estimated to be 7,000 tonnes of nutmeg and 1,000 tonnes of mace, sixty per cent of which is being produced in Indonesia. Grenada is the second largest exporter of nutmeg.

The spices such as nutmeg, clove and cinnamon are quite suitable under Kerala conditions especially as an

*Source: DGCIS, Calcutta.

intercrop in coconut and arecanut gardens. The demand for spices is increasing both for internal consumption and for export due to the increase in standard of living. This demand resulted in high prices for the spices which gave encouragement for large scale planting of nutmeg. The area under nutmeg is estimated at around 400 ha during 1975 (Sriram, 1977). But the same has increased considerably and it is estimated to be around 1,000 ha at present. Though nutmeg was known in India during the first century B.C for medicinal purpose, the crop has gained popularity only during the last two decades because of its higher demand and consequent higher prices. The present internal demand is estimated at around 130 tonnes and even to meet the internal demand the cultivation should be more extensive and intensive. Additionally, the demand in the world market is also increasing. The uses of nutmeg and its products are quite wide and there is ample scope for further exploitation.

The profitability and acceptability of crops like nutmeg by the cultivators depend upon the advanced technology that can be constantly supplied to them in time. Being a new commercial crop, no serious attempt has been made to tackle the field problems of nutmeg cultivation in India. The work on this crop is rather negligible even in other countries of the world, considering its importance. Few workers (Prestoe, 1948;

Flach, 1966; Flach and Cruickshank, 1969) had studied certain aspects of flowering and sex expression. No significant studies on any aspect have so far been made in India except certain scientific observations. Long pre-bearing age, the dioecious nature, low set, heavy drop, wide variability in the production potential among the progenies etc are some of the most important problems in nutmeg which require immediate attention.

In perennial crops the importance of growth studies need hardly any emphasis. They are of fundamental nature and will facilitate the understanding of the complex processes leading to successful crop production. Those who are interested in the broader problems of biology will be concerned with the laws of growth, while those interested in the art of Horticulture may gather from such study something that is fundamental to fruit production. The success of fruit production depends upon several factors of which the growth of shoot, flowering habit, mode of pollination, pollen viability, fruit set and fruit drop are quite important.

In view of the above facts, the present investigation has been undertaken in nutmeg with the following objectives.

To study (i) the pattern of growth and flowering
(ii) the floral biology and fruit set
(iii) The fruit drop and development

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The genus Myristica was established for the nutmeg tree by Linnaeus (1742). He placed it under a special appendix 'fragmenta varia' apparently because Linnaeus could not determine on the basis of the available material, whether the plant was dioecious or monoecious.

Nutmeg (Myristica fragrans Hout.) a native of Moluccas islands belongs to family Myristicaceae (Guenther, 1952; Flach and Cruickshank, 1969). Joshi (1946) and Rendle (1971) indicated the close relationship between Myristicaceae and Annonaceae. Garret (1933), Smith and Woodehouse (1938) and Eames (1961) indicated its better relationship with Lauraceae.

Eventhough nutmeg belongs to one of the primitive families, very little attention has been given to it and the works to be reviewed is very scanty.

1. GROWTH STUDIES

Gustafson (1926), Reed (1929), Barnad (1932) and McMunn (1939) working on deciduous fruits have stressed the value of growth studies in relation to flowering and fruiting.

The relationship between vegetative growth and fruitfulness is evident from the works of Barnard and Reed (1933), Naik and Rao (1942), Raimund (1949), Spencer

and Kennard (1955), Nakasone et al. (1955), Sundararajan (1961), Krishnamurthi et al. (1960, 1961), Randhawa and Sinha (1963), Randhawa and Khanna (1963), Paulas (1964), Aravindakshan (1964), Khanal (1964), Singh and Ghose (1965), Teotia et al. (1970) and Hariano and Morioko (1975) on different fruit trees such as apple, citrus, mango, guava, sapota, Annona spp. and jack.

Among tropical trees, the mango and citrus species had been studied for growth behaviour in great detail. In mango growth in a particular season decides the capacity for flower production in the succeeding season. Naik and Rao (1942) and Krishnamurthi et al. (1961) have described the nature of shoot growth in mango as cyclic i.e., a period of growth alternated with a period of quiescence. Five cycles of shoot were recorded during the course of one year. The March growth cycle was more important both in duration and intensity of growth. Paulas (1964) studied the growth and flowering of different classes of shoots. Works by Teotia et al. (1970) revealed the use of the tree vigour as a criteria for yield in mango.

The growth flushes and their importance had been studied by Halma and Compton (1936) in citrus. Krishnamurthi et al. (1960) had given a detailed account of the cyclic behaviour of the shoot, root and radial growth. Five distinct cycles of shoot growth had been noted for one year. The maximum total growth was in the month of March, followed by July,

August and September in the descending order. This was supported by Randhawa and Sinha (1963) and Singh and Ghose (1965). They had reported significant variation in extension growth, size, number of leaves and leaf area per shoot in growth of different flushes and among varieties. The leaf area, extension growth, and leaf size were more on bearing shoots.

Saur (1951) classified the citrus shoots in relation to its flowering as (1) shoots bearing flowers but no leaves (2) shoots bearing flowers and few leaves (3) shoots with leaves and solitary flowers (4) shoots with several flowers and several large leaves (5) vegetative shoots with no flowers. Ahamed (1962-64) reported the shoots of medium size and vigour as more fruitful than weak or highly vegetative shoots. In mango Naik and Rao (1942) classified shoots into flowered leaders, nonflowered leaders and current year's laterals. In guava Dasarathy (1951) classed the current season shoots into flowering and vegetative types. Aravindakshan (1960) classed them into three as, shoots which produced flowers and ceased growth, shoots which continued growth producing flowers and shoots purely vegetative.

Nutmeg may be considered a slow grower. According to Flach and Cruickshank (1969) a good growing plantation in

New Guinea reached in four years an average height of approximately three metres and a girth of 15.7 cm above ground level at 40 cm height. Growth continued very long upto 60 to 80 years. Plants differed much in growth, vigour, productivity, sex of flowers, size and shape of leaves. Flach (1966) found a strong correlation (r =+0.05) between tree girth at 40 cm above ground level and production of fruits. He found a slight difference in tree size between female and male trees.

2. SEX AND SEX RATIO

Eventhough the dioecious nature is widely accepted quite a few scientists such as Warburg (1897), Janse (1898), Deimum (1949) and Guenther (1960) have given their opinion about sex in nutmeg. According to Flach (1966) there are two different sexes; female and male. The latter being subdivided into four different groups i.e., male, bisexual male, bisexual and bisexual female.

There had been an attempt to correlate the sex of nutmeg trees with some morphological characters. Janse (1898) stated that male trees have smaller leaves and less horizontal branches. Young trees showed these characters much less clearly and hence it was not possible to determine the sex of the trees by this method. Flach (1966) did not agree with him. Prestoe (1948) claimed that the leaves of female plants were nearly elliptical with more or less straight veins, while

the leaves of male plants were nearly obovate, with their veins rounded to the more pronounced point of the leaf. Phadnis and Choudhari (1971) reported some colour difference between the leaf extracts of male and female nutmeg plants when treated with ammonium molybdate. Nair et al. (1977) postulated a method for distinguishing the sex by examining the shape of calcium oxalate crystals in the epidermal cells of the leaves of two year old plants.

Investigations of the chromosomal mechanism of sex by Flaeh (1966) showed that nutmeg is having 44 heterokinetic chromosomes. His hypothesis is that, nutmeg may possess a mechanism consisting of four pairs of sex chromosomes. The female sex is supposed to be heterogenetic to the effect that four of the eight sex chromosomes show facultative nucleolar properties which especially show up in female meiosis, when the nucleolus orientates these four chromosomes to one side. The different male flowering tree types would then have to be explained by partial failure of the mechanism of orientation.

3. FLOWER PRODUCTION AND BLOSSOM STUDIES

No work has been done on flower bud differentiation and floral biology of nutmeg. However, detailed investigations on these aspects were undertaken in several fruit crops. Singh (1960) studied the fruit bud differentiation in mango

as affected by some climatological factors. His works in 1961 revealed that leaves in mango play an important and immediate role in fruit bud differentiation and their effect may be localised more particularly branchwise.

In citrus, Singh and Dhuria (1960) studied the blossom bud differentiation of sweet lime. The capacity for flowering and fruiting in Washington Naval oranges has been worked out by Ito et al. (1976). They have classified the inflorescence into four types and it was reported that flowers were produced most abundantly on poorest growth.

In guava Seth (1962) has given a detailed account on the floral biology. He distinguished two seasons of flower production with maximum initial set in rainy season and in summer, with no fruit set in certain cases. Similar studies have been made by Sehgal and Singh (1967) and Teotia et al. (1970).

According to Thakur and Singh (1965) flowering in all the species of Annona a close relative of Myristica started on current seasons growth simultaneously with the sprouting of vegetative buds. The flowering intensity was high only in the early summer, after which it gradually slowed down. The species took 27 to 35 days for complete

floral development from bud initiation to anthesis stage. Stigmatic receptivity was highest at anthesis time. Studies in Annona by Ramkumar and Singh (1977) revealed that flowering continued from March to August with a maximum in April-May.

The nutmeg tree usually flowers throughout the year with some peaks in fixed months. The climatic factors are responsible for such variations although it is not possible to pin point any factor (Flach and Cruickshank, 1969). The inflorescence of nutmeg is described by various workers. It is considered to be an axillary receme by Joshi (1946), a receme in the male and a cyme in the female by Nair and Bahl (1956), Umbellate cyme by Sinchlair (1958) and Talbot (1976). cymes, umbels or fascicles from the axils of the leaves by Gamble (1967). Kirtikar et al. (1975) described the male inflorescence as supra axillary recemes of 2.5 to 5 cm Flach (1966) have described the flowers as drooping unisexual or occasionally bisexual. According to Gamble (1967) the number of flowers per inflorescence varied from 3 to 5 in male and fewer in female. Nair and Bahl (1956), Gamble (1967) and Parry (1969) described the flowers as small, fleshy, pale yellow and fragrant with bract and bracteole. Leslie (1963) reported the female flowers as larger than the male and the calyx tube more oval in shape. He reported the nectar

production from a nectary at the base of the calyx tube in both male and female flowers. Flach (1966) distinguished the male and female flowers by the narrowing of the perianth towards the base of the male flowers which was absent in females.

Wilson and Maculans (1967) have described the structure of the androecium and gynoecium in M. fragrans. The androecium consists of a solid column or androphore to which is attached 14 to 22 bilocular anthers. The anthers are adnate to the androphore by a thin ridge of tissue. Each anther has a longitudinal extrose dehiscence with the stoma quite deeply sunken between the microsporangia. There is a single vertical row of microspore tetrads and a single layer of tapetal cells. Rendle (1971) gave the number of stamens as 3 to 18, united together by their filaments into a central column which may become expanded above into a disc.

The single pistil in the female flower is more or less flask shaped with a very short to non existant style and bilobed stigma. The groove bisecting the stigma continues down on one side of the pistil as an evident suture, giving the appearance of a conduplicate pistil. Among the two grooves running opposite to each other, one

is more prominent than the other (Nair and Pillai, 1959). Male trees may sometimes produce female flowers and fruits and occasionally bisexual flowers. Flach and Cruickshank (1969) have reported that female flowers on male trees are usually hard to detect but the shape of perianth may help in the detection.

The placentation in Myristica is variously described as sub basal by Nair and Bahl (1956), marginal by Saunders (1937), parietal and sometimes seemingly basal by Lawrence (1951).

There is no consensus on the nature of uniovulate carpel in Myristica. Saunders (1937), Nair and Bahl (1956) and Nair and Pillai (1959) considered gynoecium of Myristica as bicarpellate and noted that the junctions of two carpels were indicated externally by two opposite longitudinal furrows. Sastri (1954, 1959) and Wilson and Maculans (1967) treated the gynoecium of M. fragrans as mono carpellate. Corner (1976) explained the ovule as anatropus and having two integuments. The inner integument surrounded micropyle.

3.1 Anthesis

Flach (1966) reported that both pistillate and staminate flowers opened from 1800 to 1900 hours. Anther dehiscence occurred between 0600 and 0700 hours i.e., 12 hours ahead of the opening of flower.

3.2 Stigmatic receptivity

Heslop and Shivanna (1977) have made a detailed study on the characteristics of angiosperm stigma, covering almost 1000 species of plants. The major subdivision according to them are stigmas which dry at maturity having a hydrated layer but no free flowing secretion and those which remain wet bearing such a fluid in the receptive stage. Sporophytic self incompatibility was reported to be associated with dry papillate stigma. Trinucleate pollen not readily germinated in vitro tend to be associated with dry stigma while wet stigma forms tend to have bi nucleate pollen, easily germinated in liquid or semisolid media.

In nutmeg, Leslia (1963) reported a nectary secretion to be present at receptive time. Flach (1966) reported the stigma of nutmeg flower to be receptive about 12 hours ahead of opening and it retained receptivity till 1½ hours on the day after flower opening.

4. POLLEN STUDIES

Study of pollen grains has attracted the attention of research workers in recent years in view of its great significance in floral biology and in interpreting taxonomic relationship and the origin of plants. The storage and germination of pollen grains play an important role in assisted pollination and hybridisation programmes.

4.1 Pollen production

A method for evaluating pollen production has been given by Oberle and Geortzen (1952) and Rao and Khadar (1962). They have suggested the use of a haemocytometer in estimating the pollen produced per anther. Pollen production is seen to depend on various factors. Sajtan (1952) reported pollen from southern and western sides of the apple tree to be more potent than from North and East. In apple, apricot and peach, pollen of flowers borne towards the base and middle of the branch were of better quality than those borne on upper end. Chira (1966) supported this view, after his works in Pinus.

Brooks and Puri (1963) reported atmospheric conditions to influence pollen production. This was backed by the results obtained by Sharma and Singh (1970) in mango. Higher temperature and drier climate, especially the former appeared to be associated with increased pollen production per anther. Stanley and Linskens (1974) suggested that for any one species at a given location, a regression coefficient could be derived to predict the day of maximum pollen shed from the 'degree hour heat sums', if sufficient data is available.

4.2 Pollen morphology

The close association between applied palynology and plant taxonomy has been emphasised by various workers.

According to Woodhouse (1935) the form of pollen grains were as useful as any other characteristic in the classification of plants. As a general rule, they served best in distinguishing between and showing the relationships among higher groups of plants such as tribes, families, genera and some species. This view was backed by the recent works of Fogle (1977) and Maas (1977). They have suggested pollen ultrastructure as a means to identify the tree fruit species and even clones within species.

4.3 Pollen viability

Stanley and Linskens (1974) have suggested various methods for testing the viability of pollen grains, including both germination and non germination assays.

4.3.1 Stain tests

Zirkle (1937) had described a method of mounting pollen grains in acetocarmine. The grains which stained well, looked plumpy and well shaped were taken by him as fertile and the unstained, shrivelled ones as nonviable or sterile. Balasubramanyam (1959) in guava, Nirmalendunath and Randhawa (1959) in pomergranate, Singh (1961) in mango, Singh (1962) in litchi, Nalawadi et al. (1975) in Annona and Nalawadi et al. (1977) in sapota, have followed this method to find out the percentage fertility.

The staining property of various other compounds such as iodine, reported by Barnett and Carver (1967) and Brooks and Brooks (1967), tetrazolium salts, reported by Aslam et al. (1964) and propinocarmine, reported by Deshmukh et al. (1978) were suggestive of pollen fertility.

Stanley and Linskens (1974) explained the principle behind the use of stains as their specific staining property. Acetocarmine preferentially stains chromosome, iodine stains starch and tetrazolium salts change their colour in presence of enzymes present in the viable pollen. They suggested the use of stains as not sufficiently accurate, when compared to germination tests as the immature and aborted pollen grains contain levels of constitutive chemicals sufficient to yield positive results in the stain test.

4.3.2 Pollen germination

Most of the pollen grains germinated successfully in sugar solutions. Two main views on this question concerning the endogenous or exogenous utilisation of nutrients have emerged. One school believed that the externally supplied sugars have only an osmotic role and were not utilised by the tube for any nutritional purpose (Jost, 1905; Martin, 1913; Anthony and Harlan, 1920; Visser, 1955).

Others pointed out that apart from having an osmotic role, the externally supplied sugars in the medium or in the style definitely served as a nutrient material for the growing tubes (Brink, 1924; O'kelly, 1955; Vasil, 1958).

There is a general unanimity of opinion on the role of sugar in controlling osmotic concentrations during germination of pollen. However, germination was not an osmotic or turgor phenomenon neither, as shown by the work of O'kelly (1955) nor did sugar serve merely as a source of nutrition.

Adams (1916) has reported good pollen germination at various concentration of cane sugar for different crops - 2.5 to 10 per cent for apple, 4 to 8 per cent for pear, eight per cent for strawberry, six per cent for raspberry and 16 per cent for black currants. More recent reports on pollen germination include 20 per cent sugar and 1.5 per cent agar for plum (Randhawa and Nair, 1960), 25 per cent sucrose and 0.5 per cent agar for mango (Singh, 1961), 16 per cent sucrose and 0.7 per cent agar for sapota (Rao and Khadar, 1960), 30 per cent sucrose for cashew (Damodaran et al., 1966), 25 per cent sucrose for Annona (Nalawadi et al., 1975), 15 per cent sucrose for plum (Ghanshyamsud et al., 1977) and 15 per cent sucrose for cocoa (Ravindran, 1977).

Addiott (1943) and Visser (1955) have reported pollen germination and pollen tube growth as two distinct physiological

processes independent of each other.

Brink (1924), observed that when pollen was cultured in sugar or sugar agar medium, the pollen tubes were as long or even longer than those formed in nature.

4.3.2.1 Effect of boric acid and calcium nitrate

Schumucker (1935) discovered that boric acid (1 to 10 ppm) was a stimulent to pollen germination and tube growth in Nymphaea and in many other species. The element was found to occur in the tissues of the pistil of the species studied by him. The role of boric acid and boron in the germination of pollen and pollen tube growth had since been studied by various workers in many plants. Thompson and Batjer (1950) in their studies on the pollen of different species of fruit trees found that boron or boric acid in low concentration, such as 25 to 40 ppm stimulated pollen germination and pollen tube growth. They also observed that higher concentrations inhibited the pollen germination and tube growth. Resnik (1956) obtained 10 to 15 per cent increased pollen germination in 'Mayer' lemon by addition of boric acid at concentrations ranging from 10 to 100 ppm. He obtained similar results with many other varieties and species of citrus.

Studies by Munzer (1960) revealed that 1 to 10 per cent boric acid stimulated pollen germination and pollen tube

growth in more than 60 species of angiosperms. Singh (1961) recorded increased pollen germination and tube elongation in mango with 20 ppm boron or boric acid. Rao and Khadar (1960) found that germination of pollen of sapota could be enhanced appreciably by the addition of 100 ppm of boric acid to the sucrose-agar medium. Jose and Magoon (1972) recorded higher pollen germination and tube length when 200 ppm boric acid was added to 5 per cent sucrose medium. Ravindran (1977) also emphasised the need of boric acid (100 ppm) for proper pollen germination and tube growth in 15 per cent sucrose medium in cocoa.

Calcium nitrate, eventhough not as effective as boric acid is reported by various workers to influence the pollen germination and tube growth. It has been found that the addition of electrolytes to pollen cultures hinder growth or inhibits it entirely. Lidforss (1896) and Brink (1924) observed that calcium nitrate even in small amounts were toxic to pollen. But in contrary to this, works by Brewbaker and Kwack (1963), Kwack and Brewbaker (1963), Kwack (1965), Jose and Magoon (1972) and Ravindran (1977) have revealed the essential role of calcium in pollen germination and tube growth. The action of calcium appeared to be based on the non metabolic incorporation of calcium into pectic substances of the pollen wall. Pollen germination studies are not reported in nutmeg.

4.4 Pollen storage

Pollen being a very delicate material, its handling requires great care. Methods of collecting pollen were described in detail by various workers (Fletcher, 1906; Barrett and Arisumi, 1952; and Stanley and Linskens, 1974).

King (1962) proposed a new term 'pollinicuration' which referred to such procedures as collection, drying, testing viability, storage and shipment, particularly as those inclusive in the techniques of plant breeding.

The storage life of the pollen grains of several hundred genera has been recorded in various reviews made by Pfundt (1910), Knowlton (1922), Doroshenko (1928), Nebel and Ruttle (1937), Maheswari (1944), Visser (1955), and Singh et al. (1961). A proper combination of factors such as low temperature, relative humidity and light have great bearing on pollen storage.

4.4.1 Storage by controlling temperature and humidity

King and Hesse (1938) studied the pollen storage requirements of as many as 16 deciduous fruits and found the optimum temperature for storing pollen to be about 30°F. Nebel (1939) was able to store the pollen of apple, pear, plum, peach and apricot for 2 to 5½ years in desiccator over sulphuric acid with 50 per cent R.H at 28°C.

Gollmick (1942) could keep grape pollen alive for a year at 1°C and 40 to 50 per cent R.H. Similar pollen longivity studies were conducted in relation to temperature and humidity in papaya by Traub and O'Rork (1936), in coconut palm by Liyanage (1949), in olive by Nicolaissen (1953) in stone fruits by Remy (1953), in litchi and mango by Singh (1962), in grapes by Nagarajan et al. (1965), in jack by Sinha (1972) and in lime by Shukla and Misra (1975).

4.4.2 Storage by freezing

Griggs et al. (1953) successfully stored the pollen of plum, peach, almond, apple, pear, cherry and olive for 1 to 3 years in a home freezer at -18°C. They did not find much difference in the germination percentage of pollen at the time of collection and almost after one year of storage. Singh (1962a) have reported mango pollen to be stored in deep freeze conditions in a dessicator for 14 months. Litchi pollen gave a longivity of 31 months under deep freeze at -23°C (Singh, 1962). In citrus, Sachan and Patro (1970) have reported 50 per cent viability after 90 days storage in deep freeze. Shukla and Misra (1975) have reported 40 to 64 per cent fruit set in kagzi lime with pollen stored in deep freeze for 15 days. Lyophilization or freeze drying of pollen has been reported to be one of the efficient methods of pollen storage by Stanley and Linskens (1974) and Nair (1977).

4.4.3 Storage by drying and dehydration

Sedov (1955) found that shade dried pollen of apple gave better germination than sun dried. Pollen dried in shade and stored in a desiccator over calcium chloride in darkness was found to be most viable. Good storage life over calcium chloride had been reported in various fruit crops by Tatarincev and Ostrowhova (1950, 1956), Soost and Cameron (1954), Singh (1960, 1961, 1962) and Sajtan and Kleeva (1964). In apple Sajtan and Kleeva (1964) have reported that, eventhough pollen stored in desiccator for one year did not germinate in artificial media showed germination in the stigmatic surface.

4.4.4 Storage in organic solvents

Iwanami (1972a, 1972b, 1973) and Iwanami and Nakamura (1972) tested the efficacy of storing pollen of many taxa in organic solvents such as benzene, petroleum ether, ethanol, acetone and chloroform. Iwanami (1975) suggested this technique as one of the best methods of storage for 3 celled taxon which loose germinability very rapidly after shedding.

With regard to nutmeg, Flach (1966) reported the pollen to be trinucleate and hence could not be saved for later pollination.

5. POLLINATION

Riabov (1930) have given a most comprehensive survey

of the literature on the pollination of trees containing about 800 references. He stressed the possible influence of environment on the mode of pollination and physiological conditions of the plant on fruit set.

Inadequate pollination or conditions existing after pollination were reported as one of the main reasons responsible for poor fruit set in mango (Mukherjee, 1953), in Annona and jack (Krishnamoorthi and Rao, 1965) and in apple (Teskey and Shoemaker, 1972).

Iwaski (1954) found that, in Satsuma orange pollination with pollen from mature bud resulted in better fruit set than pollen from flowers. According to Carlone (1958) cited by Krishnamoorthi and Rao (1965), pollination before anthesis was better than during anthesis or with a fully open flower in apple.

According to Deinum (1949), pollination in nutmeg is usually effected by a moth. Leslie (1963) felt that pollination in nutmeg is effected either by small insects or by wind. For effective pollination in nutmeg, the male and female ratio reported is 1:10 (Cruickshank, 1973). Perrl (1938) concluded that M. fragrans may be able to produce seeds without pollination whereas Flach (1966) was of the view that cross pollination in M. fragrans is obligatory. Duncan and Fergusen (1967/1968) after detailed

studies of the embryo sac and events leading upto fruit formation suggested that an incompatibility mechanism may be operating to ensure cross pollination in nutmeg.

Deimum (1949) reported artificial pollination in nutmeg to be very simple and easy. Flach (1966) was of the view that artificial pollination increased the chances of shedding. He also suggested the influence of pollination on the off springs. According to him, progenies of freely pollinated bisexual trees will be more female than that of freely pollinated female trees. He explained the reason for the higher female progenies by the fact that, in case of monoecious trees, the chances of self pollination was more than that of dioecious plant. The chances of such self pollination was increased in case of monoecious trees with more male flowers, resulting in less production; but with more female progeny. The reverse was true in case of monoecious trees with more female flowers.

6. FRUIT SET AND DEVELOPMENT

In most of the horticultural crops, flowering could not be taken as an index for estimating the final crop. Low production was not due to low flower production; but due to the low percentage of set and further retainment.

Mukherjee (1949) reported the ultimate set in mango as one per cent. Korrigs and Kester (1959) reported the

set in almond as 40 per cent. It was 0.2 per cent in Washington Naval orange as reported by Erickson and Brannaman (1960). Singh (1964) concluded high per cent of female flowers, defective pollination, wet weather causing pollen loss and vegetative growth at the expense of fruiting as causes of poor set in mango.

In nutmeg, many of the female flowers are shed after flowering. Flach (1966) reported the initial set to be 50 per cent in New Guinea. According to him, the percentage set was still lower in artificial pollination. He found nineteen artificially pollinated flowers out of 20 shed within few days and the solitary one left was dropped within three months. According to him, fruit set was influenced by the proximity of the male trees and also the availability of both staminate and pistillate flowers at the same time. The bigger the flower, the greater was the set. Trees in which the flowers were borne on larger pedicels recorded increased fruit set. Fruit set was 10 to 27 per cent in plants with wider opening of the perianth, whereas it was only 1 to 9 per cent in flowers with narrow opening.

With regard to fruit development, little has been worked out in nutmeg. Saini et al. (1971, 1972) have made reports on fruit development in mango. Their studies

revealed the fact that growth of the fruits were comparatively slow upto 21 days, became rapid between 21 to 64 days and thereafter it again slowed down lasting till maturity. Sigmoid growth pattern was characteristic to both fruit and seed. Highest per cent increase in growth of fruit and seed was found in April followed by May. Seed development promoted the growth of fruit by its own development. The slowing down of growth after a particular period from anthesis was associated with the hardening of endocarp and stopping of the growth by the seed. Initially, the growth of the fruit was mainly due to cell division accompanied by cell enlargement. Once the cell division had stopped, other factors which contribute to the fruit growth were cell enlargement and increase in size and number of laciferous canals. Similar studies had been previously carried out in citrus (Motilal, 1964) and in carambola (Nand, 1971).

In nutmeg the time required for the fruits to attain maturity from flowering is reported to be five to six months in England by Leslia (1963), nine months in Grenada by Flach and Cruickshank (1969) and Cruickshank (1973).

7. FRUIT DROP

Not much work on fruit drop of nutmeg is available although it is a major problem. But this phenomenon,

typical in many fruit crops has long been subjected to much studies as by Coit and Hodgson (1916, 1918 and 1919), Murneek (1933), Harrold (1935), Srivastava (1938), Nauriyal (1955), Korrigs and Kester (1959), Singh (1960 and 1961), Chadha and Singh (1963, 1964), Singh (1965), Palmer et al. (1968), Pollard and Biggs (1969), Wilson (1969), Rogers (1971), Jawanda et al. (1972) and Hariom et al. (1975). However, our knowledge concerning the intensity and periodicity of shedding of developing fruits is essentially limited.

According to Lewis (1946), the relative post fertilisation production of hormones by the developing embryo determined the further retainment. If embryo failed to develop, the ovulary tissues abscised. If they developed the ovulary remain attached until maturity. In mango, degeneration and abortion of ovule as early as at the four nucleate stage of embryo sac was responsible for the drop of 40 to 50 per cent of fruits (Singh, 1965).

Chandler (1925) recognised three waves of abscission of young fruits of deciduous fruit trees as (1) at blooming time or shortly after flowering pistal abortion (2) two weeks after bloom flowering following failure of fertilisation and (3) June drop following competition for nutrients and failure of embryo development.

Addicott and Lynch (1955) reported that fruit drop was influenced by an abscission mechanism. The phenomenon of abscission layer formation was supported by various workers as Chadha and Singh (1963) and Randhawa (1971). Leuty and Bukovac (1968) reported a relationship between endosperm and embryo development and fruit abscission. Fruits about to abscise and those considered potential drops were characterised by a smaller pericarp or no embryo or an aborting embryo or more than one of these factors. Persisting fruits contained seeds with a rapidly developing embryo and endosperm. Among the external factors reports have been mostly made on temperature (Yamaguchi, 1954) and moisture status of the soil (Carns, 1951).

Among the internal factors reported, hormones are the most important. Auxin-abscission relationship has been supported by several workers (Addicott and Lynch, 1955; Coyne and Al-Yasuri, 1964; Bardwaj, 1975; Hariom et al., 1975; Varma, 1976; Addicott and Wiater, 1977). The influence of gibberellins, abscisin, cytokinin and ethylene on abscission had also been discussed by various workers (Gustafson, 1960; Cooper and Henry, 1971; Varma, 1976; Addicott and Wiater, 1977).

After a detailed study, Bardwaj (1975) concluded that the interaction between various growth regulators determine

the ultimate abscission. The auxins and gibberellins produced in the seed and the abscisin in the pericarp may be transported to and interact at the abscission zone located at the base of the pedicel. If auxin and gibberellin were not available in sufficient amounts so as to neutralise the effect of abscisin, the flower or fruit shed. Thus ultimately, the relative balance between various plant growth regulators determine the retention and abscission.

7.1 Waves of drop

The abscission of partially developed fruits subsequent to bloom is not ordinarily continuous but proceeds in more or less definite waves. According to Randhawa (1971) the period elapsing from petal fall to the first wave and between successive waves and their intensity depend upon several factors such as species, variety, occurrence of fertilisation, position of flower and prevailing weather conditions. The waves of drop have been worked out in different crops.

Howlett (1927) recognised two abscission periods in apple. One termed as first drop, which was heavy and beginning shortly after petal fall continued for two to three weeks and the other, the so called June drop, which began a few days after the completion of the first drop continued for two to four weeks. This view was later supported by McCown (1938), Vyvyan (1946) and Randhawa (1971). All of them were in a general agreement of an abscission layer

formation which ultimately resulted in the fruit drop.

Singh (1960) observed an arresting of growth of fruits one week in advance of drop in mango. Chadha and Singh (1964) recorded three waves of drop in mango i.e., pinhead drop, post setting or April drop and unripe fruit drop or May drop. Randhawa (1971) found maximum drop just after setting in mango. In citrus also, three waves of drop were recorded by Randhawa (1971). The waves were during the month following full bloom, June drop and preharvest drop.

In nutmeg, Sloff (1950) reported a drop of about 60 per cent from fertilisation to harvest. According to several workers quoted by him, it is possible that the drop is influenced by genetical factors to certain extent as they found individual trees free from drop and also an increase in drop when the age of plant increased. A heavy cropping, limited water supply, heavy root competition due to inter-planting and heavy shade were found to be other contributory factors. Affected nuts were also found to be infected with Coryneum myristicae. Ramakrishnan and Damodaran (1954) and Pierrie (1964) have also reported the occurrence of various diseases which likely increased the percentage drop. But such diseases were not found to cause fruit drop and they attributed the drop to a physiological disorder.

8. YIELD

In East Indies, the trees bear fruits more or less all through the year round; but in most places, the crop is obtained in May-June and again in August-September. In West Indies, the tree produced fruits all the year round, though most heavily in August and September (Guenther, 1960). In Grenada, there exist two distinct production peaks, January-April and September-October (Cruickshank, 1973). The harvest calendar given by GATT (1977) showed the peak season of harvest as April-June for Indonesia, February-April and August-September for West Indies and February-March for Sri Lanka. In India, though the crop is available through out the year, the peak harvesting period is June-August (Nair et al., 1977).

According to Flach (1966) in Grenada, the best plantation showed an average production of 1500 fruits per tree. In a new and adequately spaced plantation, the production reached 700 kg nutmeg and 140 kg mace per year (the number of trees per hectare = 100 females). Shanmughavelu and Rao (1977) stated that a 10 year old tree may be expected to yield 500 to 800 fruits and a 20 year old tree, 2000 to 3000 fruits in India. According to Nair (1977), on an average, a good tree yields about 1000 fruits per year, though yields may vary from 500 upto 10,000.

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigations were conducted on the nutmeg trees at the District Agricultural Farm, Mannuthy, during a period of 12 months commencing from 30th March, 1978. Four mature bearing female trees, four flowering male trees and one hermaphrodite tree (bearing both male and female flowers; but predominently male) were selected for the study. The trees (raised from seedlings) were of the same age (17 years) and were under uniform cultural and manurial treatments as per the package of practices of the Kerala Agricultural University. They were irrigated from November to April at weekly intervals. On each tree, one square metre area within a height of two metre was selected on four aspects (East, West, South and North) and the following observations were made:

1. Extension growth of shoots for a period of one year
2. Flower characters
3. Fruit set, fruit drop and fruit development

The detailed procedures for the study of each character were as follows:

1. EXTENSION GROWTH

Twenty five lateral shoots on each aspect were selected at random from the one square metre area of the four female

trees (T_1 to T_4), one male (T_5) and one hermaphrodite (T_6) tree. The shoots were tagged and numbered serially. Thus extension growth was measured in cm at fortnightly intervals starting from 5th April, 1978 to 18th April, 1979.

2. FLOWER CHARACTERS

The studies were conducted in four male and four female trees in respect of flowering pattern, flower development and floral biology (anthesis, anther dehiscence, stigmatic receptivity, pollen studies and mode of pollination).

2.1 Pattern of flowering

To study the flowering pattern of male and female trees, observations were made for a period of one year for the number of shoots flowered and the number of flowers per flowering shoot by taking 100 shoots at random on each tree.

2.2 Flower development

In an attempt to find out the exact time of visual emergence of flower buds, the shoots tagged for shoot extension studies were observed at weekly intervals. To study the progressive stages of flower bud development, 100 buds each of male and female were tagged at random on four trees. Tagging was done soon after the emergence of the bud on the new flushes, as a light green protuberance with a blunt tip. Observations were made at weekly intervals. The developing buds were noted and drawings were made to

study the stages of development. The length and girth were measured for the pedicel and the bud separately.

2.3 Floral biology

To study the floral biology flowers were collected from the male, female and the hermaphrodite trees separately. The flowers were described and drawings were made.

2.3.1 Anthesis

To know the exact time of anthesis, 25 mature buds (buds with creamy perianth) were separately tagged on the male and female trees. Observations were made twice daily in the morning and evening. Initial observations showed that anthesis occurred during the late evening. Later, shoots of male and female trees with mature buds were plucked at 1700 hours and kept with their basal portion immersed in water. The shoots were observed at bihourly intervals. The results were then confirmed by field observations.

2.3.2 Anther dehiscence

The period of anther dehiscence was studied by tagging 100 immature buds of uniform size having light green perianth parts. The observations were initially made by forcing open the perianth parts twice daily in the morning and evening and checking the anthers with the help of a hand lens. Later, observations were made at bihourly intervals from 1700 hours

onward selecting mature buds with creamy perianth which had not dehisced.

2.3.3 Stigmatic receptivity

The receptivity of stigma was judged by the fresh, whitish creamy colour, the shiny appearance and the nectar like secretion on the stigma. This was again confirmed by pollination studies. Mature female buds bagged with muslin bags were observed at 0900 hours. The buds and flowers were then pollinated with the pollen collected from dehisced male buds with the help of a needle. Pollination was done daily between 0900 and 1000 hours on 25 flowers each at different stages starting from one day prior to anthesis to seven days after anthesis. Twenty five buds were left bagged without pollination to observe whether fruit set was possible in nutmeg without pollination.

2.3.4 Pollen studies

Several aspects of pollen such as morphology, fertility, number of pollen per anther, pollen germination, pollen viability and mode of pollination were studied. The pollen utilised for the studies were collected between 0800 and 0900 hours from mature buds, maturity being initially judged by the bright creamy colour of the perianth, the colour of the open flower. The maturity was later confirmed by removing the perianth and checking the anthers for

dehiscence. Only dehisced anthers were utilised for the study. Open flowers were avoided for the reason that anthesis being at night, a good number of pollen would have been lost by next day morning. The detailed procedure carried out is described below:

2.3.4.1 Morphology and fertility

Twenty five well shaped mature buds were selected from the male trees for the study. Pollen from each bud were separately collected in acetocarmine and glycerine, kept on a clean slide. A clean coverglass was placed over that and the slides were kept for about 30 minutes to allow the pollen grains to take the stain properly before examining under a microscope. The diameter of pollen grains was measured using an occular micrometer and their average was taken as the diameter of each pollen grain. The diameter of 100 normal, well shaped and well stained pollen grain at random was recorded from each slide. Fertility was calculated from the total number of well stained pollen grains. The experiment was repeated with potassium iodide iodine solution (0.1 per cent iodine in 2 per cent potassium iodide) as the stain.

2.3.4.2 Estimation of pollen production

The number of pollen per flower was estimated using haemocytometer as adopted by Rao and Khadar (1962). Creamy

male flower buds were collected. The perianth parts were carefully removed and the anther column was observed under the hand lens for non dehiscence. Such anthers which were almost mature and straight but not yet dehisced were marked out. Ten such anther column were selected from each tree. They were kept in vials and then stored in desiccator over calcium chloride for six hours to facilitate dehiscence. After the dehiscence, 2.5 ml water containing 0.25 per cent calgon (Oberle and Geortzen, 1952) was added and the contents thoroughly stirred in order to obtain an even dispersion of the grains in the suspension. A drop of this suspension drawn in a fine pipette was transferred to each of the two counting chambers of a New bauer improved double haemocytometer. Each chamber had an area of nine square millimeter ruled into square millimeter areas. Each of the four corner square millimeter areas were ruled into 16 while other five square millimeter areas were ruled into smaller divisions. The counting chambers were 0.1 mm in depth so that the volume of solution over a mm^2 was 0.1 mm^3. The number of pollen per flower was calculated as,

If N = average number of pollen counted per corner square,

X = number of pollen/flower

N:X = 0.1:250 i.e., 0.1X = 250 N

$\therefore$ X = 2500 N

The pollen grains in each of the four corner squares of each counting chamber were counted with the help of a hand tally counter and by using the low power objective of the microscope.

For each tree, ten such estimates were made and the total flower examined per tree was 100 numbers.

2.4.3 Effect of sucrose in pollen germination

Since the optimum medium for pollen germination in nutmeg had not been studied, initially different concentrations of sucrose (10, 15, 20 and 25 per cent) with 1.5 per cent agar were tried by incubating in a moist chamber. Since there was no germination even upto 48 hours, the experiment was repeated with 5, 30, 40 and 50 per cent sucrose with better results in 5 per cent sucrose media. The experiment was repeated with 0, 2, 4, 6, 8 and 10 per cent sucrose with 1.5 per cent agar, where satisfactory germination was observed.

To know the optimum time for incubation, observations were made at hourly intervals in six per cent sucrose agar media.

2.3.4.4 Effect of boric acid and calcium nitrate in pollen germination

Effect of boric acid and calcium nitrate was tested at different levels of sucrose with 1.5 per cent agar.

Observations were made after five hours incubation in a humid chamber after which the growth was arrested with Carnoy's fluid (Johnson, 1940). The different levels tried were 0, 2, 4, 6 and 8 per cent in case of sucrose and 25, 50, 75 and 100 ppm in case of boric acid and calcium nitrate with 1.5 per cent agar. The independent effects of boric acid and calcium nitrate at different concentrations of sucrose agar and their combined effects were also studied.

On an average 750 pollen grains were counted for germination from twenty microscopic fields and for tube length, 100 pollen tubes were measured. Germination was expressed in percentage and tube length in μ. The experiment was repeated three times and the average was taken.

2.3.4.5 Pollen storage

Mature buds were collected from male trees. The perianth was removed and the anther column was tested for dehiscence, with the help of a hand lens. The dehisced anthers were collected and treated in different ways as follows:

1. Mature buds kept intact without any treatment
2. The anther column along with pollen grains and the pollen grains alone were kept at room temperature without any treatment.

3. The anther column along with the pollen grains and the pollen grains alone were placed in a desiccator over calcium chloride at room temperature and at 4 °C
4. The anther column along with the pollen grains and the pollen grains alone were placed at 4 °C.
5. The pollen grains were soaked in organic solvents, such as petroleum ether, acetone and benzene and stored at 4 °C.

The viability and tube length of pollen were recorded each treatment at daily intervals in six per cent sucrose agar media after five hours incubation in moist chamber.

2.3.5 Mode of pollination

To study the mode of pollination, the male and female trees were closely observed during the flowering season. To trap the insects if any visiting the flowers during the night, the inflorescences on male trees in one square metre area were sprayed with 0.1 per cent sumicidine at 1800 hours. A square wooden frame with muslin cloth fitted on it was suspended to collect the insects which might fall down. Observations were made just after the spray, next day morning and 24 hours later.

The same treatment was repeated thrice at different sides of the tree.

To observe the extent of air borne pollen, slides covered with cellophane tape with the sticky side exposed were suspended at different sites near the male and female trees at 1700 hours. Next day morning, pollen counts were made from the slides at different microscopic fields for the nutmeg pollen and foreign matters.

3. FRUIT SET, FRUIT DROP AND FRUIT DEVELOPMENT

3.1 Fruit set

To know whether there was any apomictic fruit set, 100 mature female buds were bagged with muslin bag. The bagged flowers were examined at weekly intervals for a period of one month without opening the bag. The number of flowers dropped and those retained was recorded.

The percentage of natural set was assessed by tagging 100 female flowers each on four female trees and observations were made at weekly intervals for a period of one month.

To study the effect of artificial pollination 100 flowers were pollinated with pollen collected from mature, dehisced buds with the help of a needle. The pollinated flowers were tagged and observations made at weekly intervals for a period of one month.

3.2 Fruit drop

To study the extent of post set drop, young fruits of 15 to 20 days old (marble stage) were tagged and observed

at weekly intervals. The number dropped was recorded. Twenty five fruits on each aspect of the four female trees i.e., a total of 400 young fruits were taken for the study.

3.3 Fruit development

To study the developmental stages of the fruit on the tree 25 young fruits of marble stage were tagged on four aspects of each tree.

The tagged fruits were observed at weekly intervals and the girth was measured using a thin, narrow, non elastic twine and scale. The observations were continued upto the harvest stage.

3.4 Yield

Number of fruits obtained in daily harvest from each tree were recorded for the main harvest season (March to September) and the total yield was calculated.

4. STATISTICAL ANALYSIS

Suitable methods of analysis had been employed in cases where it was found necessary following the procedure given by Snedecor and Cochran (1967). For the percentage values, analysis were done after angular transformation.

RESULTS

RESULTS

The results of the detailed study on the growth, flowering, fruit set and fruit development in nutmeg are presented below. The analysis of variance tables for the different characters are given in appendices III to XII.

1. SHOOT GROWTH

The shoot growth was measured as the extension in growth of the shoot recorded for a period of one year from April 1978 to March 1979. The data presented in Table 1 indicate that, there was growth in all the months although the extent of growth varied from month to month significantly at one per cent level. The maximum mean growth was recorded during the month of September (4.06 cm) which accounted 35.94 per cent of the total growth for the year. This was closely followed by growth in May and June with no significant difference between the two. Mean extension growth in rest of the months showed no significant variation. However, growth was minimum during the month of April (0.03 cm) which accounted 0.25 per cent of the total growth. The total extension growth for the year was 11.31 cm.

The percentage of shoots that showed growth in different months also followed the same trend as for the mean growth (Table 1). Maximum percentage of shoots showed

Table 1. Mean monthly growth of nutmeg shoots

	Months	A	B	C
1978	April	0.03	0.25	2.16 (5.62)
	May	2.47	21.84	73.33 (59.90)
	June	2.40	21.28	66.00 (55.46)
	July	0.40	3.54	27.60 (31.06)
	August	1.01	8.94	40.83 (39.38)
	September	4.06	35.94	75.00 (62.60)
	October	0.12	1.07	6.33 (10.42)
	November	0.11	0.94	3.00 (6.67)
	December	0.25	2.16	5.33 (11.98)
1979	January	0.18	1.63	7.50 (13.00)
	February	0.23	2.04	7.33 (11.52)
	March	0.05	0.47	3.16 (8.07)
F. Value		25.35**		64.81**
CD		0.74		7.86

A = Mean extension in cm
B = Growth expressed as percentage of the total
C = Percentage of shoots showing growth
Values in the parenthesis denote the means of the transformed data.
** = Significantat 1 per cent level

growth in September (75%) and minimum in April (2.16%). Shoot growth in relation to temperature, rainfall and relative humidity is illustrated in Fig 1.

In general, two peak seasons were observed for shoot growth. The first in May-June and the second in September. During these two peak seasons of growth the temperature averaged between 29.85°C and 26.25°C and the total rainfall during the above two periods were 287.5 mm to 848.5 mm and 68.3 mm (Appendix I). It can also be seen that the rainfall during September-October was rather scanty while the shoot growth was maximum. The relative humidity within the main season of growth was 71.5 to 83.0 and 79.0 per cent. During the summer months (December to March), when the growth was very low, the temperature varied only between 26.35°C and 29.50°C. The relative humidity during the summer months ranged between 66.5 and 70.5 per cent. In effect, it can be seen that there is not much difference in the temperature during the main growth season and in summer; but the variation is only in the rainfall and the relative humidity.

The aspect wise difference in growth is presented in Table 2. Eventhough there was slight variation in the mean extension of shoot and percentage of shoots that showed growth, statistical analysis showed the variation to be not significant.

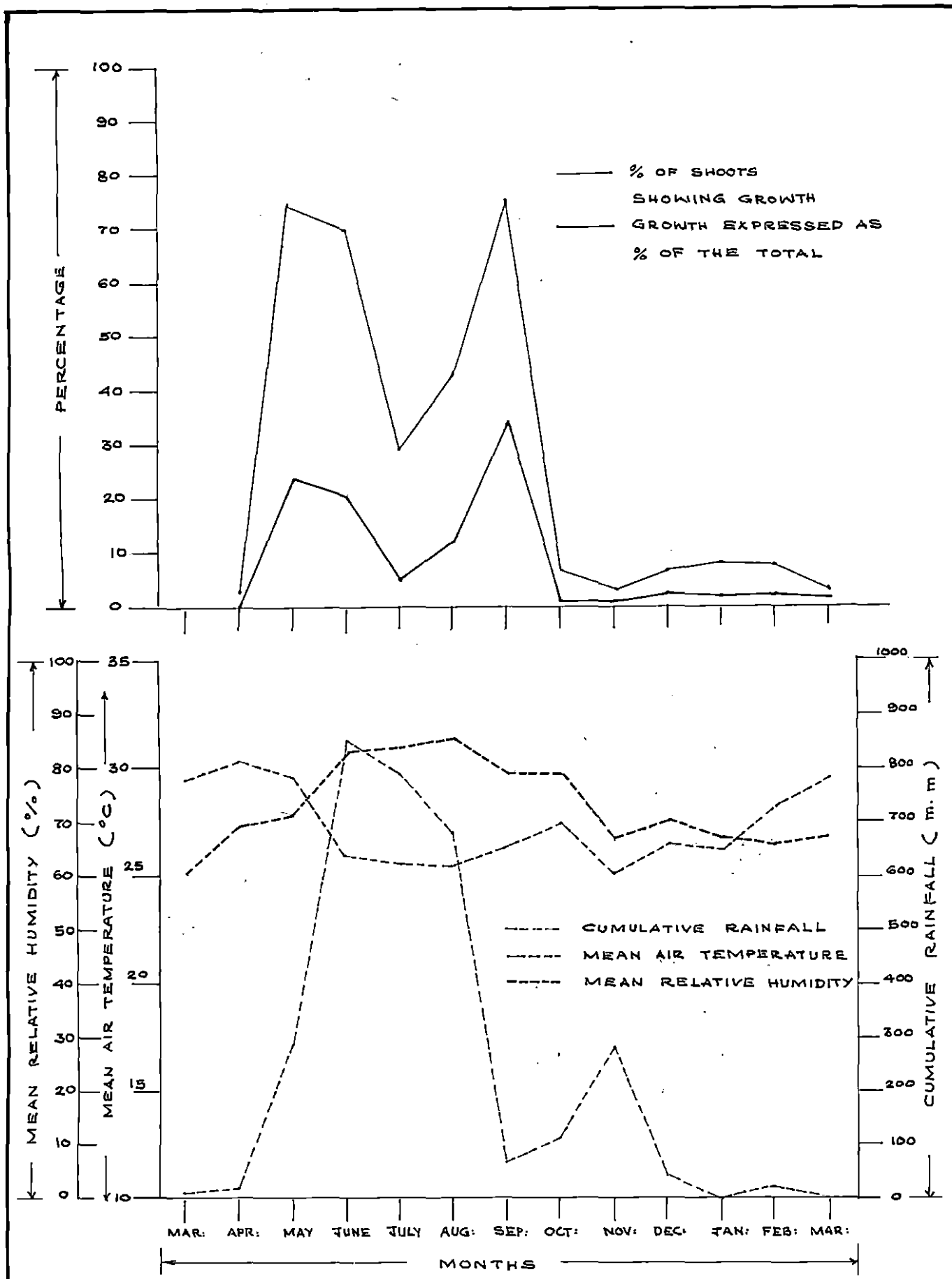


FIG: 1 SHOOT GROWTH IN RELATION TO TEMPERATURE RAIN FALL & RELATIVE HUMIDITY

Table 2. Mean growth of nutmeg shoots on different aspects

Aspects	A	B
East	0.83	25.49 (27.26)
South	1.02	31.35 (31.60)
West	1.03	29.00 (28.91)
North	0.87	26.60 (27.75)
F value	1.38^{NS}	2.25^{NS}

Table 3. Mean growth of nutmeg shoots on different trees

Trees	A	B
1 (♀)	0.70	23.16 (23.64)
2 (♀)	1.20	29.58 (28.37)
3 (♀)	0.95	28.66 (27.68)
4 (♀)	0.89	32.16 (32.03)
5 (♂)	0.99	26.75 (26.34)
6 (♀)	0.92	18.75 (19.76)
F value	0.78^{NS}	17.77^{**}
CD		5.56

A = Mean extension in cm
B = Percentage of shoots showing growth
Values in the parenthesis denote the means of the transformed data
** = Significant at 1 per cent level
NS = Not significant

The mean growth for individual trees is presented in Table 3. Statistical analysis showed the variation in mean shoot extension to be not significant but the mean percentage of shoots that had shown growth in each tree varied significantly.

Maximum percentage of shoots showed growth in a female tree, T_4 followed by T_2 and T_3 which were also females, with no significant difference between the three. The variation between T_2, T_3, T_5 (male) and T_1 (female) were also not significant. Again, T_1 and T_6 (hermaphrodite) were on par with no significant variation between the two. Thus, eventhough the trees varied significantly, no significant difference was noted between the male, female and hermaphrodite trees.

The data of individual shoot growth showed that in nutmeg, growth was not continuous but in flushes (Table 4). Eventhough the tree showed growth in all the months, it was on different flushes that the growth occurred. No flushes were observed after September. The duration in growth of each flush is given in Fig 2. Six flushes were observed in an year. Thus, the growth in nutmeg was found to be cyclic- a period of growth followed by a quiescence.

2. FLOWER CHARACTERS

The results of the detailed studies on floral characters are described below under different heads.

Table 4. Mean shoot growth per month in different flushes (cm)

	Mean growth	Flushes					
		April	May	June	July	August	September
1978	April	3					
	May	1	5.2				
	June	0	2.8	2.5			
	July	0	0	3	4		
	August	0	0	0	0	4	
	September	3.5	5.5	1.5	6	0	2.5
	October	2	1.2	0	0	5	4
	November	0	0	0	0	1.5	0
	December	0	0	0	2	0	0
1979	January	0	2.8	0	1.8	0	0
	February	0	1.0	0.8	0	1.5	0
	March	0	0	0.7	0	0	2

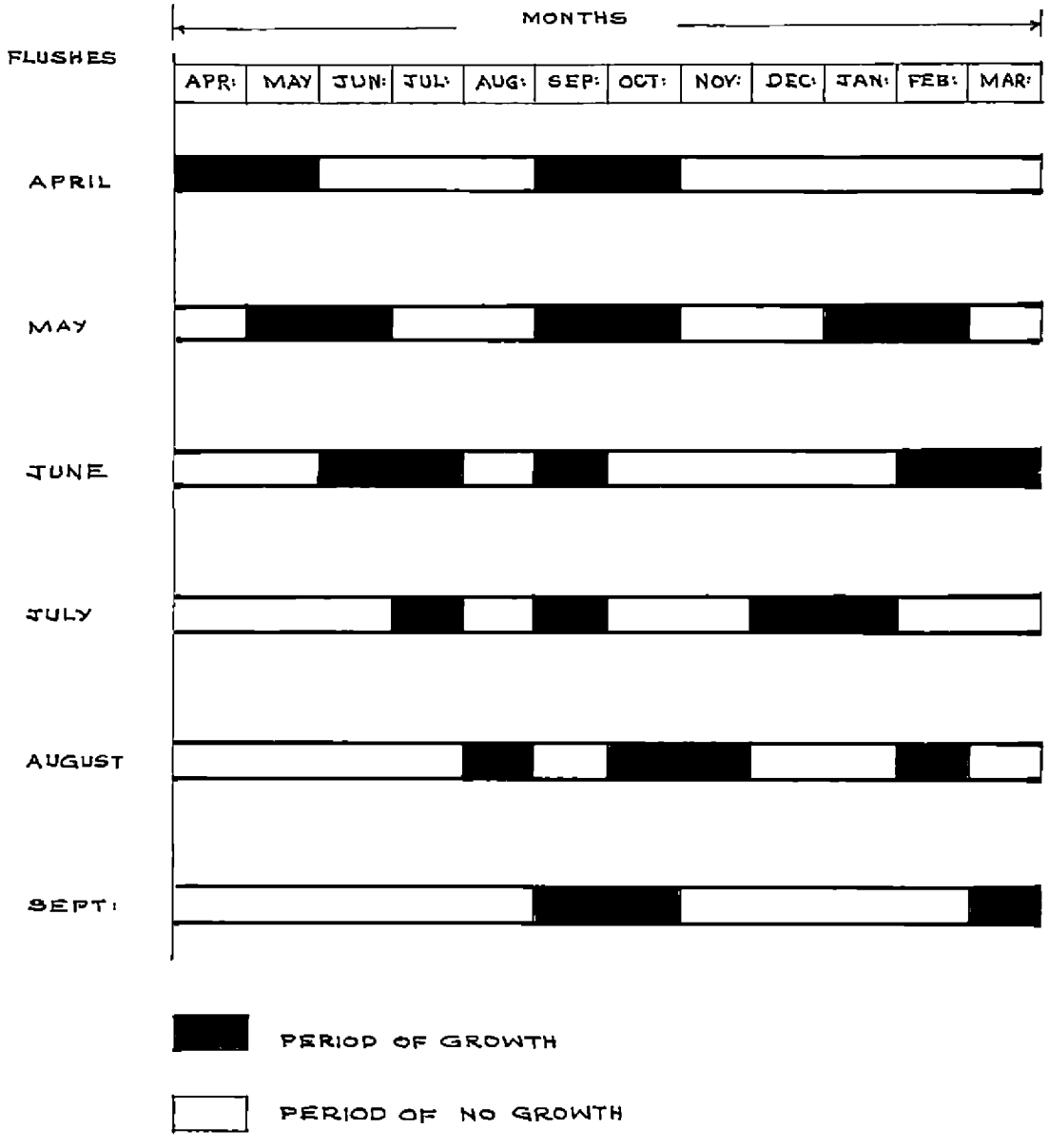


FIG:2 DURATION OF GROWTH IN DIFFERENT FLUSHES

2.1 Flowering pattern

The data on flowering of male and female nutmeg trees is presented in Table 5. Male and female trees showed variation in the pattern of flowering. The male trees showed flowering throughout the year at varying intensities. Maximum percentage of shoots flowered in July (72.75%) followed by October (60.50%), November (40.25%), March (39.00%), June (35.00%) and April (30.00%). During the remaining months the percentage of shoots flowered was below 30.00. Least flowering was recorded in December (7.50%). Statistical analysis showed that the values for November and March were on par. The variation between May, February, September, August and January were also not significant. The data for mean number of flowers per flowering shoot showed maximum in April and July (16.98%) and minimum in December (6.80%). The months differed significantly for the number of flowers per flowering shoot.

The flowering pattern of female trees was entirely different from that of male. Flowering was observed continuously from June to October and then in January and February (Table 5). Maximum percentage of shoots flowered in July (24.50%) followed by October (18.25%), June (11.50%), August (5.75%), September (4.50%), January (2.50%) and February (1.75%). However, no significant variation was

Table 5. Monthly flowering of nutmeg trees

Months		Male		Female	
		A	B	A	B
1978	April	30.00 (33.18)	16.98	0.00	0.00
	May	16.25 (23.78)	9.65	0.00	0.00
	June	35.00 (36.26)	9.70	11.50 (19.72)	1.15
	July	72.75 (58.54)	16.98	24.50 (29.35)	1.50
	August	13.00 (21.07)	8.83	5.75 (13.77)	1.05
	September	13.00 (21.10)	7.63	4.50 (12.10)	1.00
	October	60.50 (51.07)	15.25	18.25 (25.21)	1.28
	November	40.25 (39.37)	13.00	0.00	0.00
	December	7.50 (15.85)	6.80	0.00	0.00
1979	January	11.50 (19.73)	9.08	2.50 (7.76)	1.00
	February	14.75 (22.50)	9.63	1.75 (5.26)	1.00
	March	39.00 (38.61)	14.95	0.00	0.00
F value		297.60**	12.19**	50.70**	
CD		2.25	3.03	3.73	

A = Percentage of shoots flowered
B = Mean number of flowers per flowering shoot
Values in the parenthesis denote means of the transformed data

** = Significant at 1 per cent level

observed for August and September as well as for January and February. The mean number of flowers per flowering shoot also followed the same pattern, with the maximum in July (1.50%) and minimum in February (1.00%).

Flowering of individual trees is presented in Table 6. In males, T_4 and T_3 recorded significantly higher flowering than T_2 and T_1 both in percentage and mean number. In females also, significant tree to tree difference was noted. T_3 showed maximum percentage followed by T_1, T_4 and T_2 with no significant difference between T_1 and T_4.

2.2 Flower bud development

Stages of bud development was studied by taking the buds initiated on 'May' flush. The whole period from bud emergence to flower opening was divided into six stages. The period under each stage for male and female flowers is presented in Table 7. The male and female flower bud development could be described as follows:

2.2.1 Male flower

Stage 1. Small light green blunt protuberances 1.0 to 2.0 mm long were noted on the leaf axils of the new flush (Plate I - Fig 1). This stage continued for one month.

Stage 2. The bud attained a length of 0.75 cm with the tip portion covered by a bract distinguished by a light

Table 6. Extent of flowering in individual trees

Trees	Male		Female	
	A	B	A	B
1	27.50 (30.34)	10.41	6.00 (17.20)	1.16
2	28.75 (31.37)	10.23	3.58 (11.80)	1.12
3	30.75 (32.66)	12.73	8.00 (20.58)	1.24
4	30.83 (32.81)	12.78	5.33 (15.08)	1.03
F value	6.52**	5.36**	15.05**	
CD	1.30	1.75	2.82	

A = Percentage of shoots flowered
B = Mean number of flowers per flowering shoot
Values in the parenthesis denote the means for the transformed data
** = Significant at 1 per cent level

Table 7. Chronology of stages from bud emergence to flower opening in nutmeg

Sex of the plant	Number of buds observed	Days required for passing from the one stage to another					Total number of days required	Days for the inflorescence to complete anthesis
		1st to 2nd	2nd to 3rd	3rd to 4th	4th to 5th	5th to 6th		
Male	100	30.2	8.4	12.6	28.4	5.6	84.2	9.5
Female	100	64.2	30.3	15.7	35.1	8.8	154.1	..

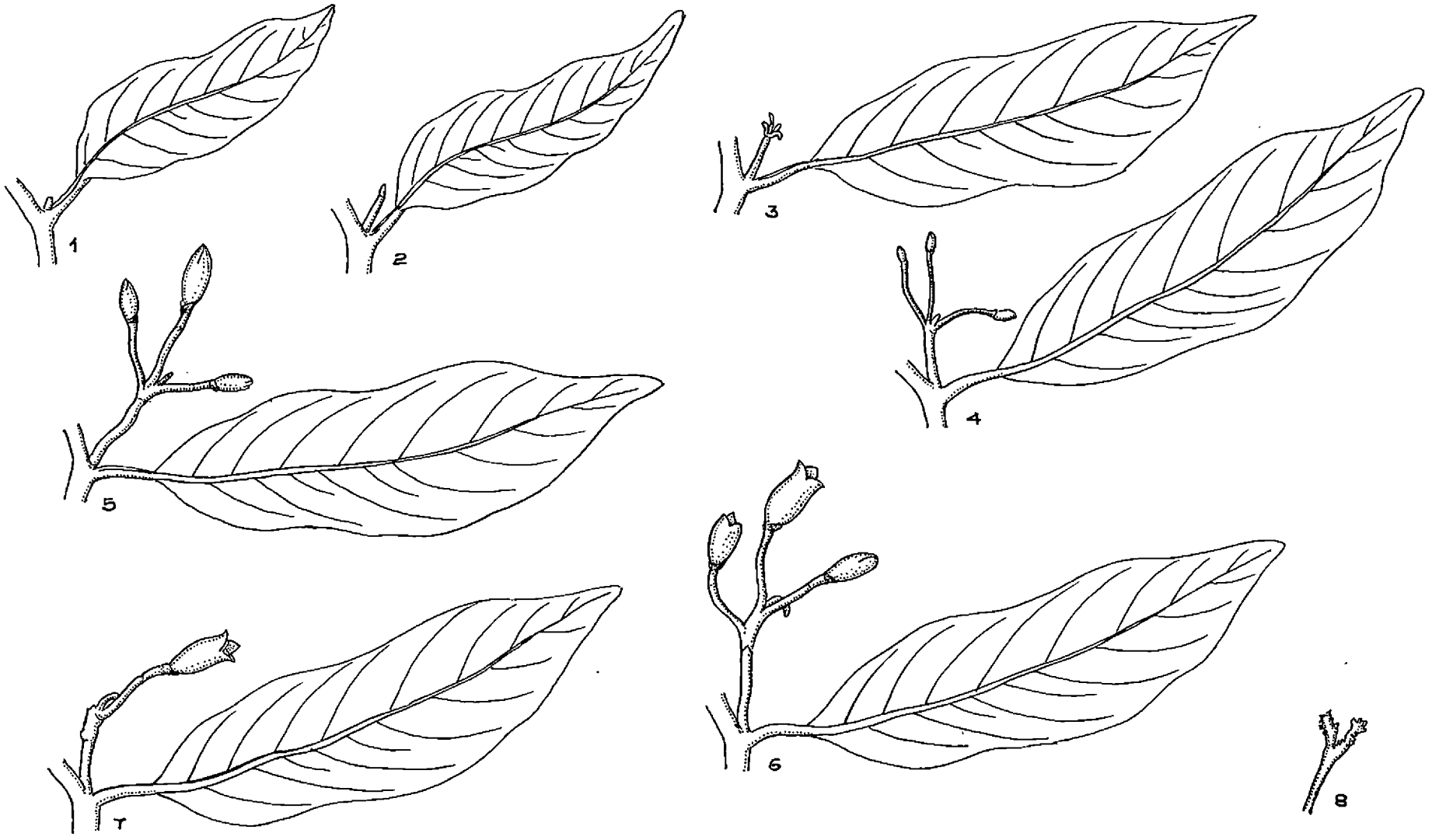


PLATE-I STAGES OF MALE FLOWER DEVELOPMENT IN NUTMEG

brown demarcation (Plate I - Fig 2). This stage continued for 7 to 9 days.

Stage 3. The tip portion showed signs of bud separation. The peduncle attained a length of about 0.8 cm. The bract fell off leaving a scar behind. The elder bud attained a length of 0.2 to 0.3 cm (Plate I - Fig 3). The duration of this stage was 10 to 15 days. The leaf on the axil of which the bud was borne attained full size; but was light green in colour.

Stage 4. All the buds in an inflorescence were clearly seperated. The buds were light green in colour, with the peduncle 0.7 to 0.9 cm, pedicel of the eldest bud 0.3 to 0.8 cm and the perianth 0.2 to 0.3 cm in length (Plate I - Fig 4). By this time, the leaf attained dark green colour. This stage lasted for about one month.

Stage 5. The inflorescence had 2 to 6 buds, each with a bracteole. The peduncle attained 1 to 1.3 cm in length, and the eldest bud had a pedicel of 1 to 1.3 cm greenish white perianth of 0.7 to 0.9 cm length and 1.6 cm girth (Plate I - Fig 5). It took six days for the bud to enter the next stage.

Stage 6. The anthesis of the first flower commenced. The open flower was with a greenish pedicel of 1.2 to 1.7 cm length and 0.2 cm girth, a lobed creamy white perianth of 0.8 to 1.2 cm length and 1.5 to 1.8 cm girth. In some

flowers, bracteole persisted. The peduncle bearing the flowers was green, 1.0 to 1.3 cm in length and 0.4 cm in girth (Plate I - Fig 6). The anthesis in an inflorescence was completed in 7 to 11 days (Plate I - Fig 7). On an average, it took 84 days from the bud emergence to complete opening of all the buds in an inflorescence in one season. After anthesis, the inflorescence axis remained dormant, with a bud at the tip, which again followed the same pattern of flower development in the next season (Plate I - Fig 8).

2.2.2 Female flower

Stage 1. The first stage of male and female bud resembled each other. The young bud appeared on the leaf axil of new flushes as a light green blunt protuberance of 1 to 2 mm length (Plate II - Fig 1). The bud remained as such for two months.

Stage 2. The young bud elongated slightly to a length of 2 to 4 mm. The tip portion, covered with the bract, appeared brownish. The leaf on the axil of which the bud was borne fully developed and turned dark green (Plate II - Fig 3). This stage was of about one month duration.

Stage 3. The bud attained 5 to 7 mm length. The brownish tip portion of the second stage elongated further. The bract was dropped leaving a scar behind (Plate II - Fig 3).

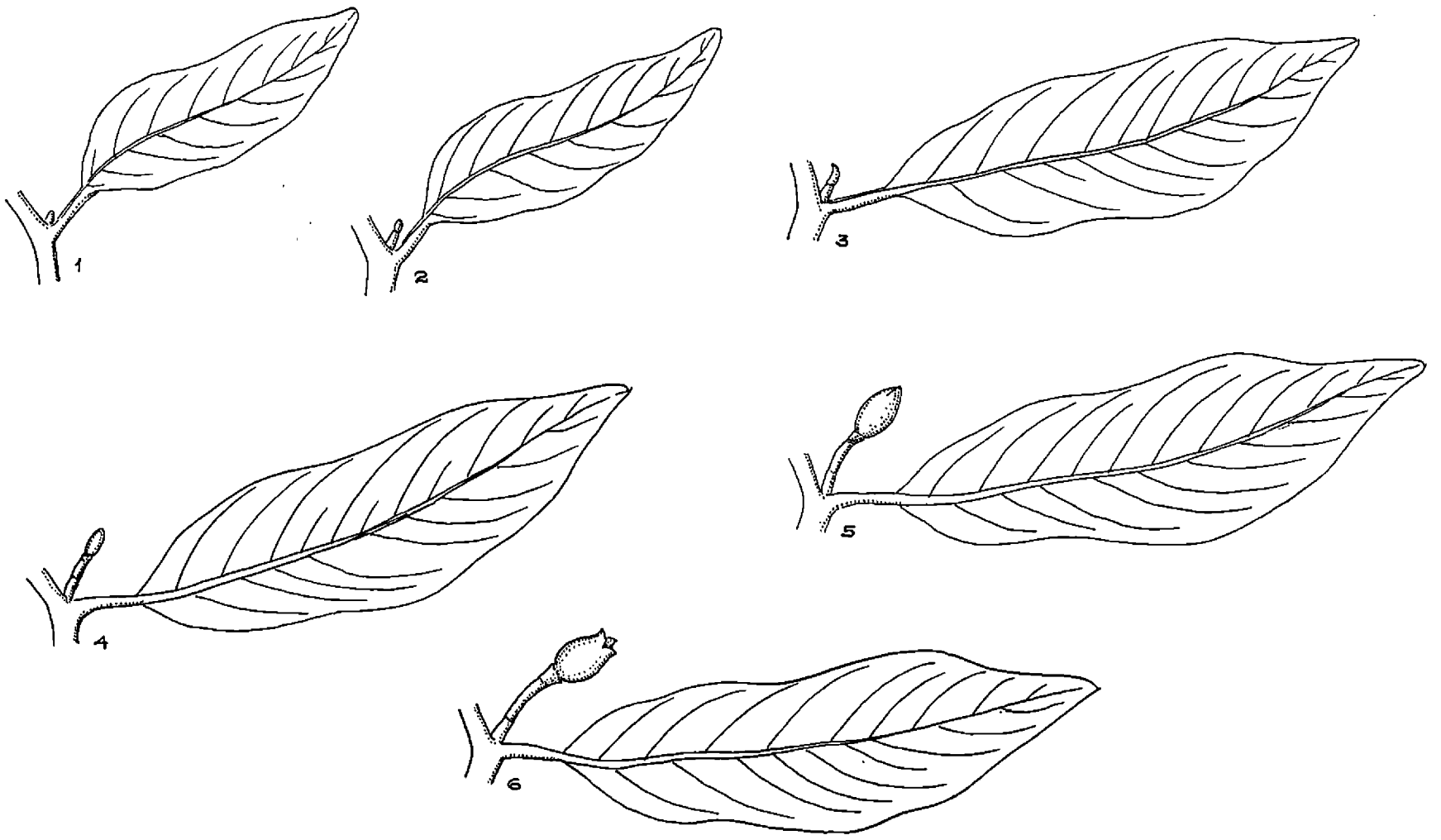


PLATE - II STAGES OF FEMALE FLOWER DEVELOPMENT IN NUTMEG

This stage lasted for about 15 days.

Stage 4. The young bud was with a short, green peduncle and a pedicel distinguished by a bulging tip. The whole bud attained a length of 1.0 to 1.2 cm (Plate II - Fig 4). It took 35 days for the bud to pass to the fifth stage.

Stage 5. The bud became fully developed with a well demarcated greenish peduncle of 0.3 to 0.5 cm length, 0.4 cm girth together with a greenish pedicel of 1.3 cm length, 0.4 cm girth and a greenish white perianth 0.5 to 0.7 cm in length and 1.3 to 1.6 cm in girth (Plate II - Fig 5). This stage was of 7 to 10 days duration.

Stage 6. Anthesis was observed. The flower was with a greenish peduncle of 0.3 to 0.5 cm length and 0.4 cm girth together with a greenish pedicel of 1.0 to 1.5 cm length and 0.4 cm girth. A trilobed creamy white perianth of 0.75 to 0.90 cm length and 1.7 to 1.9 cm girth was also visible. The bracteole persisted in certain cases (Plate II - Fig 6).

The average number of days between bud emergence and flower opening was 154. By the time the flower opened, new flushes had started on the same shoot.

2.3 Floral biology

Nutmeg is generally treated as dioecious; but occurrence of male and female flowers on the same tree is also seen.

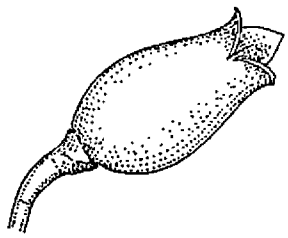
2.3.1 Male flower

Usually produced on shoots up to one year old in panicled cymes of 2 to 6 flowers on leaf axils. When all the flowers were shed, the axis was zigzag in nature (sympodium - Plate III). After one season's flowering new buds arose from the same axis in the next season. Flowers were fragrant; peduncle pale green, unbranched 1.0 to 1.5 cm in length, 0.4 cm in girth; pedicil drooping, 1.0 to 1.5 cm in length, 0.2 cm in girth, bract small and deciduous; bracteole present, oblique at the base of the perianth; perianth bell shaped, creamy white, three lobed, valvate, 0.70 to 0.95 cm in length, 1.8 cm in girth; androecium stalked, filaments and connectives connate in a column, usually produced beyond the anthers, anthers elongate, dehiscence longitudinal; pollen grains were abundant, spherical, pale yellow and powdery. The details of the flower are given in Plate IV.

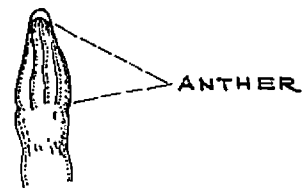
2.3.2 Female flower

Usually one flowered or a new flowered cyme was seen on the leaf axils of last season's growth. Flowers were fragrant; peduncle green, unbranched, 0.35 cm in length, 0.4 cm in girth, pedicel green, drooping, sturdier than

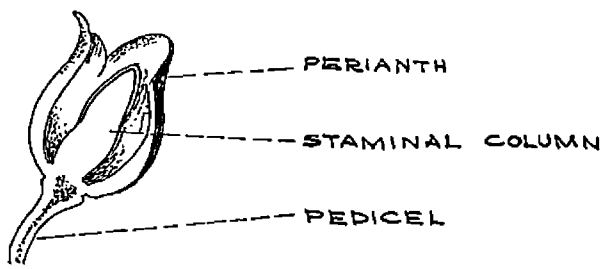
ENTIRE FLOWER



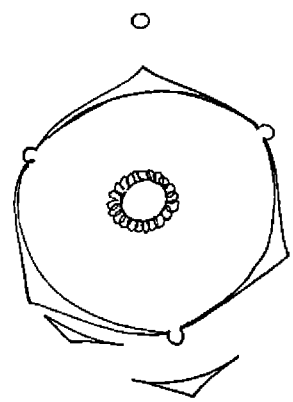
STAMINAL COLUMN



L.S. OF THE FLOWER



FLORAL DIAGRAM



Br. Bal. δ ⊕ $P_{(3)}$ A_{8-13} G_0

PLATE-IV MALE FLOWER (×4)

that of male, 1.2 cm in length, 0.4 cm in girth; bract small and deciduous; bracteole present, oblique at the base of the perianth; perianth creamy white, bell shaped, 2 to 3 lobed, valuate, 0.75 cm in length, 1.8 cm in girth; carpel solitary and free; ovary sessile, ovoid, poberulous; ovule single, basal, anatropus; style very short or obsolate; stigma bilobed and triangular. The details of the flower are given in Plate V.

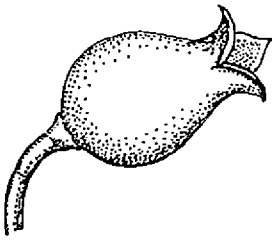
2.3.3 Female flowers of the hermaphrodite tree

There were two types of female flowers on hermaphrodite trees - the normal females and the abnormal ones which were found rarely. The flowers were borne solitary on leaf axils or on an otherwise male inflorescence. They externally resembled the male flowers of the tree but with stouter and more greenish pedicels. Usually the pistil did not resemble that of normal female flower. Carpels 2 to 3; ovary angular; stigma 3 to 6 lobed, lobes corresponding to the number of carpels. Staminodes were 1 to 2 often present. The details of the flower are given in Plate VI.

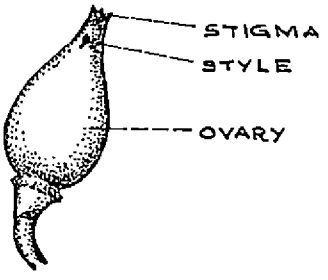
2.3.4 Anthesis

The data in Table 8 give the anthesis time of male and female flowers. In male the anthesis started between 1700 and 1900 hours and continued upto 0700 hours of the next day. Maximum number of flowers opened between 1900 hours

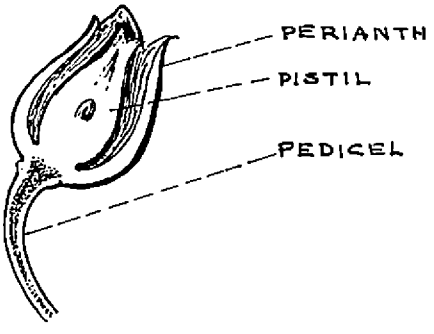
ENTIRE FLOWER



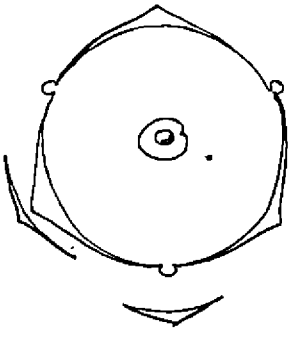
PISTIL



L.S. OF THE FLOWER



FLORAL DIAGRAM

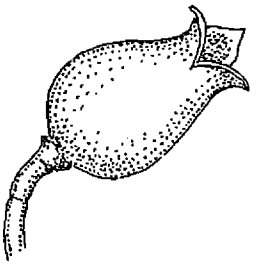


$Br.Brl.\ ♀\ ⊕\ P_{(3)}\ A_0\ \underline{G_1}$

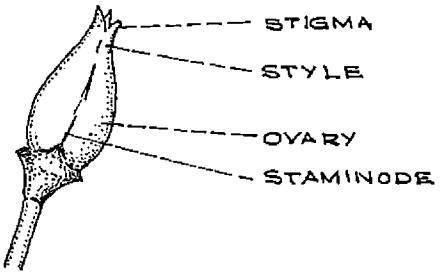
T.S. OF OVARY

PLATE - V FEMALE FLOWER (x4)

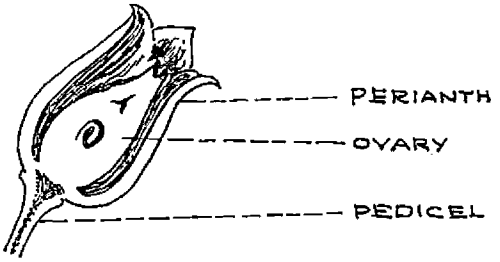
ENTIRE FLOWER



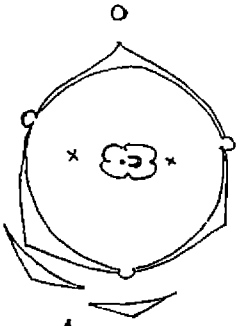
PISTIL



L. S. OF THE FLOWER



FLORAL DIAGRAM



Br. Brl. ♀ ⊘ $P_{(3)}\,A_{0-2}\,\underline{G_{1-2}}$

T. S. OF OVARY

PLATE- VI FEMALE FLOWER OF MALE TREE (×4)

and 0100 hour of the next day. In female, anthesis started between 1900 and 2100 hours and continued upto 0700 hours of the next day with a maximum between 2100 and 0300 hours of the next day.

2.3.5 Anther dehiscence

From initial observations, it was noted that anther dehiscence took place much earlier to anthesis. Buds which were to open in the night hours were seen to have dehisced 12 hours in advance. Later observations at bihourly intervals are presented in Table 8. The data showed that, dehiscence started by 1900 hours and continued upto 0500 hours of the next day i.e., in a male flower, anther dehiscence occurred about 24 hours prior to anthesis.

2.3.6 Stigmatic receptivity

The whitish cream, shiny stigmatic surface was found to be retained upto 3 to 5 days after anthesis. Pollination studies presented in Table 9 showed that fruit set occurred when pollinated from the day of anthesis upto six days after anthesis. Maximum fruit set was recorded for the first three days where the set ranged from 80 to 82 per cent. The set was only 60, 32 and 4 per cent on fourth and fifth and sixth day respectively after anthesis. The set was practically nil there after.

Table 8. Anthesis and dehiscence period of male and female flowers

Time (hours)	Anthesis						Dehiscence		
	Male			Female			Male		
	A	B	C	A	B	C	A	B	C
1700	108	0		61	0		67	0	
1900		15	13.88		0			1	1.49
2100		40	37.04		8	13.11		28	41.79
2300		23	21.30		12	19.67		21	31.34
0100		15	13.89		20	32.79		6	8.96
0300		10	9.26		13	21.31		8	11.94
0500		3	2.78		6	9.84		3	4.48
0700		2	1.85		2	3.28		0	0.00
0900		0	0.00		0	0.00		0	0.00
Total		108	100.00		61	100.00		67	100.00

A = Number observed
B = Number opened/dehisced
C = Percentage of the total

Table 9. Percentage of fruit set on hand pollination at different intervals

Pollinated	Number treated	Number set	Percentage set
One day before anthesis	25	0	0
First day of anthesis	25	20	80
Second day after anthesis	25	21	82
Third day after anthesis	25	21	82
Fourth day after anthesis	25	15	60
Fifth day after anthesis	25	8	32
Sixth day after anthesis	25	1	4
Seventh day after anthesis	25	0	0
Eighth day after anthesis	25	0	0
No pollination	25	0	0

2.3.6 Pollen studies

The results of different aspects of pollen studies are described under the following heads:

2.3.6.1 Morphology and fertility

Pollen appeared as a yellowish powdery mass to the naked eye. Microscopic examination showed them as yellowish spherical mass with a well demarcated exine. A single pollen grain measured 40 to 45 μ in diameter with a mean reaching 42.6 μ. The fertility recorded by stain test was 98.2 per cent (Table 10).

2.3.6.2 Pollen production

The recorded anther number per flower ranged from 8 to 13 and the number of pollen per flower ranged from 3250 and 23000 (Table 11) with a mean of 10.03 anthers and 11843.75 pollen. Statistical analysis of the mean number of anthers per flower and the mean number of pollen per flower showed that there exist significant variation at one per cent level for both the number of anthers and number of pollen per flower among the trees. In both the cases, T_3 recorded the maximum followed by T_1, T_4 and T_2 But there was no significant difference between T_1 and T_4 and also T_4 and T_2 with regard to number of anther per flower. There was no significant difference between T_3 and T_1 and T_1 and also T_1 and T_4 with regard to number of pollen per flower.

Table 10. Pollen morphology and fertility

Stain used	Number of pollen observed	Viable	Nonviable	Percentage Fertility	Average size of pollen (u)
Acetocarmine	1288	1260	28	97.83	44.80
Iodine (0.1%)	1193	1176	17	98.58	40.40
Total	2481	2436	45	196.41	85.20
Mean		1218	22.50	98.20	42.60

Table 11. Variation in anther and pollen number of male flower

Tree Number	Number of flowers observed	Number of anther/flower		Number of pollen/flower	
		Mean	Range	Mean	Range
1	100	10.15	8-12	12975	7000-18500
2	100	9.25	8-10	6825	3250-12000
3	100	11.25	10-13	15875	9500-23000
4	100	9.70	9-12	11700	6000-19500
Total	400	40.15		47375	
Mean	100	10.03		11843.75	
F value		17.12**		9.86**	
CD		0.59		3447.09	

** = Significant at 1 per cent level

2.3.6.3 Effect of sucrose in pollen germination

Results of the pollen germination in different sucrose concentrations are given in Table 12. Maximum germination (76.6%) was observed in six per cent sucrose followed by eight, four, two and zero. There was no germination in ten per cent sucrose media. Statistical analysis showed significant difference between each treatment at one per cent level. The data in Table 13 showed that the percentage germination in six per cent sucrose agar media reached the maximum of 76.6 per cent in five hours after planting at room temperature in humid chamber. Tube growth was found to increase length upto ten hours after incubation. No significant difference in germination was observed for pollen from different trees (Table 14).

2.3.6.4 Effect of boric acid and calcium nitrate

The data on percentage pollen germination and tube length in 1.5 per cent agar media with varied concentrations of sucrose, boric acid and calcium nitrate are presented in Tables 15a to 15c. The separate effects of boric acid and calcium nitrate at different sucrose concentrations are given in Table 16 and 17 respectively. Table 16 revealed the fact that, addition of boric acid at all concentrations of sucrose increased pollen germination and tube length.

Table 12. Pollen germination in sucrose agar media

Sucrose conc. (%)	Percentage germination	Mean tube length (μ)
0	2.8	61.4
2	27.6	165.1
4	43.8	272.6
6	76.6	304.6
8	63.9	230.4
10	0	0

Table 13. The duration of optimum incubation for maximum germination in 6 per cent sucrose agar media.

Sl. No.	Hours after pollen planting	Percentage germination	Tube length (μ)
1	1	31.15	130.60
2	2	46.35	143.36
3	3	57.33	213.76
4	4	65.25	236.80
5	5	76.62	304.64
6	6	76.60	421.12
7	8	76.40	440.72
8	10	76.20	490.50
9	12	76.50	490.20
10	24	76.80	489.60

Table 14. Pollen germination of different trees in 6 per cent sucrose agar media

Tree number	Percentage germination	Mean tube growth (μ)
T_1	74.18 (59.49)	289.60
T_2	75.58 (60.45)	272.00
T_3	76.43 (60.95)	315.10
T_4	74.93 (59.98)	325.70
F value	0.483^{NS}	

Values in parenthesis denote the means of the transformed data.

NS = Not significant

Table 15a. Mean pollen germination (%) and tube length (μ) in 1.5 per cent agar media with varied concentrations of sucrose boric acid and Ca NO_3.

Sucrose 0%; Agar 1.5%	Ca NO_3 concentration (ppm)	Boric acid concentration (ppm)				
		0	25	50	75	100
	0	2.8 (614.0)	13.5 (64.0)	15.9 (84.5)	18.5 (102.4)	21.3 (110.1)
	25	9.2 (81.9)	15.3 (88.6)	18.9 (99.8)	21.0 (111.3)	24.1 (114.7)
	50	11.4 (104.9)	17.4 (110.1)	19.9 (117.8)	24.9 (122.8)	27.8 (126.7)
	75	16.4 (111.36)	18.2 (121.6)	21.9 (129.2)	26.4 (139.5)	29.9 (140.8)
	100	8.9 (115.2)	20.3 (130.6)	22.4 (144.6)	27.8 (148.4)	31.8 (147.2)

Table 15b.

Sucrose 2%; Agar 1.5%						
	0	27.6 (165.1)	38.8 (189.4)	54.1 (250.8)	55.6 (267.5)	51.8 (171.5)
	25	33.9 (285.7)	50.1 (259.7)	57.4 (282.8)	59.7 (294.4)	54.8 (209.8)
	50	37.9 (302.1)	58.8 (308.7)	66.8 (334.1)	67.4 (358.4)	56.3 (222.7)
	75	39.6 (344.3)	56.0 (320.0)	61.9 (335.4)	62.5 (348.1)	58.6 (243.7)
	100	32.1 (195.8)	43.9 (318.1)	50.2 (346.8)	58.2 (325.1)	48.7 (220.1)

Table 15c.

	$Ca\ NO_3$ concentration (ppm)	Boric acid concentration (ppm)				
		0	25	50	75	100
Sucrose 4%; Agar 1.5%	0	43.8 (272.6)	82.9 (284.1)	91.3 (300.8)	92.7 (304.6)	85.1 (281.6)
	25	49.5 (275.2)	93.1 (354.5)	95.9 (359.6)	96.9 (352.0)	85.7 (281.8)
	50	69.5 (304.6)	89.8 (350.7)	91.3 (326.4)	92.3 (320.0)	84.5 (309.7)
	75	70.6 (306.2)	85.7 (345.0)	86.0 (339.2)	88.9 (330.2)	81.4 (307.2)
	100	66.8 (308.4)	81.8 (335.3)	83.7 (321.3)	85.2 (314.8)	79.7 (308.4)

Table 15d.

Sucrose 6%; Agar 1.5%	0	76.6 (304.6)	84.7 (341.8)	88.6 (46.1)	91.7 (47.1)	89.9 (416.0)
	25	81.1 (358.4)	86.6 (416.0)	94.2 (486.4)	93.0 (449.3)	85.6 (386.7)
	50	82.8 (435.2)	75.6 (423.6)	83.7 (478.7)	89.2 (464.6)	84.1 (384.0)
	75	76.0 (350.3)	77.6 (408.3)	91.5 (387.8)	83.2 (437.8)	78.3 (353.3)
	100	69.6 (321.3)	75.0 (393.9)	87.1 (307.2)	82.5 (431.3)	64.9 (326.6)

Table 15e.

Sucrose 8%; Agar 1.5%	$Ca(NO_3)_2$ concentration (ppm)	Boric acid concentration (ppm)				
		0	25	50	75	100
	0	63.9 (230.4)	68.5 (256.0)	71.8 (281.6)	71.6 (268.8)	70.8 (256.0)
	25	65.0 (270.1)	85.6 (314.8)	88.2 (363.5)	84.00 (300.8)	70.00 (275.2)
	50	65.9 (304.6)	80.1 (317.4)	86.4 (320.0)	78.4 (330.2)	68.0 (252.2)
	75	62.8 (293.1)	63.9 (271.3)	74.3 (311.0)	73.0 (320.0)	58.3 (236.8)
	100	59.6 (131.8)	61.5 (260.2)	71.2 (290.5)	68.0 (313.6)	51.5 (217.6)

CD for marginal mean = 0.316

CD for combinations = 0.707

The values in parenthesis denote the mean tube length

Table 16. Effect of boric acid on pollen germination (%) and tube length (μ) at different sucrose concentrations

Sucrose (%)	Concentration of boric acid (ppm)				
	0	25	50	75	100
0	2.8 (61.5)	13.5 (64.0)	15.9 (84.5)	18.5 (108.4)	21.3 (110.1)
2	27.6 (165.0)	38.8 (189.4)	54.1 (250.8)	55.6 (267.5)	51.8 (171.5)
4	43.8 (272.8)	82.9 (284.1)	91.3 (300.8)	92.7 (304.6)	85.1 (281.6)
6	76.6 (324.6)	84.7 (341.7)	88.6 (460.8)	91.7 (471.0)	89.9 (416.0)
8	63.9 (230.4)	68.5 (256.0)	71.8 (281.6)	71.6 (268.8)	70.8 (256.0)

The values in parenthesis denote the mean tube length.

Table 17. Effect of Ca NO_3 on pollen germination (%) and tube length (μ) at different sucrose concentrations

Sucrose (%)	Concentration of boric acid (ppm)				
	0	25	50	75	100
0	2.8 (61.4)	9.2 (81.9)	11.4 (104.9)	16.4 (111.4)	18.9 (116.5)
2	27.6 (165.1)	33.9 (245.7)	37.0 (302.1)	39.6 (344.3)	32.1 (195.8)
4	43.8 (272.8)	49.5 (275.2)	69.5 (304.6)	70.6 (306.2)	66.9 (298.4)
6	76.6 (324.6)	81.1 (368.4)	82.8 (435.2)	76.0 (353.3)	69.6 (321.8)
8	63.9 (230.4)	65.0 (270.1)	65.9 (304.6)	62.8 (293.1)	59.6 (131.8)

Values in parenthesis denote the mean tube length in μ.

This was true for all the levels of boric acid concentrations tried for zero per cent sucrose. However, the maximum germination percentage (92.7%) was recorded in four per cent sucrose with 75 ppm boric acid. It was found that, in the presence of sucrose, boric acid at 100 ppm decreased pollen germination and tube length than the other levels.

Data in Table 17 showed that the presence of calcium nitrate in the media increased the pollen germination percentage at all levels of sucrose. The increase was maximum (82.8%) at 50 ppm in six per cent sucrose media.

However, the maximum percentage of pollen germination (96.9%) was observed for 75 ppm boric acid and 25 ppm calcium nitrate in four per cent sucrose and 1.5 per cent agar media (Table 15c).

Statistical analysis of the data for pollen germination showed that the treatments varied significantly. The individual effects and the combined effects of all the treatments were found to be significant at 1 per cent level. Normal pollen grains and tube growth in sucrose agar media are illustrated in Plates VII and VIII respectively.

2.3.4.5 Pollen storage

The percentage viability and mean tube length of pollen grains under different treatments were recorded at daily intervals and presented in Table 18. The data showed that

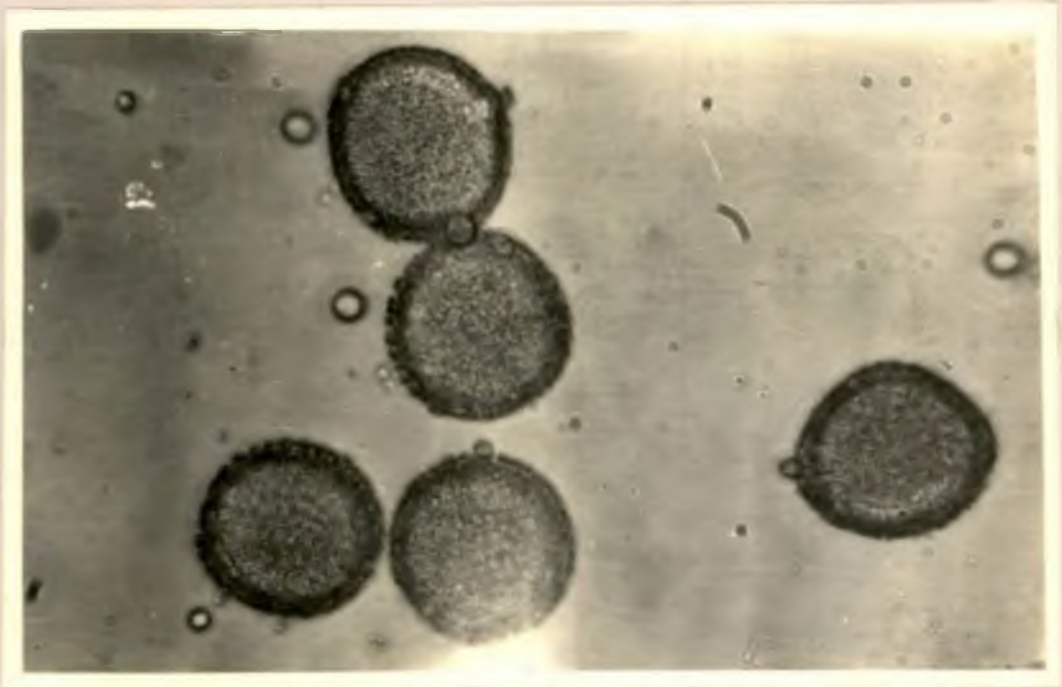


Table 18. Pollen viability under different conditions

Sl. No.	Treatments	Days after collection 1		2		3		4		5	
		Germination (%)	Tube length (μ)	Germination (%)	Tube length (μ)	Germination (%)	Tube length (μ)	Germination (%)	Tube length (μ)	Germination (%)	Tube length (μ)
1	Buds kept in tact at room temperature	73.36	267	48.30	185	34.40	120	6.40	94	0	0
2	Anther column at 4°C	60.20	230	53.10	198	33.40	201	0	0		
3	Anther column over calcium chloride at 4°C	27.27	158	4.31	66	2.60	53	0	0		
4	Pollen soaked in petroleum ether at 4°C	26.05	140	20.17	69	1.98	58	0	0		
5	Anther column in tact at room temperature	56.4	224	40.50	208	0	0				
6	Anther column over calcium chloride at room temperature	18.60	154	9.78	101	0	0				
7	Pollen soaked in Benzene at 4°C	8.36	104	0	0						
8	Pollen at 4°C	4.45	105	0	0						
9	Pollen over calcium chloride at 4°C	3.23	86	0	0						
10	Pollen over calcium chloride at room temperature	0.96	78	0	0						
11	Pollen at room temperature	0	0	0	0						
12	Pollen soaked in acetone at 4°C	0	0								

the storage capacity of the pollen when once detached from the anther column was very low (0.to 26.05%) under different treatments. The detached pollen lost viability within a day except in petroleum ether (26.05%) which was comparatively low against a range of 18.60 to 73.36 per cent in case of non detached pollen. Treatments at low temperature and at low humidity gave no better results.

Mature buds kept intact at room temperature, without removing the perianth parts gave better results among the treatments tried. Such pollen gave 73.36 per cent germination with mean tube length of 267 μ next day after collection and were viable upto four days after collection with 6.4 per cent germination and a tube length of 94 μ on the fourth day. Next to this anther column kept at 4°C followed by anther column over calcium chloride at 4°C and pollen soaked in petroleum ether and kept at 4°C gave better results. Pollen remained viable for three days under these treatments with a germination of 33.40, 2.60 and 1.98 per cent respectively and a mean tube length of 201, 53 and 58 μ respectively. Anther column intact at room temperature and anther column over calcium chloride at room temperature gave next better results and were viable for two days after collection. They recorded 40.50 and 9.78 per cent germination and a tube length of 208 and 101 μ respectively. Anther column kept at room temperature and at 4°C were seen to be subjected to fungus

attack after two and three days respectively after collection.

Pollen soaked in benzene and kept at $4^{o}C$ followed by pollen at $4^{o}C$, pollen over calcium chloride at $4^{o}C$ and pollen over calcium chloride at room temperature remained viable for one day after collection with a germination of 8.36, 4.45, 3.23 and 0.96 per cent respectively and a tube length of 104, 105, 86 and 78 μ respectively.

Pollen stored at room temperature and pollen soaked in acetone lost viability even on the next day after collection.

Therefore it was found that pollen grains attached to the anther column recorded better viability than when detached. Low temperature treatment was better than low humidity and a combination of low temperature and low humidity. Among the organic solvents, petroleum ether gave better results than the others tried.

Hence the pollen of nutmeg could be stored as the mature buds intact for one to two days with 73.36 to 48.30 per cent germination. This indicates that the best time for pollination in the field is the day of male flower opening. About 48 per cent success could be expected during the second day and the effect of pollen for germination was very low during the next two days. It was practically nil thereafter.

2.3.7 Mode of pollination

The mode of pollination in nutmeg was studied by trapping the insects visiting the flower and by collecting the pollen dispersed by wind. No insects were trapped except the spiders, ants and rice bugs (Leptocoryza oryzae). Air sampling showed that, there exist 2.08 pollen grains per microscopic field (Table 19). So, pollination in nutmeg could be through wind. The extent to which the pollen could be carried by wind depend upon several factors such as wind velocity and direction, rainfall, barrier plants, position of male tree etc.

3. FRUIT SET, FRUIT DROP AND FRUIT DEVELOPMENT

The results of studies carried out are presented below:

3.1 Fruit set

The percentage of fruits set under different conditions were recorded (Table 20). The data showed significant difference at one per cent level for the percentage set by open pollination and hand pollination. The percentage set was nil for the flowers which were excluded from pollination. Open pollination recorded 33.10 per cent set whereas hand pollination recorded a much higher percentage i.e., 88.75. The results of fruit set showed no possibility for apomictic fruit development in nutmeg.

Table 19. Intensity of atmospheric pollen

Sl. No.	Date of observation	Number of slides observed	Average number of pollen grains per microscopic field (10x)	
			Nutmeg pollen	Foreign matter
1	25.10.1978	10	1.2	0.8
2	27.10.1978	10	2.3	0.2
3	29.10.1978	10	1.6	0.7
4	1.11.1978	10	1.7	1.2
5	3.11.1978	10	2.2	0.5
6	5.11.1978	10	2.5	0.6
7	7.11.1978	10	2.7	0.3
8	9.11.1978	10	2.4	0.2
Total			16.60	4.50
Mean			2.08	0.56

Table 20. Fruit set under different conditions

Treatments	Number observed	Number set	Percentage set
No pollination	100	Nil	Nil
Open pollination	456	151	33.1
Hand pollination	80	71	88.7
			$\chi^2 = 86.83^{**}$

** Significant at 1 per cent level

The data for percentage fruit set on different trees and on different aspects are presented in Table 21. There existed both aspect wise and tree wise difference in fruit set. Statistical analysis showed variation at one per cent level in both the cases. T_2 recorded maximum set followed by T_1, T_3 and T_4. Among the aspects, set was maximum on west, followed closely by East, South and North. There was no significant difference between T_2 and T_1 and aspects west and east and also between south and north.

Therefore the data clearly indicate that hand pollination with dehisced pollen (pollen collected from mature bud that is to open on the same day night) could increase fruit set by 2.5 times than that of natural pollination. The chances of natural set was also found to be more in the western and eastern aspects than that of the other two aspects.

3.2 Fruit drop

The percentage fruit drop after set presented in Tables 22 and 23 were formulated from the data on the fruit drop recorded at weekly intervals (given in appendix II). The drop at fortnightly intervals is presented in fig 3. The data showed that, there was drop in all the months commencing from the first to the last, with varying intensities. The maximum was recorded during the period

Table 21. Variation in fruitset on different trees and aspects

Tree number	Percentage fruitset	Aspects	Percentage fruitset
T_1	39.00 (38.63)	East	36.63 (37.16)
T_2	41.60 (40.19)	South	30.50 (33.43)
T_3	29.50 (32.86)	West	37.60 (37.71)
T_4	25.00 (29.90)	North	30.38 (33.30)
F value	38.32**		9.31**
CD	2.48		2.48

Values in parenthesis denote the means transformed data

** = Significant at 1 per cent level

Table 22. Mean monthly increase in fruit girth and percentage fruit drop

Months after set	Increase in girth		Percentage drop
	Mean	Mean expressed as percentage of the total	
1	2.25	15.38	3.48 (10.71)
2	2.80	18.66	1.95 (7.97)
3	4.59	30.21	24.75 (29.79)
4	3.38	24.37	31.90 (34.37)
5	0.88	6.29	8.17 (16.60)
6	0.45	3.17	2.65 (9.35)
7	0.28	1.92	1.50 (7.02)
Total	14.63	100	74.40
F value	74.4**		276.42**
CD	0.56		

Values in parenthesis denote the means for the transformed data

** Significant at 1 per cent level.

Table 23. Mean fruit girth and percentage drop

Tree Number	Fruit girth		Percentage drop		Aspects	Fruit girth		Percentage drop	
	Total	Mean for the month	Total	Mean for the month		Total	Mean for the month	Total	Mean for the month
1	14.30	2.04	62.90	8.99 (14.71)	East	14.60	2.08	75	10.71 (16.73)
2	15	2.14	58.90	8.41 (14.34)	South	14.80	2.11	72	10.23 (16.21)
3	14.70	2.10	94.5	13.50 (19.26)	West	14.40	2.06	73.10	10.44 (16.38)
4	14.90	2.13	87.4	12.49 (17.82)	North	14.10	2.01	77.50	11.07 (16.89)
F value		0.11^{NS}		25.78**			0.11^{NS}		0.31^{NS}
CD				1.40					

NS = Not significant
** = Significant at 1 per cent level
Values in parenthesis give the means for the transformed data

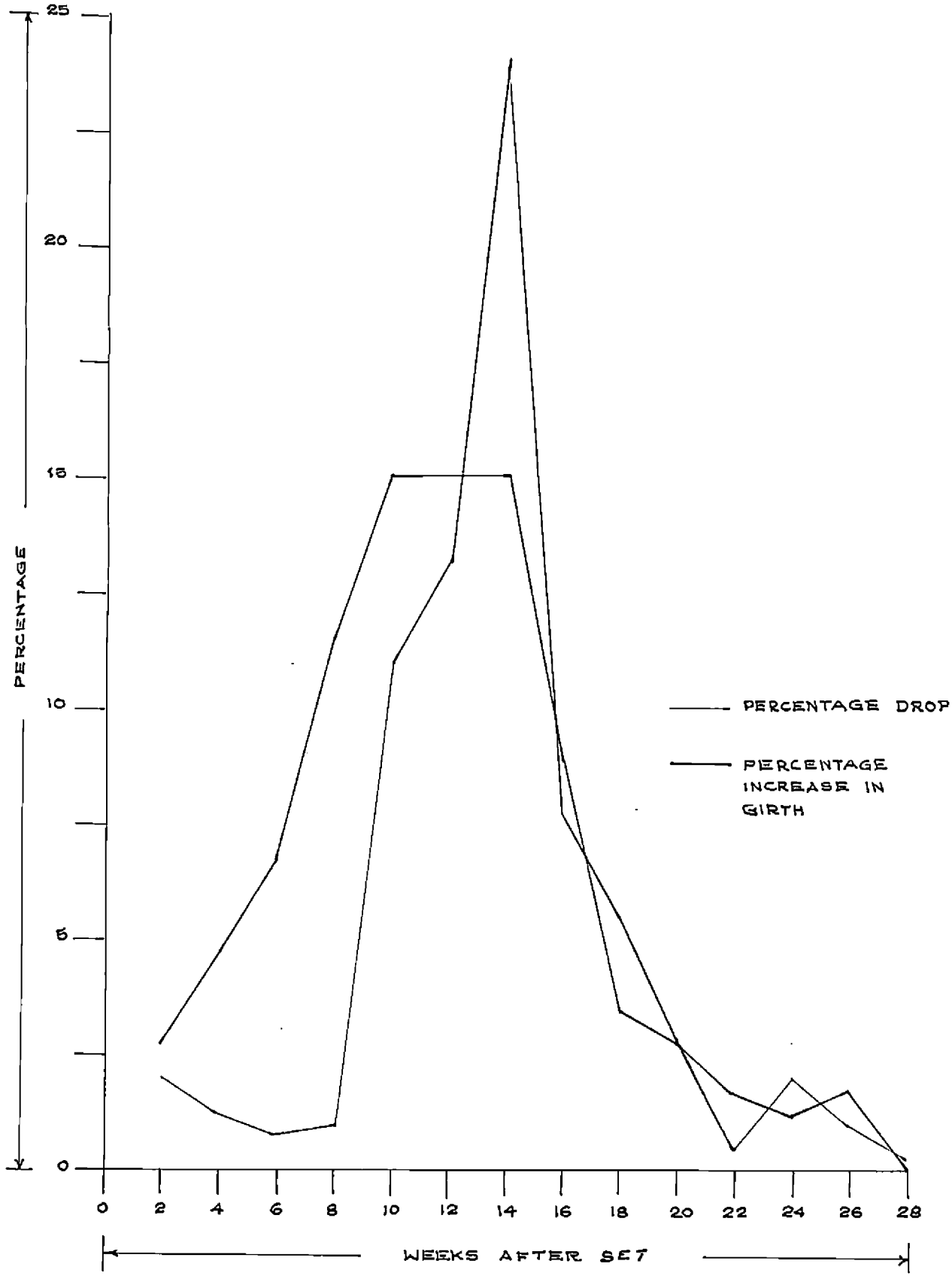


FIG:3 PERCENTAGE INCREASE IN FRUIT GIRTH AND FRUIT DROP

between eighth and sixteenth weeks after fruit set (fig 3). Statistical analysis showed no significant aspect wise difference (Table 23) but the variation between months (Table 22) and between trees (Table 23) were significant at one per cent level. Maximum drop was recorded during the fourth month which accounted to 31.90 per cent drop followed by third, fifth, first, sixth, second and lastly the seventh month (1.50%). But values for first and sixth; sixth and second; second and seventh month were on par.

Among the trees, third tree showed maximum drop which accounted for 94.50 per cent followed by fourth, first and lastly the second (58.90%). But there was no significant difference between the first and the second tree.

Thus it was seen that, eventhough the flowers produced in a tree was considerably high, the number that was carried upto harvest were very low. The initial set was recorded to be 33.10 per cent were (Table 20) in case of open pollination. After set, the mean percentage drop accounted to 74.40 per cent. The number harvested thus accounted for only 8.47 per cent of the total flowers produced.

The freshly dropped flowers and fruits were subjected to thorough examination for the presence of any pests or diseases with no positive results. The fruits were found to detach at the base of the pedicel. The portion exposed by

detachment were dry and light brown in colour, whereas in healthy fruits it was greenish white in colour. The cross section of the dropped fruits just after the drop revealed a browning at the basal end of the fruit covering the pericarp and seed whereas for fruits retained on the tree, it was pure white (Plate IX).

Some of the fruits dropped during fifth and sixth months after set were found to be splitted before reaching maturity (Plate Xa). The seeds in such case were whitish with a whitish but fully developed mace (Plate Xb).

In hermaphrodite trees, no immature splitting was noted. In them the splitting was found to be delayed for the reason that, most of them possessed more than two grooves, representing the stigmatic lobes. The fruits in such cases were either of normal shape or irregular with one or more seeds (Plate Xa & b).

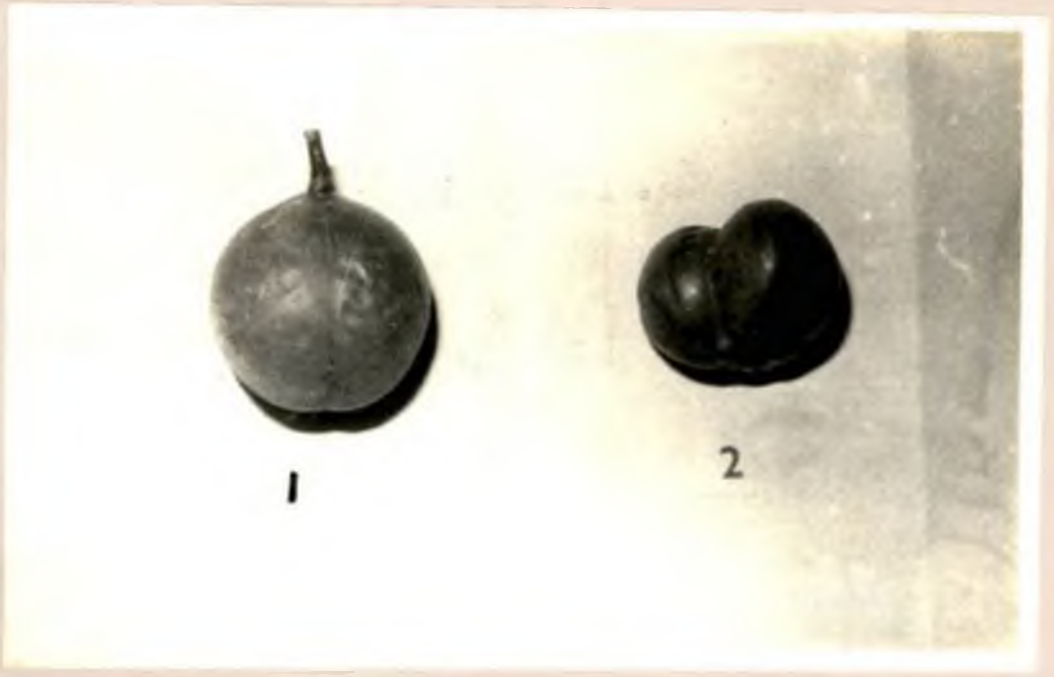
3.3 Fruit development

Mean increase in fruit girth was recorded at weekly intervals (Appendix II). Mean monthly increase in girth is presented in Table 22. Statistical analysis of the data showed significant difference at one per cent level for the mean monthly growth. The growth was found to increase gradually from second week after set. The development was quicker during the period between sixth and sixteenth week


1
2


1
2


1
2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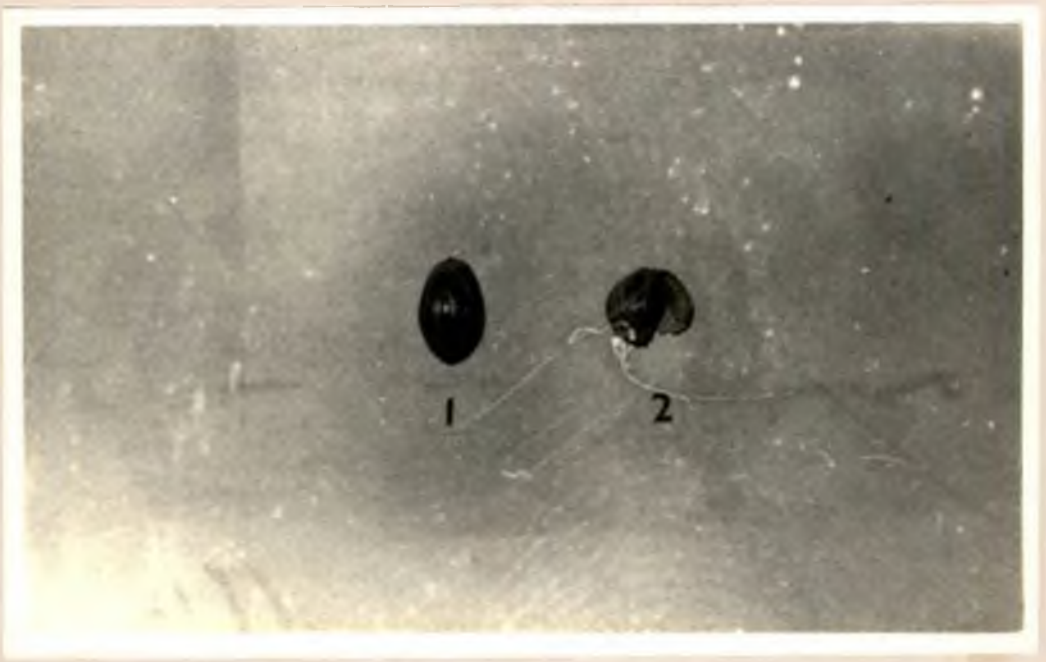
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after set (Fig 3) and thereafter it decreased gradually till eighteenth week. The increase in growth was very low between 18th and 25th week and there was no growth thereafter. The fruits started splitting in 206 to 237 days (seven to eight months) after set. No significant difference was noted between trees and between aspects (Table 23). The different stages of fruit development per month after flower opening are illustrated in Plate XII.

4. YIELD

The nutmeg tree bear fruits more or less all through the year round.

The harvest season was found to extend mainly for seven months (March to September) in an year with maximum during April to July (131.00 to 216.25). The mean yield recorded for each month and for each tree are presented in Table 24a and b. The data showed that the number of fruits harvested varied significantly from month to month. The yield during the months April, May, June and July were on par. No significant difference was noted for the number harvested during March, August and September.

Significant difference at one per cent level was noted for fruits harvested from individual trees. Maximum was recorded for first tree followed by second, fourth and third. The yield for the year ranged between 56 to 1238.

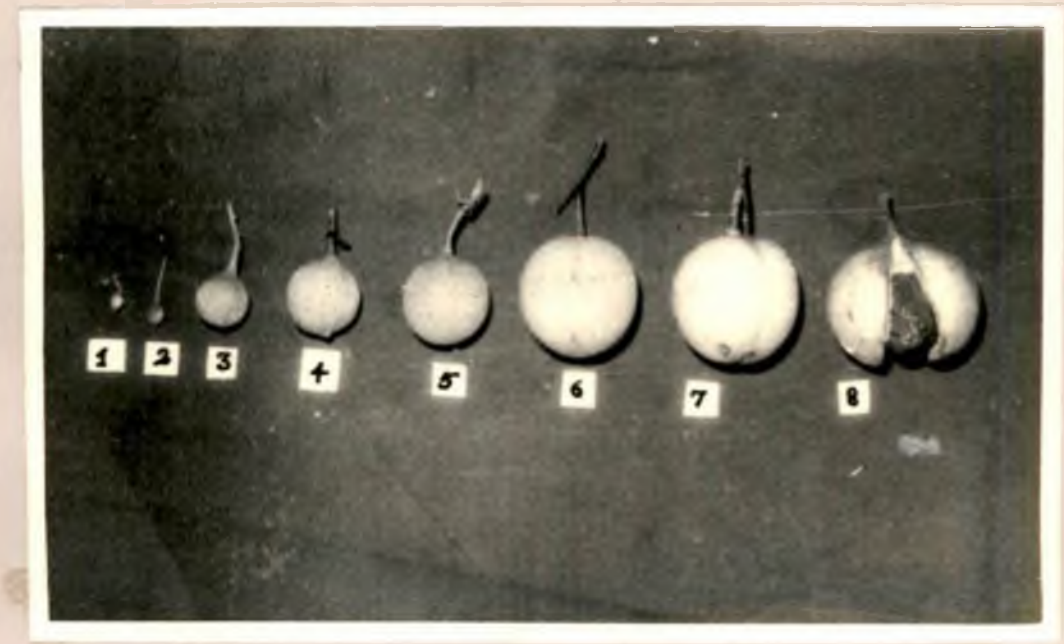
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Table 24a. Monthly yield of nutmeg (during 1979)

Months	Mean number of fruits harvested
March	11.50
April	131.00
May	136.25
June	113.00
July	216.25
August	38.25
September	2.75
F value	5.53**
CD	114.08

Table 24b. Variation in yield of different trees

Tree number	Number of fruits harvested	
	Total	Month
1	1238	176.86
2	717	102.43
3	56	8.00
4	585	83.57
F value		7.62**
CD		80.68

** = Significant at 1 per cent level

DISCUSSION

DISCUSSION

1. SHOOT GROWTH

The shoot growth in nutmeg was found to be cyclic; a period of growth followed by a period of quiescence. There were six flushes during one year. Growth was not seen in all the shoots during all the flushes. However, when the entire tree was considered, continuous growth was observed in all the months; though it was negligible in summer months. These were two main peak season of extension growth (May-June and September). In September alone, 35.94 per cent of the total growth was recorded. This was closely followed by the growth in May (21.84%) and June (21.18%) with no significant difference between the latter two.

Several workers (Sen and Mallik, 1941; Naik and Rao, 1942; Krishnamurthi *et al.*, 1961; Randhawa and Sinha, 1963 and Singh and Ghose, 1965) have reported cyclic growth in perennial trees. Similar cyclic pattern of growth was observed in nutmeg also. The higher growth during September and May-June is quite reasonable considering the high soil moisture level and optimum temperature during the periods. The low moisture level in summer, coupled with comparatively low relative humidity may be the possible reason for the abscence of growth or poor growth during the summer months. The climatic factors such as temperature and relative humidity may not be the only limiting factors for the growth of nutmeg

under the humid tropical conditions of Kerala. The moisture level of the soil and the internal physiological condition of the tree may be the controlling factors, as the data clearly indicate that the growth is possible through out the year. The flower production, being on the leaf axil of the current season's growth is also possible through out the year depending upon the moisture level and physiological condition of the tree.

Compared to many other perennial crops, the mean extension growth of shoots in nutmeg for a period of one year was found to be low. This is in conformity with the findings of Flach and Cruickshank (1969) who have also reported that the nutmeg is a slow grower. Flach (1966) found a slight difference in tree size between female and male trees. But in the present investigation, no such variation was noted in the mean extension and percentage of shoots that showed growth. The difference in the tree size noted might be due to the bearing habit of the female tree as a result of which the branches will appear more drooping than those of the male tree.

2. FLOWER CHARACTERS

2.1 Flowering pattern

The flowering pattern of male and female trees in nutmeg was found to vary much. The male trees flowered through out the year in varying intensities with a maximum in July and

minimum in December. In female trees, flowering was confined to seven months (June to October, January and February) with minimum in July and minimum in February. The variation in the percentage of shoots flowered and mean number of flowers per flowering shoot was significant for different months and for different trees.

The year round flowering of nutmeg tree with peaks in certain months has been mentioned by Flach and Cruickshank (1969) They have attributed the reason to the prevailing climatic factors. The possible reason for the variation in flowering pattern of male and female trees may be the fruit bearing habit of the female tree for which a good amount of stored food is utilised. For male tree which is non productive but receiving similar cultural practices as the female, the tendency for increased flowering will be reasonable. In addition, in male tree the inflorescence axis, after one season of flowering is retained on the tree and is capable of producing flowers continuously for one year. The striking difference in the duration of male and female flowers to develop may be another reason for the increased flowering of male trees. Tree to tree variation in flowering may be due to the physiological conditions of the plant. Seasonal variation in flowering could be attributed to the cyclic growth behaviour and seasonal variation in the growth of male and female trees coupled with the climatic changes. This being the first study on the flowering pattern of nutmeg, no comparison is possible.

2.2 Flower bud development

In nutmeg, flower buds were first seen along with the sprouting of the vegetative buds. The flower development from bud emergence to anthesis was found to follow different stages. Six such stages were identified (Plates I and II) for both male and female. The total number of days taken for anthesis of male flower from the bud emergence was 84.2 on an average, while for the female it was 154.1. In female flowers the first two stages took comparatively more time than that for the male. The male flowers were found to vary from two to six per inflorescence and it took on an average 9.5 days to complete the anthesis. The female flowers were generally solitary. No work has been reported on these lines in nutmeg. However, in Annona spp., a close relative of Myristica, flowering has been reported to start with sprouting of the vegetative buds. The period taken for complete bud development was reported to be 27 to 35 days (Thakur and Singh, 1965).

The flowers will not be strikingly visible along with the new growth flushes as it will take about 90 days (in females) to complete the first two stages when it will be easily visible on the leaf axils. By the time the flowers fully develop, the second flush would have already appeared. Similar observations were also made by Thakur and Singh (1965) in Annona spp.

2.3 Floral biology

Three types of flowers - normal males, normal females and females on hermaphrodite trees were observed in nutmeg. All the three could be distinguished by the morphological characters. Similar reports have been made by Flach and Cruickshank (1969) as well as Shanmugavelu and Rao (1977).

Male flowers were seen as panicled cymes but appeared as recemes due to the zig-zag nature of the inflorescence axis. However, the male inflorescence was described as a receme by Joshi (1946) and Kirtikar et al. (1975). The zig-zag nature of the inflorescence axis could have led Joshi (1946) and Kirtikar et al. (1975) to classify the male inflorescence as a receme. This observation is in conformity with the views of Sinclair (1958), Gamble (1967) and Talbot (1976).

Female flowers were one to three flowered cymes. Nair and Bahl (1956), Sinclair (1958) and Talbot (1976) also made similar record. Flowers were with bracts and bracteoles as reported by Parry (1969).

The normal female flowers were with solitary carpel, sessile ovary, single, basal, anatropus ovule, very short or obsolate style and a bilobed triangular stigma. The observations are in agreement with those of Wilson and Maculans (1967). However, bicarpellate ovary has been reported by Saunders (1937), Lawrence (1951) and Nair and Pillai (1959).

Female flowers were seen on male trees also. They externally resembled the male flowers but had stouter pedicels. Usually pistil did not resemble that of the normal females. Difference was observed with respect to carpels, ovary, stigma and staminoides (Plate VI). Eventhough Flach (1966) had reported the occurrence of female flowers on male trees, the differences were not recorded. The structural difference of a female flower on a male tree with those of a normal female flower could be explained by the partial failure of the mechanism of the orientation of sex chromosomes as postulated by Flach (1966).

2.3.1 Anthesis and dehiscence

In male flowers, anthesis was observed between 1700 hours and 0700 hours on the next day, with a maximum between 1900 hours and 0100 hour. In female, anthesis started between 1900 and 2100 hours and continued upto 0700 hours on the next day, with the peak between 2100 hours and 0300 hours on the next day day. Anther dehiscence occurred about 24 hours prior to anthesis.

The anthesis and dehiscence period have been reported in nutmeg by Flach (1966). According to him, both staminate and pistillate flowers opened between 1800 and 1900 hours in Grenada. Anther dehiscence occurred 12 hours ahead of

the opening. Variation in anthesis and dehiscence period observed on the present investigation may be attributed to the climatic variations between Grenada and Kerala.

2.3.2 Stigmatic receptivity

Stigmatic receptivity commenced from the day of anthesis and lasted upto six days after anthesis, with 80 to 82 per cent set on the first three days. Receptivity was not observed during the pre anthesis stage. Flach (1966) has reported stigmatic receptivity between 12 hours before and 14.5 hours after anthesis. The variation in the result may be due to the climatic factors and differences in the method adopted. Flach had taken the open male flowers which would have dehisced about 12 hours in advance, while the present investigation was done with the pollen taken from dehisced buds.

2.3.3 Pollen studies

Nutmeg pollen appeared as a yellowish powdery mass. Individual pollen grain was spherical, measuring within a range of 40 to 45 u in diameter with a mean of 42.6 u. Stain tests recorded 98.2 per cent fertility. Trees showed significant variation for the number of anthers and number of pollen grains per flower. The anther number per flower ranged from 8 to 13 with a mean of 10.03. Pollen number per flower ranged from 3250 to 23000 with a mean of 11843.75.

Wilson and Maculans (1967) have recorded the number of anthers as 14 to 22. Rendle (1971) has reported the number of stamens as 3 to 18. Variation in pollen production per anther has been reported in different crops (Sajtan, 1952 in apple; Chira, 1966 in Pinus; Sharma and Singh, 1970 in mango). They have attributed the variation to climatic factors especially temperature and also to position of flowers. Variation in the anther and pollen number found in the present study in nutmeg may be due to the climatic and genetical factors. This requires further study. The variation in anther number will also be a contributing factor for the variation of pollen per flower.

Pollen germination studies showed that sucrose, boric acid and calcium nitrate had profound influence on germination of nutmeg pollen. Pollen germination was observed in zero to eight per cent sucrose with 1.5 per cent agar with a maximum (76.6%) in six per cent sucrose agar. Optimum time for incubation was found to be five hours. In the presence of sucrose and boric acid, maximum germination (92.7%) was recorded in four per cent sucrose with 75 ppm boric acid. With calcium nitrate, maximum (82.8%) was recorded for 50 ppm calcium nitrate in six per cent sucrose agar media. With regard to the combined effects of the three, maximum was observed for 75 ppm boric acid and 25 ppm calcium nitrate in four per cent sucrose and 1.5 per cent agar (96.9% germination)

Pollen germination in sucrose media has been reported in several crops, the concentration of which varied according to crop such as 25 per cent sucrose and 0.5 per cent agar for mango (Singh, 1961), 16 per cent sucrose and 0.7 per cent agar for sapota (Rao and Khadar, 1962), 30 per cent sucrose for cashew (Damodaran et al. 1966), 25 per cent sucrose for Annona, (Nalawadi et al., 1975) and 15 per cent sucrose for cocoa (Ravindran, 1977). The effect of sucrose in pollen germination may be either nutritive or due to the osmotic or turgor phenomena of sugar or it may be a combination of various factors as postulated by O'kelly (1955).

The stimulative influence of boric acid on pollen germination has been reported by various workers such as 25 to 40 ppm by Thompson and Batjer (1950) in various fruit crops; 10 to 100 ppm by Resnik (1956) in citrus; 20 ppm by Singh (1961) in mango; 200 ppm by Jose and Magoon (1972) in sapota and 100 ppm by Ravindran (1977) in cocoa. The results of the present investigation are in agreement with the above workers except in the concentration, which was found to vary from crop to crop. The beneficial effect of boron could be explained from its natural occurrence in the stigmatic fluids and tissues of the pistil as suggested by Schumucker (1935).

Calcium nitrate has been described both as an inhibitor (Lidforss, 1896; Brink, 1924) and as a promoter (Kwack and Brewbacker, 1963; Jose and Magoon, 1972 and Ravindran, 1977)

of pollen germination. The promotive action found in the present investigation may be due to the non-metabolic incorporation of calcium with pectic substances of the pollen wall as suggested by Jose and Magoon, 1972.

Studies on pollen storage showed that pollen grains attached to the anther column recorded better viability than when detached (Table 18). Low temperature treatment was better than low humidity or a combination of both. Among the organic solvents tried, petroleum ether gave better results. The studies also indicated the storage capacity of nutmeg pollen to be low. It could be stored as mature intact buds upto three days. However there was rapid deterioration as evidenced by 73.36 per cent germination one day after collection to 34.40 per cent germination three days after collection.

Different methods for efficient storage of pollen have been reported in several plants. But in nutmeg, the review of the extant literature showed no such studies. However, Flach (1966) has reported an incidental observation that the pollen of nutmeg could not be saved for later pollination. The present investigations demonstrated that nutmeg pollen could be stored for upto three days with acceptable germination. Better viability observed in the present studies (when stored in the bud condition) may be due to the humid and natural conditions prevailing inside

the bud. The possibility of storing pollen eventhough for a shorter period, indicated the scope of assisted pollination for better set in nutmeg.

2.4 Pollination

The pollination in nutmeg was found to be effected by wind as no particular insect was found to visit the flower. The fact that nutmeg pollen was present in the air samples near the female trees confirmed the above view. This differed with the observations of Deinum (1949) who found that certain moths were responsible for pollination in nutmeg. The present result is partially in conformity with those of Leslia (1963) who has reported that the pollination in nutmeg is effected by insect or wind.

The fragrant flowers of Myristica may be attractive to certain insects which may be absent in the particular climatic condition in the area or perhaps in the entire state, the confirmation of which require further studies in different areas.

3. FRUIT SET, FRUIT DROP AND FRUIT DEVELOPMENT

3.1 Fruit set

Hand pollination with pollen from mature buds recorded 88.75 per cent set as against 33.10 per cent for open pollination. The absence of fruit set and fruit development when pollen was excluded, indicated that there was no possibility for apomictic fruit development in nutmeg.

The observations of Flach (1966) and Cruickshank (1973) have indicated that pollination is obligatory for fruitset in nutmeg. The present observation of no fruitset without pollination disproved the observation of Perrl (1938) who was of opinion that Myristica fragrans might be able to produce seeds without pollination. Flach (1966) had reported the initial set as 50 per cent in New Guinea. According to him, the set was still lower by artificial pollination. This differs with the results obtained in the present investigation. This may be due to the fact that he had utilised the open male flowers for pollination, in which the pollen would be very scanty whereas pollen from mature buds ensured good pollen planting on the stigmatic surface. The lower percentage of natural set observed may be due to the difference in climatic factors especially the heavy rain experienced at the time of flowering in Kerala. The possibilities of variation in natural set are also likely in the same area in different seasons depending upon the weather conditions as wind is the agent of pollination.

3.2 Fruit drop

Fruit drop was recorded in all the months after set, at varying intensities. The maximum was recorded during the period between second and fourth month after set (Fig 3). The variations in fruit drop between the months and between trees were significant at one per cent level. The mean

percentage drop before set accounted to 66.9 per cent. Of the 33.1 per cent flowers set, 74.4 per cent were dropped which meant that only 25.6 per cent were carried to maturity. Thus, the actual percentage of fruits retained upto harvest was only 8.47 per cent of the total flowers produced. The dropping pattern of nutmeg was similar to the waves of drop observed in different crops such as in apple by McCown (1938), Vyvyan (1946) and Randhawa (1971); and in mango by Singh (1960) and Chadha and Singh (1963). In nutmeg, Sloff (1950) had reported about 60 per cent drop from fertilization to harvest. This is almost in conformity with the result obtained in the present studies.

The possible reason for the drop before set may be lack of fertilization. The varying intensities of post-set drop can be attributed to different reasons. The fruit drop may be the result of an abscission mechanism as reported by Addicott and Lynch (1955), Chadha and Singh (1963) and Randhawa (1971) in different crops. The brown colouration found at the tip of the pedicel of the abscised fruit indicated the abscission layer formation. The fruit abscission may be related to the relative production of hormones by the developing embryo, as stated by Lewis (1946). The failure of embryo development could account for the

browning of the embryo and the surrounding tissues visualised in abscised fruits. Another possible reason for fruit drop could be the imbalance between various plant growth regulators as suggested by Bardwaj (1975). According to him, the auxins and gibberellins produced in the seed and the abscisin in the pericarp might be transported to and interact at the abscission zone located at the base of the pedicel. If auxin and gibberellin were not available in sufficient amounts so as to neutralise the effect of abscisin, the flower or fruit shed. The fact that the peak for the fruit drop curve and the peak for the curve for rate of growth of fruits occur at just about the same period (Fig 3) indicate that competition for nutrients might be the cause for the observed drop. The significant variation in fruit drop among different trees could be explained by the increased production of flowers in T_3 (Table 6) in which maximum drop was recorded (Table 23). Production of larger number of flowers might lead to competition among the young developing fruits resulting in shedding of the fruits.

The drop of abnormal fruits of hermaphrodite tree could be attributed to their inability to split, as the number of grooves present on such fruits differed from that of the normal ones (Plate XIa). In addition to all

the above factors, it is possible that this character is influenced by climatic and genetic factors to some extent, as reported by several workers quoted by Sloff (1950).

3.3 Fruit development

In nutmeg the time required from anthesis to maturity of fruits has been found to range between 206 and 237 days (about seven to eight months). The rate of development varied significantly from month to month. A peak was observed between the latter half of second month to the end of fourth month, with 30.21 per cent in the third month. No significant difference was noted between trees and between aspects.

Sigmoid growth pattern with a peak in certain months has been reported in various crops like citrus (Motilal, 1964), carambola (Nand, 1971), and mango (Saini et al., 1971, 1972). The growth in nutmeg fruits was slow initially, became rapid for about two months and thereafter again slowed down till maturity. The slowing down of growth after a particular period may be due to the hardening of the endocarp and stopping of the growth of the seed, as reported by Saini et al. (1971 and 1972) in mango.

In nutmeg, the period required for the fruits to attain maturity has been reported to be five to six months (Leslie, 1963). Flach and Cruickshank (1969) and Cruickshank (1973) estimated the above period to be nine

months in Grenada. The period observed in the present investigation came within the range reported by the above workers. The variation in the period taken for the fruits to attain maturity could be attributed mainly to the climatic differences.

4. YIELD

The yield was found to vary significantly in different months and in different trees. The harvest season ranged from March to September with a peak between April and July.

The harvest season has been reported as May-June and August-September in the East Indies; all the year round, with peak in August-September in the West Indies (Guenther, 1960); January-April and September-October in Grenada (Cruickshank, 1973) and April-June in Indonesia (GATT, 1977). In India, Nair et al. (1977) have reported the crop as available throughout the year with the peak harvest period in June-August. The present results are more or less on the same lines. The variation in the peak harvest is also likely to be changed slightly from year to year and from place to place depending upon the variation in rain and temperature and consequent changes in growth and development.

SUMMARY

SUMMARY

The present investigations were carried out at the department of plantation crops, College of Horticulture on nutmeg trees located at the District Agricultural Farm, Mannuthy during a period of 12 months commencing from March, 1978 with the following objectives.

To study (i) the pattern of growth and flowering (ii) the floral biology and (iii) the fruit set, fruit drop and fruit development.

The following conclusions were made based on the present investigations.

1. Shoot growth in nutmeg was found to be cyclic; with six flushes during the period of one year.

2. All the flushes were not seen in all the shoots. Therefore growth was observed in all the months though it was negligible in summer months.

3. Significant difference was observed for the mean extension growth in different months. Two peaks were observed in May and in September. The percentage of shoots that showed growth per month also followed the same trend.

4. No significant difference was noted for the mean growth in different trees.

5. The growth of nutmeg trees was found to be very slow with a mean extension of 11.31 cm for a period of one year.

6. The male and female trees differed in their flowering pattern. There was monthly variation in the extent of flowering of both male and female trees. In females flowering was constrained to seven months i.e., continuous from June to October and then in January-February. In male trees flowering was observed in all the months at varying intensities.

7. The pattern of flower bud development was specific for male and female trees. Six stages of development were identified for both male and female flowers. The period from visible induction to anthesis was only 84.20 days on an average for male flowers where as it was 154.10 days for female flowers.

8. Three type of flowers were observed in nutmeg - normal male, normal female and female on hermaphrodite trees. They resembled each other to a great extent; but differed in the characters of stamen and pistil.

9. Anthesis in male trees started between 1700 and 1900 hours and continued upto 0700 hours of the next day. The peak was recorded between 1900 hours and 0010 hour. In female

trees, anthesis started between 1900 and 2100 hours and continued upto 0700 hours of the next day with the maximum between 2100 and 0300 hours.

10. The flowers were found to be receptive from the day of anthesis upto six days after anthesis with the maximum set (80 to 82%) for the first three days.

11. Anther number and pollen production per flower varied significantly from tree to tree. Sucrose, boric acid and calcium nitrate were found to have profound influence on pollen germination at specific concentrations. Without boric acid and calcium nitrate six per cent sucrose gave maximum germination (76.6%). A germination of 82.8 per cent was recorded in six per cent sucrose with 50 ppm calcium nitrate. Boric acid showed maximum germination (92.7%) in four per cent sucrose media, at a concentration of 75 ppm. However, a combination of the three was found to be the best. Maximum germination of 96.9 per cent was recorded in the media containing four per cent sucrose, 25 ppm calcium nitrate and 75 ppm boric acid.

12. The pollen was found to be viable for only two days with 48.3 per cent germination in six per cent sucrose media. The storage condition was in the mature bud stage stored as such at room temperature.

13. The chief agent of pollination was found to be wind.

14. Hand pollination increased the percentage set from 33.1 to 88.7 compared to open pollination. Parthenocarpic fruit set was not observed in nutmeg.

15. The percentage set varied from tree to tree and also for different aspects with a mean of 33.1 per cent.

16. The mean percentage drop after set was 74.4 per cent. The drop was maximum for second to fourth month after set. The percentage drop varied from tree to tree. The harvested fruits accounted to 8.47 per cent of the total flowers produced.

17. The fruits attained maturity in 206 to 237 days (seven to eight months) after fruit set.

18. The developing fruits followed a sigmoid growth pattern with maximum increase in growth between sixth and sixteenth week after set.

19. There was variation for the number of fruits harvested from each tree. The peak harvest season ranged between April and July.

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* Originals not seen.

APPENDICES

APPENDIX I.

Weather data (monthly average) for the period from March 1978 to March 1979

Month	Temperature	Relative humidity %	Windspeed km/hr	Total rainfall mm	Sunshine hrs./day
March	29.80	60.0	10.9	5.2	9.5
April	30.45	69.5	6.4	19.9	9.0
May	29.85	71.5	7.2	287.5	7.5
June	26.15	83.0	5.3	848.5	3.9
July	25.55	84.0	7.9	790.4	5.6
August	25.80	85.0	9.0	679.5	3.1
September	26.25	79.0	6.4	68.3	8.2
October	27.50	79.5	7.7	114.1	7.6
November	25.20	67.0	11.4	284.2	9.5
December	26.95	70.5	18.3	43.9	8.9
1979 January	26.35	67.0	21.2	nil	9.3
February	28.35	66.5	13.7	22.0	9.0
March	29.50	67.0	12.4	3.2	9.2

Source 'B' Class Observatory, Mannuthy.

APPENDIX II.

Percentage increase in fruit girth and fruit drop at weekly invervals.

Weeks after set	Percentage increase in fruit girth	Percentage increase in fruit drop
1	1.20	0.50
2	1.50	1.60
3	2.74	0.51
4	2.05	0.87
5	3.96	0.20
6	3.22	0.62
7	4.64	0.60
8	6.84	0.63
9	8.00	1.03
10	7.17	10.31
11	7.86	6.19
12	7.18	7.22
13	9.37	14.00
14	5.67	10.11
15	6.49	3.12
16	2.94	4.67
17	2.53	3.63
18	1.03	1.81
19	1.68	0.91
20	1.05	1.82
21	0.84	0.30
22	0.86	0.28
23	0.85	0.80
24	0.82	1.27
25	1.18	0.38
26	0.74	0.75
27	0	0.37
28	0	0

APPENDIX III

Analysis of variance for monthly growth of different trees

Source	d f	Mean squares	
		Mean growth	Percentage of shoots showing growth
Total	71		
Months	11	10.390	2990.015
Trees	5	0.319	820.010
Error	55	0.410	46.138

APPENDIX IV

Analysis of variance for monthly growth on different aspects

Source	d f	Mean squares	
		Mean growth	Percentage of shoots showing growth
Total	47		
Months	11	5.439	1746.790
Aspects	3	0.126	45.240
Error	33	0.091	20.110

APPENDIX V

Analysis of variance for the flowering of nutmeg trees

Source	MALE			FEMALE	
		Mean squares			Mean squares
	d f	Number of shoots flowered	Number of flowers per flowering shoot	d f	Number of shoots flowered
Total	47			27	
Months	11	724.292	53.992	6	320.128
Tree	3	15.879	23.756	3	95.055
Error	33	2.434	4.430	18	6.314

APPENDIX VI

Analysis of variance for anther and pollen number per flower

Source	d f	Mean squares	
		Anther number	Pollen number
Total	39		
Tree	3	7.338	142464062.50
Error	36	0.429	14442881.94

APPENDIX VII

Analysis of variance for the pollen germination in agar medium with varied concentrations of sucrose, boric acid and calcium nitrate

Source	d f	Mean squares	F values
Total	374		
Sucrose (S)	4	52806.18	54678.03**
Boric acid (B)	4	4131.42	4277.87**
S x B	16	402.69	416.97**
Calcium nitrate (C)	4	709.79	734.95**
S x C	16	266.58	276.03**
B x C	16	97.68	101.14**
S x B x C	64	44.08	45.64**
Error	250	0.97	

APPENDIX VIII

Analysis of variance for the germination of pollen from different trees in 6 per cent sucrose agar media

Source	d f	Mean squares
Total	15	
Tree	3	1.566
Error	12	3.242

APPENDIX IX

Analysis of variance for fruit set

Source	d f	Mean squares
Total	15	
Tree	3	91.967
Aspect	3	22.342
Error	9	2.400

APPENDIX X

Analysis of variance for mean monthly increase in fruit girth and fruit drop on different trees

Source	d f	Mean squares	
		Fruit girth	Percentage fruit drop
Total	27		
Months	6	10.105	548.638
Trees	3	0.013	40.191
Error	18	0.123	1.646

APPENDIX XI

Analysis of variance for mean monthly increase in fruit girth and fruit drop on different aspects

Source	d f	Mean squares	
		Fruit girth	Percentage fruit drop
Total	27		
Months	6	10.788	495.620
Aspects	3	0.021	0.559
Error	18	0.145	1.892

APPENDIX XII

Analysis of variance for monthly yield from different trees

Source	d f	Mean square
Total	27	
Months	6	24459.62
Trees	3	33680.47
Error	18	4422.81

STUDIES ON GROWTH, FLOWERING, FRUIT SET AND FRUIT DEVELOPMENT IN NUTMEG (*Myristica fragrans* Hout.)

BY

P. A. NAZEEM

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirements

for the degree of

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Kerala Agricultural University

Department of Plantation Crops

COLLEGE OF HORTICULTURE

VELLANIKKARA, TRICHUR.

1979

ABSTRACT

The present investigations were carried out in the College of Horticulture, Kerala Agricultural University during the year 1978-'79. The object was to study the pattern of growth and flowering, floral biology, fruit set, fruit drop and fruit development in nutmeg.

The studies were conducted on male and female trees of about 17 years old receiving cultural practices as recommended by Kerala Agricultural University.

Shoot growth in nutmeg was found to be cyclic, a period of growth followed by a quiescence. Six flushes were observed during the period of one year. All the flushes were not seen in all the shoots which resulted in continuous growth in nutmeg. The mean growth varied significantly from month to month, with minimum in summer months. Two peaks were observed in May, June and September. Nutmeg trees were found to be slow growers when compared to other perennial trees. Flowering pattern of male and female trees differed. There was monthly variation in the extent of flowering of both male and female trees. In females, flowering was constrained to seven months whereas in male, flowering was observed through out the year. Maximum flowering in both the cases was in July followed by October.

The flower bud development in male and female trees

followed specific pattern. The male flowers took only about half the period taken by the female flowers to develop. The female flowers took 154 days for complete development. Three types of flowers were observed in nutmeg which resembled and differed each other for different characters. In male flowers, peak anthesis was between 1900 hours and 0100 hour and in females, it was between 2100 hours and 0300 hours. Anther dehiscence occurred about 24 hours prior to anthesis. The stigmatic receptivity lasted for six days after anthesis with the maximum for the first three days. The chief agent of pollination was wind.

Anther number and pollen production per flower varied from tree to tree. Sucrose at concentrations of 2, 4, 6 and 8 per cent, boric acid and calcium nitrate at concentrations of 25, 50, 75 and 100 ppm each were found to promote pollen germination. A combination of the three (4% sucrose, 25 ppm calcium nitrate and 75 ppm boric acid) gave maximum germination (96.9%). Pollen was found to be viable for three days in the dehisced bud condition and the viability was greatly reduced thereafter.

The percentage set varied for different trees and for different aspects with maximum set on western and eastern aspects. Hand pollination increased the percentage set than open pollination, indicating the possibilities of assisted pollination for better production. There was no apomictic fruit development.

The mean percentage drop after set was 74.4 per cent. The number of fruits harvested accounted to only 8.47 per cent of the total flowers produced. The period of maximum drop after set coincided with the period of maximum development of the fruit.

The fruits attained maturity in 206 to 237 days after fruit set. The developing fruits followed a sigmoid growth pattern. The peak harvest season ranged between April and July. The trees varied for the percentage drop and number of fruits harvested.