POLLINATION STUDIES IN CASHEW

By

ELSY, C. R.

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Pollination studies in cashew" is a bonafide record of research work done by me during the course of research work and that 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,
15-1-1985.

Riby, C.R.

CERTIFICATE

Certified that this thesis entitled "Pollination studies in cashew" is a record of research work done independently by Smt. Rizy, C.R., 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,
15-1-1985.

Dr. K.M. Narayanan Namboodiri,
Professor and Head,
Department of Agricultural Botany,
College of Horticulture,
Vellanikkara.

CERTIFICATE

We, the undersigned, members of the Advisory Committee of Smt. Elsy, C.R., a candidate for the degree of Master of Science in Agriculture with major in Agricultural Botany, agree that the thesis entitled "Pollination studies in cashew" may be submitted by Smt. Elsy, C.R., in partial fulfilment of the requirements for the degree.

Chairman:

Dr. K.M. Narayanan Namboodiri

Members :

Prof. K.K. Vidhyadharan

Sri. P.G. Veeraraghavan

Smt. Achamma Oommen

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Introduction

INTRODUCTION

Cashew (Anacardium occidentale L.) is considered as one of the important gifts of the New World to the Old World. It is a native of tropical belt of Eastern Brazil. It is believed that cashew was introduced to India in the sixteenth century mainly for the purpose of checking soil erosion. But gradually it established itself as an important commercial crop. Today cashewnut is one of the most prestigeous export items of our country. The other important countries where cashew is commercially cultivated are Brazil, Tanzania, Mosambique and Kenya. Of late it is seen that more and more countries are taking up cashew cultivation.

Cashew is grown mainly for its kernels which on roasting have a pleasant taste and flavour. It is highly nutritious also. Cashewnut is the most popular edible nut and has admirers all over the world. In India, the extraction and processing of nut is an important industry giving employment opportunities to over one and half lakh persons. Cashewnut shell liquid, a by-product of the processing industry, is a raw material in paint, chemical and water-proofing industries. Cashew apple is a rich source of vitamin C and minerals

and can be utilised for the preparation of various products like jam, jelly, chutney, soft drinks and also alcoholic beverages. Extensive research activities for finding out methods of effective preservation and economic utilization of cashew apple are in progress in various centres.

It is gratifying to note that India is the biggest exporter of cashew kernels in the world market and has been enjoying the monopoly in the supply of cashew kernels till recently. During 1983, export of cashew kernels amounted to 35,695 metric tonnes earning Rs. 137.71 crores of foreign exchange. In addition to this, export of cashew shell liquid has earned another Rs. 1.75 crores (The Cashew Export Promotion Council, 1984). However other countries are strongly competing with India and consequently recent trend of events indicate that we are slowly loosing our monopoly. Of late our cashew industry is facing a very serious set back from the non-availability of raw materials. Cashew industry in India has been built up from the very beginning, depending mainly on the imported raw nuts. East African countries are the main suppliers of raw nuts to India. Now these countries have established their own mechanical processing units and as such India can no longer depend on them for raw nuts.

In other words we have to produce our own raw materials for supporting the industry. Our annual production of raw nuts for the year 1981-82 is estimated to be 1,95,760 metric tonnes (Directorate of Cashewnut Development, 1983) which is only 25 to 30 per cent of the requirement of our industry.

The demand for cashewnut is increasing day by day. It has been officially estimated that India should produce about 4.5 lakh tonnes of raw nuts annually, if it has to maintain its present position in the trade and to ensure employment to the workers in the industry (Nambiar, 1979). Considering the above situations, the need for stepping up the average yield of cashew tree assumes great importance.

In India cashew is a neglected crop of the marginal lands which are inherently very poor in fertility. In spite of its importance in agricultural, industrial and above all, commercial economy of our country, cashew is not receiving adequate attention. This is very well illustrated by the very low per hectare yield of 314 kg realised in our country. Cultivation in marginal infertile land, lack of proper management practices adopted by growers, inadequate research support etc. may perhaps explain the low per hectare yield realised in India. Low fruit set under natural conditions and high premature fruit drop are the

limiting factors for obtaining higher yields in cashew. The situation, which is very serious at the moment, has to be improved. In order to understand the factors that stand in the way of reducing the yield of cashew, the present study was taken up with the following objectives:-

1. To study the anthesis in cashew with particular reference to various climatic factors.
2. To evaluate extent of fruit set taking place in cashew under naturally pollinated condition and to find out a methodology to increase the fruit set.
3. To find out the role of different pollinating agents such as wind, water, insects etc. in effecting pollination in cashew.
4. To find out the quantum of available pollen in the atmosphere and the isolation distance for cashew.

Review of Literature

REVIEW OF LITERATURE

Research on cashew in India was started nearly three decades back. However, little information is available on the aspects relating to its anthesis, pollination, fruit set and fruit drop. An attempt is made here to bring out a brief review of the available works in cashew on the above aspects. In order to project the real picture, work done on other allied crops is also included in the review.

1. Flower opening and its relationship with climatic factors.

Studies conducted at various research stations showed that there existed considerable variation in the time of opening of both male and hermaphrodite flowers and this could be attributed to the different environmental conditions existing at each location (Damodaran et al., 1966).

1.1 Pattern of flower opening.

Pavithran and Ravindranathan (1976) observed three distinct phases of flowering of a cashew panicle. These were (1) the first male phase during which only staminate flowers opened, (2) the mixed phase during which both staminate and hermaphrodite flowers opened but mostly male flowers, (3) the second male phase during which few male flowers only opened.

Aiyadurai and Koyamu (1957) after studying the anthesis of staminate and perfect flowers reported that staminate flowers opened between 9 AM and 11 AM while bisexual flowers opened between 2 PM and 4 PM. Rao and Hassan (1957) reported from Vittal in Karnataka that staminate flowers started opening from 9 to 10 AM and continued till 1 PM. The peak anthesis was between 9 to 11 AM.

Damodaran *et al.*, (1966) found that under Kottarakkara conditions nearly half of the staminate flowers opened before 7 AM and the opening of over 95 per cent was completed before 11 AM. There was practically no anthesis of staminate flowers after 2 PM. In the case of perfect flowers the peak period of anthesis was between 10 AM and 12 Noon. According to Northwood (1966b) most of the flowers opened between 6 AM and 6 PM in Tanzania with a peak opening between 11 AM and 12.30 PM.

Studies at Cashew Research Station, Vengurla (1968) showed that 50 per cent of staminate flowers opened between 9 AM and 12 Noon. Studies at Vittal in Karnataka, showed that the male flowers opened from 01.00 to 17.00 hr, 90 per cent being opened between 05.00 and 11.00 hr. Hermaphrodite flowers opened between 08.00 to 15.00 hr, 80 per cent being opened

from 10 to 12 hr (CPCRI, Regional Station, Vittal, 1977). Results of experiments conducted under All India Co-ordinated Spices and Cashewnut Improvement Project at Kasaragod, revealed that for male flower opening, there were two peak periods, before 6 AM and about 10 AM. The peak periods for bisexual flower opening were 11 AM and 1.30 PM (ICAR, 1977).

According to Ohler (1979) the flowers started opening as early as 7 AM and continued to open until around 3 PM, the opening of the perfect flowers showing a peak between 9 AM and 11 AM in India and between 11.30 AM and 3 PM in Tanzania. Rai (1979) from the Cashewnut Research Station, Ullal, reported that the peak anthesis was found to be between 9 and 11 AM. According to Raju (1979) male flowers commenced opening before 6 AM both in the periphery as well as in the inner position of the canopy of foliage and it continued till 1 PM except in one type (K-27-1) in which the opening before 7 AM was only 3 per cent and the period continued till 8 PM. The peak period of anthesis of male flowers was between 7 and 8 AM and that of hermaphrodite flowers was between 9 and 11 AM. He found that the time span of anthesis of hermaphrodite flowers lasted only for shorter period as compared to male flowers. In general, hermaphrodite flowers started opening after 7 AM and continued upto 1 PM.

Thimmaraju et al., (1980) observed that the anthesis commenced at 6 AM and continued till 10 AM. Staminate flowers opened early in the morning than the hermaphrodite flowers. They further reported that, after 10 AM there was only sporadic anthesis. According to the results of experiments conducted at Kasaragod, peak anthesis of male and bisexual flowers was at 6 and 11 AM respectively (CPCRI, 1981). Nair (1981) reported that the staminate flowers started opening from 6 AM and continued to open till 4 PM. The opening of the perfect flowers was mostly between 10 AM and 12 noon.

Reports from Vittal showed that peak periods of anthesis of male and bisexual flowers were around 6 AM and 11 AM respectively. No anthesis took place in the night hours except in the early hours of the morning, in very low frequencies (ICAR, 1982).

In mango, according to Bana et al., (1976) maximum anthesis occurred between 02.00 hr and 04.00 hr.

1.2 Relationship between anthesis and climatic factors.

Eventhough studies on the pattern of anthesis in cashew were undertaken by different research workers, information on the relationship between anthesis and climatic factors, is found to be scanty.

In cashew, initially, Rao and Hassan (1957) indicated that the climatic and environmental factors could influence the process of anthesis. Damodaran et al., (1966) while conducting the studies on morphology and biology of cashew flower, found that the opening of perfect flowers on the shady side of the tree was a little later than that on sunny side. Veeraraghavan and Vasavan (1977) studied the influence of rainfall on the productivity of cashew and found that high rainfall adversely affected flower opening. According to Raju (1979), environmental factors seemed to have some influence in the time of flower opening. The slightly delayed anthesis of flowers situated within the canopy of foliage indicated the influence of humidity and temperature on anthesis.

The influence of relative humidity and temperature on flower opening was studied in some other fruit trees also. Nath and Randhawa (1959) in pomegranate and Yamdagni et al., (1967) in ber recorded that with rise in temperature and decrease in relative humidity, the anthesis and opening of flowers were considerably hastened. On the other hand in litchi no correlation was found between anthesis, temperature and relative humidity (Chadha and Rajpoot, 1969). Observations made by Misra and Bajpai (1975) on floral biology of jamun supported the idea that with fall in temperature and

increase in relative humidity the anthesis was delayed. Similar results were obtained by Kuspe and Ugale (1977) working in Carica papaya.

2. Sex-ratio, extent of fruit set and fruit drop .

Sex-ratio is an important factor in the extent of fruit set.

2.1 Flower counts

Morada (1941) reported 120 to 1100 flowers in each panicle. Rao and Hassan (1957) found 21 to 881 flowers in one panicle with an average of 328. Damodaran et al., (1979) counted a mean number of 486 flowers per healthy inflorescence.

2.2.1 Sex ratio

Sex-ratio had been reported as a factor controlling yield in cashew.

Morada (1941) reported that 90 to 99 per cent of flowers in a panicle were staminate, while Rao and Hassan (1957) observed the percentage of staminate flowers to be 96. Bigger (1960) noted a ratio of 6:1 of staminate to perfect flowers in cashew.

Damodaran et al., (1965) after detailed studies on the flowering habit and sex-ratio of cashew reported that in most of the panicles studied, the flowers that opened in the early stages were generally staminate while the perfect flowers made their appearance during the middle of the flowering period of the panicle. The proportion

of perfect flowers was found to vary considerably even between the panicles of same tree. They observed that panicles which emerged earlier in the season had a higher proportion of staminate flowers than those produced later in the season. Sex-ratio in cashew was found to be influenced considerably by environmental conditions and certain internal factors of individual flowering twigs. According to them the proportion of perfect flowers varied from as low as 0.45 per cent to 24.9 per cent in different trees. However the fact that some of the trees consistently produced a higher proportion of perfect flowers as compared to some others growing under the same environment, suggested sex-ratio as an inherent tree character.

Studies at Cashew Research Station, Vengurla (1968) showed that the average percentage of bisexual flowers was 11.2. According to the observations made at CPCRI, Kasaragod (1976), in early season panicles, the proportion of bisexual to male flowers ranged from 1:2.7 to 1:252 while in late season panicles it ranged from 1:5.5 to 1:498. Pillai and Pillai (1975) reported that staminate and perfect flowers in the inflorescence had generally a ratio of 10:1.

CPCRI (1979) reported that of the innumerable number of flowers produced by a cashew tree, less than 10 per cent were perfect.

Kumaran et al., (1979) obtained a wide variation in the proportion of male to bisexual flowers as 1:1.4 to 1:218.8. They further noted that 43 per cent accessions came in the range of 1:2 to 1:8.

According to Raju (1979) the percentage of hermaphrodite flowers was 22 to 68 under natural condition and growth regulators at different concentrations influenced the percentage of hermaphrodite flowers. In cashew flowering appears in two or three distinct phases and those appearing in the intermediate stage are generally the most productive one.

Thimmaraju et al., (1980) obtained a ratio of 440 staminate: 40 hermaphrodite flowers.

Ashok and Thimmaraju (1981) observed that panicles produced in the lower position of the tree were found to have slightly higher percentage of hermaphrodite flowers than those produced in the middle position of the tree. Number of hermaphrodite flowers recorded as well as the ratio of male to hermaphrodite flowers was recorded the lowest in the panicles emerged from two months old shoots.

Chakravarty et al., (1981) reported that the ratio of male to hermaphrodite flowers was found to be the maximum in the south and minimum in the east. Fluctuations in the flowers in different sides of the tree could be ascribed to effect of light and temperature.

Studies conducted at Vittal, indicated that the sex-ratio expressed as percentage of bisexual flowers over total flowers ranged from 1 to 42 (ICAR, 1982).

In the case of Mango, (Variety - Dasheri) Singh (1960) reported that the average percentage of hermaphrodite flowers and the sex-ratio were 43.99 and 1.37:1 while for Langra, it was 60.82 per cent and 0.64:1 respectively. Singh (1964) found that the mango the percentage of hermaphrodite flowers varied from 0.74 to 77.9 depending upon variety and environmental conditions. The sex ratio was as high as 133:1 or as low as 0.45:1 in certain varieties. The variation in the number of male and hermaphrodite flowers per panicle was also governed by the age of the tree and earliness or lateness of the emergence of the panicles. It had been observed that trees of higher age group had a higher percentage of hermaphrodite flowers per panicle than that of the lower age group.

Murthy et al., (1979) reported in cashew the percentage of bisexual flowers as 4.57. Rai (1979) observed that nearly 96 per cent of the flowers were staminate while only four per cent bisexual. Gunjate et al.,(1983) observed that the percentage of hermaphrodite flowers and fruit set were greater in late than in early flushes.

2.2.2 Influence of sex-ratio on yield.

Rao and Hassan (1957) reported that the yield in cashew depended largely on the proportion of hermaphrodite flowers produced in the panicle. Damodaran et al., (1965) observed a weak positive correlation between the number of hermaphrodite flowers and yield of cashew trees. Contrary to this, studies conducted by Gopikumar (1978) revealed that there was no correlation between sex-ratio and the yield of tree. Simple correlation analysis by Parameswaran (1979) indicated a positive correlation between yield and percentage of bisexual flowers.

In Mango, Naik and Rao (1943) reported a high positive correlation between the percentage of perfect flowers and the number of fruits carried to maturity.

2.3.1 Fruit set under natural conditions.

Rao and Hassan (1957) working in the west cost of India recorded that in cashew, fruit set was only three per cent of the hermaphrodite flowers, while Bigger (1960) from Tanzania found that 10.2 per cent of the hermaphrodite flowers produced mature fruits. Damodaran et al., (1966) reported that fruit set in cashew became evident after about seven days pollination as indicated by the swollen ovary being visible above the corolla cup. According to him the final recovery was only 4 to 6 per cent of the hermaphrodite flowers

as against 3 to 20 per cent recorded from CPCRI (1975).

Pillai and Pillai (1975) noted that nearly 85 per cent of the fruits were fertilized and out of this only 4.2 per cent were carried to maturity.

In cashew there seems to be considerable variation in the percentage of fruit set year after year. Reports from Mannuthy (ICAR, 1978) showed that nuts harvested was 6.63 per cent of the total hermaphrodite flowers. In the next year when the same experiment was repeated, it was found that in open panicles 4.67 per cent of the total hermaphrodite flowers were carried to maturity (ICAR, 1979).

Thimmaraju et al., (1980) obtained an initial set of 48 per cent from natural pollination.

Panda and Pal (1981) recorded an initial fruit set and fruit retention as 10 per cent and 8 per cent respectively.

Studies at Vittal revealed that the fruit set percentage over total hermaphrodite flowers ranged from 0 to 29 (ICAR, 1982).

In mango, according to Naik and Rao (1943) only 13 to 28 per cent of the bisexual flowers initially set fruits and from these only 0.1 to 0.25 per cent reached to maturity. Fruit set studies in Mulgoa mango revealed that the initial fruit set was very low and ranged from 0 to 55 with a mean of 11.25 fruits per panicle. The

ultimate retention of fruits observed over the initial set was only 1.35 per cent (Kalyanasundaram, 1974). In Alphonso variety, Gunjate et al., (1983) observed that the fruit set ranged from 0.61 to 0.67 per cent and of the set fruits only 5.7 per cent were harvested.

2.3.2. Fruit set under artificial pollination.

Inadequate pollination is supposed to be one of the reasons for low set in cashew, since a higher percentage of fruit set has been reported in cashew after hand pollination.

Rao and Hassan (1957) did not find pollination in cashew to be very efficient and they were able to increase fruit setting by artificial pollination, which was supported by Kumaran et al., (1976).

When hermaphrodite flowers were pollinated with pollen from the same and different trees, 55 and 64 per cent fruit set, respectively was obtained (Vimala et al., 1977).

Studies conducted at Mannuthy (ICAR, 1978) indicated that the percentage of set could be raised from 4 to 56 under artificial pollination.

Raju (1979) found that even though an initial set of 82 per cent was obtained in type K-10-2 when pollinated artificially, the ultimate yield was only 9.67 per cent as against 5.66 under natural condition. Hand pollination studies conducted by Parameswaran (1979)

resulted in 80 to 95 per cent initial fruit set. He further reported that even though the ultimate fruit retention till maturity on the hand pollinated panicles was significantly higher in number than that on the naturally pollinated panicles, the increase was not commensurate with the increased fruit set.

According to Thimmaraju et al., (1980) hand pollination resulted in 80 per cent of initial fruit set.

2.4. Fruit drop studies.

Heavy fruit drop is an important problem in many fruit trees, causing much reduction in ultimate yield.

Damodaran et al., (1966) after making detailed observations on fruit set and development reported that a large proportion of the perfect flowers dropped off before 'peanut' stage. The intensity of fruit drop was heaviest in the early stages of fruit development ie., before the fruits attained a length of 5 mm. Shedding was also found to occur during the various stages of development.

Northwood (1966a) found that the premature fruit fall was heaviest in the first three weeks after fertilization. He had the opinion that early fruit fall would have been much greater if more hermaphrodite flowers had been allowed to be pollinated. Dasarathi (1971) reported 55 per cent fruit drop at the 'mustard'

stage and 22 per cent at the 'pea nut' stage. Pillai and Pillai (1975) observed that out of 84.8 per cent fertilized fruits, 80.6 per cent dropped away at various stages of development. The maximum shedding of 40.3 per cent took place during the 'mustard' stage, followed by 19.9 per cent at 'pea nut' stage and the remaining 20.4 per cent at later stages.

Parameswaran (1979) showed that the relative influence of percentage of fruit drop on yield was greater than the relative influence of percentage of fruit set. So the ultimate yield from cashew was found to be adversely affected by the heavy drop of young fruits before reaching maturity. The intensity of drop was highest before the fruits attained a length of 5 mm (mustard stage). The intensity of drop was found to be low in the later stages when the development was very slow, and it fell suddenly as the fruits reached 'pea nut' stage and almost ceased completely when the fruits had reached about 90 to 95 per cent of their size.

According to Raju (1979),66 per cent of fruits dropped in the hand pollinated group, whereas under natural conditions the drop was only 1.49 per cent. The drop was maximum before 'pea' stage.

As far as mango is concerned Naik and Rao (1943) reported that the first two weeks after fruit set must be considered as the most important period from the

point of view of fruit shedding. Singh (1960) studied the extent of fruit drop in two mango varieties - Dasheri and Langra. Fruit drop from the panicles varied from 95.49 to 97.6 per cent and 98.1 to 99.08 per cent in the two varieties respectively. Fruit shedding was heavy during the first three weeks of fruit set and continued upto fifth week. The drop of small fruits upto 0.5 cm was heaviest in Dasheri and those upto 1 cm was equally heavy in Langra.

Srivasthava (1961) recorded three waves of fruit drop in mango, the largest occurring in the first three weeks after fruit set. Similarly according to Singh and Arora (1963) fruit drop was most serious during the first four weeks only.

According to Chadha and Singh (1964a) the rate of fruit drop in mango was very high in the initial stages of fruit growth when the development was very rapid. The rate of drop fell gradually as the fruits reached a substantial size and almost ceased completely when the fruits had reached about 90 to 95 per cent of their size. They further reported that the heaviest drop losses were caused by the May drop and only solitary fruits fell after winds. There was little difference in the rate of fruit drop between 10 and 20 years old trees. The drop during day hours was nearly double that during night hours (Chadha and Singh, 1964b).

Kalyanasundaram (1974) while studying the fruit drop in Malgoa mango found that out of 225 fruits set initially only 51 fruits were present in the following week and thus there was a severe drop of 77.32 per cent during the first week. Out of the total fruit drop of 98.65 per cent recorded for the entire period, 95.54 per cent of the drop occurred during the first three weeks.

Gunjate et al., (1983) reported 94 per cent fruit drop in Alphonso mango.

2.5. Factors influencing fruit set and fruit drop.

Several workers had attributed different reasons for the low fruit set and high fruit drop values in cashew. A deep knowledge of the factors responsible for these, is necessary for applying measures to increase fruit set and reduce fruit drop for maximising the yield.

Addicott and Lynch (1955) reported that fruit drop was influenced by an abscission mechanism. Among the external factors controlling this mechanism, reports had been mostly on temperature and moisture status of the soil. Hormones were attributed to be mostly responsible among the internal factors. They further suggested that the relative balance between auxins or gibberellins and abscission could determine the retention or abscission of fruit.

Rao and Hassan (1957) suggested that inefficient pollination was one of the reasons for low fruit set and

yield in cashew. According to Bigger (1960) in S. Tanzania it was seen that flower production, pollination and fruit setting were efficient and did not normally limit yield.

Leopold and Kriedeman (1964) suggested that fruit drop was a result of the low endogenous auxin content of the fruits. He also stated that the application of auxin generally controlled the formation of abscission layer in fruits.

Damodaran et al., (1966) found that a large proportion of the perfect flowers dropped off before 'pea nut' stage either due to lack of pollination or due to natural drop. On the other hand, Northwood (1966a) was of opinion that pollination was not a factor limiting yield in cashew since premature fruit fall was heaviest in the first three weeks of the development. Rao (1974), also had reported that lack of adequate pollination in nature was one of the reasons for poor fruit set in cashew.

According to Pillai and Pillai (1975) there was a high percentage of immature fruit drop in cashew caused by insects or other factors. Out of the total hermaphrodite flowers 20.27 percentage of fruits dropped due to insect attack and 60.40 dropped due to any factor ranging from nutritional imbalance to defective metabolism.

Cashew being a highly cross pollinated crop, it requires some pollinating agents for successful pollination.

The low percentage of fruit set was either due to lack of sufficient pollinating agents or due to lack of pollen itself (ICAR, 1978).

Studies conducted by Parameswaran (1979) clearly indicated that a large proportion of bisexual flowers remained unpollinated. He then suggested that even in trees producing a fairly high proportion of bisexual flowers, it won't be fully reflected on the ultimate yield. He further identified that attack of insect pests like Tea mosquito bug and apple and nut borer accounted for 10 to 15 per cent of the fruit drop occurring in all the three stages. Remaining 85 to 90 per cent could be attributed to other factors like the competition for nutrients among the rapidly growing young fruits and hot dry winds blowing in this part of the year. On examination of the dropped fruits, he was not able to detect any fungal infection and they contained kernels free from abnormal symptoms of decay and deformity. Subbaiah and Balasimha (1980) while studying the physiology of immature fruit abscission in cashew observed that peroxidase and cellulase activities increased during fruit drop in abscission zone and this was enhanced by ethylene application. The localization of peroxidases around the abscission zone in the immature and mature fruit pedicel further confirmed the role of these enzymes in abscission. Vidhyadharan (1983) had

the opinion that under natural conditions, pollination in cashew was not very efficient. Failure of pollination (either for want of sufficient pollen in the atmosphere or for want of pollinating agents) was one of the reasons for poor fruit set in cashew in India.

Several workers had studied the problem of fruit drop in mango. Wagle (1928) attributed diseases and pests as a major factor causing fruit drop in mango, while Young (1942) was of the opinion that ovule abortion and embryo degeneration caused fruit drop in mango. Luckwill (1948) showed that the periods of active hormone synthesis were associated with low fruit drop.

Singh (1954) suggested lack of pollination and failure of fertilization as reasons for heavy fruit drop. Wind storms also accelerated the fruit drop. According to Singh and Arora (1963) fruit drop in the earlier stages seemed to be governed by the physiological factors, but towards maturity it was caused almost entirely by the physical damage by birds, by wind storms and by fruit cracking. They also suggested that in the earlier stages, fruit drop was caused by lack of auxin. Later auxin content of the seed had reached a certain minimum level and was no longer a limiting factor in fruit retention. The internal as well as external environments of the tree controlled its entire metabolism and consequently affected the synthesis of auxin

and thus fruit drop also. They finally concluded that every tree, especially one like the mango, which had very high initial fruit set must shed some of the fruits initially set, even when the auxins were not a limiting factor. In accordance with this Chadha and Singh (1964a) suggested that early fruit drop could even be considered "essential" and desirable to produce fruits of desirable size, grade and quality.

Singh (1964) also studied the problem of fruit drop in mango. According to him, apart from the problems of sex-ratio, defective pollination might be one of the limiting factors affecting fruit set in mango. Rains at the flowering time were highly injurious and sometimes caused a total failure of the crop. Pollination was adversely affected because of a decrease in the activity of the insects. Continued moist weather encouraged heavy attack of hoppers and certain fungi, which caused heavy shedding of flowers and fruits. This resulted in reduced yield. Embryo abortion might be another factor making reduced fruit set in mango. Embryos in early stages disintegrated, blackened and as a result the fruitlets dropped at a very early stage. Drop also occurred of such fruitlets which had been normally fertilized. Some times abnormal growth of cotyledons might cause the detachment of the entire embryo from the

funicular region and thus it might get deprived of its nutrient supply. Even when there was no such disintegration of the ovary, normal fruitlets dropped in huge number in certain varieties. Although no precised factors were known to be responsible for this drop, low auxin and nutrient content might be the probable causes for this, as their depletion might cause immature formation of abscission layer. Besides, active vegetative growth during the productive period usually resulted in huge fruit drop.

Kalyanasundaram (1974) found that in Mulgoa mango, due to its low initial set, the fruit drop affected the yield adversely. He suggested that the high initial drop per cent of 85.54 with low initial set of 11.25 fruits per panicle was persumably due to degeneration of ovules besides competition for nutrition between the large number of developing fruits in a panicle.

3. Pollinating agents, Parthenocarpy and Incompatibility.

The structure of cashew flower is more conducive to cross pollination than to self pollination (Damodaran et al., 1966) and there exists divergent opinion regarding the pollinating agents.

3.1. Pollinating agents.

3.1.1. Insects.

Rao and Hassan (1957) found that except black and

red ants no other insects were seen to visit the cashew flowers. Smith (1958) suggested that in cashew, bees could be used to promote greater pollination.

Damodaran et al. (1966) observed on cashew panicle insects like black and red ants, the hoverfly (Xanthogramma scuttellaris), the housefly (Musca domestica) and the common bee (Apis indica). However he did not recognise them as cashew pollinators, as the insect visitors were found to be very few and rare.

According to Northwood (1966b) cashew flowers were strongly scented, which suggested that insects were more important than wind as pollinating agent. At flowering time, there were larger population of flies and other winged insects capable ofacting as pollinating agents and nearly always a large ant population was associated with the inflorescence.

Free (1976) included cashew among the tropical crops which were benefitted from insect pollination. The warty and sticky nature of pollen grains together with the flowers penetrating smell and attraction of remarkable insect life led Agnoloni and Giuliani (1977), to the conclusion that entomophilous pollination prevailed in Tanzania. Ants, flies and honey bees were the most commonly noted insects on cashew panicle (ICAR, 1978).

Bhattee (1979) reported that bees and red ants were seen on inflorescence and were likely to be responsible for pollinating cashew flower.

In a study conducted at Mannuthy to find out the role of honey bees in the pollination of cashew, it was found that the open panicle carried 4.67 per cent of the perfect flowers to maturity whereas it was only 0.3 per cent in panicles covered with bee proof net (ICAR, 1979). According to Ohler (1979) cashew flowers in Africa and South America were often frequented by many insects. He suggested that possibly the ants observed on flowers in India were responsible for a greater part of pollination than assumed.

Parameswaran (1979) suggested that insect pollinators like honey bees could be successfully used to supplement the natural pollination in cashew orchards.

Rai (1979) found black and red ants visiting the flowers through out the day. Similarly Thimmaraju et al., (1980) recorded that excepting black ants (crawling insects) no other insects were observed on cashew inflorescence.

Mallik (1957) suggested insects as the main pollinating agents in mango. According to him, mango represented well developed adaptations for insect pollination. He suggested that the sticky nature of pollengrains at the time of anther dehiscence favoured entomophily. According to Young (1957) among the insects, flies were the chief visitors of mango flowers.

Murthy and Rao (1963) also had the idea of entemophilous pollination in mango. Singh (1964) in accordance with the above idea suggested that rains at flowering time would interfere with pollination due to sufficiently decreased activity of the insects.

Dufing the observations made by Anderson et al., (1982) at N. Australia, large native insect species were shown to pollinate mango flowers. The pollinators in decreasing order of efficiency were wasps, bees, large ants and large flies. Diptera and the native bee-Trigona sp. frequently moved from tree to tree.

3.1.2. Wind.

Observations made by several workers, lead to the idea of wind pollination in cashew.

Rao and Hassan (1957) found that very few insects visited the flowers and that wind was most important in cashew pollination. This was further supported by Damodaran et al., (1966) who found that insect visitors were found to be very few and rare.

But, according to Northwood (1966a) due to sticky nature of pollengrains they remained attached to the anther lobes and were not easily blown away by wind. Hence he suggested that wind pollination was of limited importance as far as cashew was concerned. Similar observations were made by Agnoloni and Giuliani (1977), who found that cashew pollen was warty on the outer layer and would cling to the anther cavities so that wind could

not easily blow it away.

Again under All India Co-ordinated Spices and Cashewnut Improvement Project at Mannuthy it was found that apart from insects, wind also played an important role as pollinating agent (ICAR, 1978). Contrary to this, studies conducted at Central Plantation Crops Research Institute (1981) revealed that the chance of wind pollination was remote.

In mango Maheswari (1934) stated that wind was the chief pollinating agent. Singh (1954) found that freshly dehised pollen grains got stuck to the anthers and consequently could not be transferred by wind and thus it was concluded that wind did not play a significant role in mango pollination. According to Mallik (1957) it was evident that mango had none of the characteristics of anemophilous plant except in the number of panicles and flowers. In all the mango varieties studied, the number of male flowers was always much greater than the number of perfect flowers which also contained the functional stamens. The number of pollen grains was between two and three hundred in one pollensac. So there was abundance of pollen grains in order to compensate for the heavy loss in transition. Even though pollen grains were sticky and remained in a mass when the anthers just opened, after a few minutes they became dry and dust like which was especially helpful for wind pollination.

Young (1957) observed very little pollen in the air and that pollen grains were too sticky for wind pollination.

3.1.3. Rain.

According to Premanad (1968), if there were rains at the flowering time pollination was definitely affected leading to very poor fruit set. In general, adequate and well distributed rains during the South West and North East monsoon periods followed by bright weather and occasional showers during the summer period constituted the most favourable climatic conditions, desirable for a good fruit set and yield in cashew.

Veeraraghavan and Vasavan (1977) also found that heavy rainy conditions affected the proper flower opening, pollination and fruit set. Bhattee (1979) reported that in Goa, there were no rains during the flowering season of cashew and hence rain water could not act as a pollinating agent.

Similarly in the case of mango Singh (1964) found that rains at the flowering time were highly injurious and sometimes caused a total failure of the crop.

3.2. Pollination of bagged panicles.

Northwood (1966a) found that bagged inflorescence did not produce nuts unless hand pollination was performed or insects were allowed inside. Studies conducted at CPCRI (1975) showed that of 100 bagged

panicles, five produced one nut each. Under All India Co-ordinated Spices and Cashewnut Improvement Project it was found that five panicles which were bagged individually set, in all two fruits (ICAR, 1977).

3.3. Parthenocarpy.

Studies of pollination in cashew proved no evidence of parthenocarpy. Hermaphrodite flowers bagged after emasculation set no fruits (ICAR, 1977). Pollination studies at CPCRI (1978) proved no evidence of parthenocarpy or self incompatibility. Studies conducted by Raju (1979) on parthenocarpic fruit set, had given negative results and hence suggested that pollination was essential for fruit set.

3.4. Incompatibility.

Controlled pollination studies by Damodaran et al., (1966) did not indicate any degree of self incompatibility in cashew, which was further supported by works at CPCRI (1981).

Gunjate et al., (1983) found no self incompatibility in Alphonso mango.

4. Studies on pollen dispersal in the atmosphere.

Air sampling is successfully employed to study the pollen and fungal spores found in atmosphere. Most of the workers conducted pollen dispersal studies as a means

to detect the presence of pollen in the atmosphere just around the crop. Information on how far successful transference of pollen by wind is possible is very scanty.

Northwood (1966a) studied the atmospheric pollen dispersal in cashew by putting a few sticky tape traps on some trees to catch wind blown pollen, but on examination no pollen was seen. This supported the view that wind pollination was of limited importance in cashew.

This type of study was undertaken in other tree crops like arecanut, where it was revealed that the mean number of pollen grains per square centimetre in the slides placed at one foot, three feet, and six feet from a spadix was 19, 7.9 and 1.9 respectively. This also showed that wind might be one of the agencies of pollination (Bhat, 1961).

Studies on atmospheric pollen of guava by Ray and Chhonkar (1981) confirmed that chances of pollination through wind were very slender, because only 1.17 guava pollen were observed per field of the slide smeared with vaseline and hung on guava branches selected randomly. Jessy Joseph (1983) by applying the same method in jack found that pollen was present in the air samples collected from around the trees.

Materials and Methods

MATERIALS AND METHODS

The investigations reported herein were undertaken at the Cashew Research Station, Madakkathara and in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period 1983-84.

A. Materials

From the cashew germplasm maintained at the Cashew Research Station, Madakkathara a type (BLA-139/1) was made use of for the present study. This type was characterised by short, early, synchronised flowering habit. Six year old trees of BLA-139/1 (air layers) were utilised in the present study. All the trees included in the investigation were receiving uniform cultural, manurial and plant protection measures as per the Package of Practices Recommendations of the Kerala Agricultural University.

B. Methods

In order to find out the time of flower opening in cashew, the following experiment was conducted. Four trees of BLA-139/1 were earmarked and separately labelled. In each tree thus earmarked, five panicles of uniform age facing different directions viz., East, West, South and North were labelled. Number of male and hermaphrodite flowers opened in each of the panicles thus labelled was counted separately and recorded at bihourly intervals round the clock commencing from 1 AM.

The flowers already opened were removed from the panicle after counting. This exercise of counting was started from commencement of flowering and continued till completion of flowering in a panicle. From the data thus collected, the percentage of flowers opened to the total, in a panicle, at bihourly intervals was calculated for each panicle and the mean was calculated.

Utilising the values observed during the entire period of opening of flowers in a panicle, number of male and hermaphrodite flowers, total number of flowers, the sex-ratio (ratio of hermaphrodite to male flowers in a panicle) and percentage of hermaphrodite flowers to the total flowers in a panicle were calculated.

Data collected from the above experiment were correlated with meteorological parameters such as atmospheric temperature, relative humidity, wind velocity, sunshine hours and rainfall as detailed below. The data pertaining to meteorological parameters were collected from the records of Meteorological Observatory attached to College of Horticulture, Vellanikkara (Appendix-I)

In order to find out the relationship between flower opening and atmospheric temperature the following procedure was adopted. Utilising the values of atmospheric temperature for 7.30, 8.30, 14.30 and 17.30 hr (the above were the timings at which observations on temperature were recorded in the Meteorological Observatory)

and also the day maximum and day minimum, a graph was plotted. From this graph, the temperature for each time interval corresponding to flower opening was extrapolated. These values of atmospheric temperature were correlated with the percentage of flowers opened at each interval.

The same procedure was adopted for finding out the correlation coefficient between the percentage of flowers opened and relative humidity.

The velocity of wind observed at 8.30 in the morning was correlated with the peak percentage of flower opening for that day.

Data on sunshine intensity recorded as hours of sunshine were collected from the records of the Meteorological Observatory attached to the College of Horticulture, Vellanikkara and values of sunshine intensity corresponding to a particular interval of flower opening were computed. These were then correlated with the percentage of flower opening for that particular interval of time.

Data on rainfall were insufficient to work out the correlation coefficient of the same with flower opening since rains received during the flowering phase of the crop were scanty and hence insufficient to work out the correlation.

In order to find out the extent of fruit set under natural condition and also under assisted hand pollination four, six year old BLA-139/1 (air layers) trees which possessed early, short and synchronised flowering were earmarked. Two sets of five panicles of uniform age each facing different directions from each of the four trees were labelled before the opening of even a single hermaphrodite flower in a panicle. One set of five panicles was immediately covered by muslin cloth bags fitted on light wire frame (Plate I) and the other set of five panicles was left uncovered. Number of hermaphrodite flowers in each of the above panicles was counted without injuring the flowers, each day commencing from the beginning of flowering and ending with the completion of flower opening in a panicle. Only flowers with pale white petals were counted as these flowered on that day. Flowers already counted were marked at their petal tip with the point of a marking pen in order to avoid duplication in counting. After counting, the flowers of uncovered panicles were left as such allowing them to undergo open pollination. Opened flowers in the covered panicles, after counting, were hand pollinated by rubbing the stigmatic surface with freshly dehisced anthers collected from male flowers. Adherence of pollen grains on the stigmatic surface was confirmed by verification of the same through hand lens.

Plate I. Muslin cloth bag for controlling pollination.
(Original volume of the bag = 4121.25cm^3)
(3.14 x 7.5cm x 7.5cm x 20cm +
$\frac{1}{3}$ x 3.14 x 7.5cm x 7.5cm x 10cm)

This hand pollination was done each day between 10 and 12 during day, during which period the peak flower opening was observed under Madakkathara conditions. Number of fruits set in both the above conditions was counted in three stages viz., initial (five to seven days after pollination), 'peanut' stage (15 to 20 days after pollination)and maturity (50 to 55 days after pollination) and percentage of fruit set to the total number of hermaphrodite flowers was worked out under both the situations. Percentage of fruits reached upto 'peanut' stage and also upto maturity were again computed taking the total number of fruits initially set as the base. Based on the results, the effect of hand pollination on bringing about increased fruit set was compared with natural pollination, using Students 't' test.

With a view to finding out the role played by different pollinating agents like wind and water in cross pollinating cashew flowers, the following experiment was conducted. Four, six year old trees of BLA-139/1 (air layers) were selected for the study. Twenty panicles of uniform age were selected and labelled before the commencement of flowering separately from each tree. Five of the 20 panicles in a tree thus labelled were covered with muslin cloth bags fitted to light wire frames,

throughout the flowering phase. Another five panicles of the same tree were also covered by similar bags but covering was removed each day at peak period of anthesis (10-12 noon) and water was sprayed separately on each panicle using a hand sprayer and soon after spraying they were covered again. Another five panicles of the same tree were subjected to wind pollination by removing the bags at the time of peak period of anthesis (10-12 noon). The remaining five panicles were left without bagging allowing them to undergo open pollination. The percentage of fruit set to the total number of hermaphrodite flowers in a panicle under each of the treatments was worked out. This experiment was repeated in the three more trees of the same type. Based on the data obtained the effects of different pollinating agents in bringing about cross pollination in cashew were compared using Students 't' test. Observations were also made on the various insects that visited cashew flowers during the experiment.

In order to find out the quantity of cashew pollen available in the atmosphere, the following field experiment was conducted. Few cashew trees of about 4 m in height available in the centre of an open area attached to the Kerala Agricultural Development Project (KADP) unit of the College of Horticulture, Vellanikkara were made use

of in the study. The experiment was conducted during November to February when strong North East wind currents were prevalent in the area. Ten bamboo poles of about five meters in height were erected on the South-Western side of the cashew trees selected for the study at distances of 1, 3, 5, 7, 9, 11, 13, 16, 19 and 22 m from the trees, in such a way that the poles were in different angles from the trees (Plate II). Acrylic sheets of 30 x 10 cm size were smeared with castor oil on one side and these were fitted to all the ten poles at varying heights of 1, 2, 3 and 4 m from the ground level in such a way that the sticky surface faced the trees. These boards were removed 24 hours after fixation and the amount of pollen present on the sticky surface of the acrylic board was assessed from four random places of 18 x 18 mm area. This was continued for seven days during the peak period of flowering. From the data collected thus, the quantity of pollen present per centimetre square area was worked out. The main effects and interaction of heights and distances on the amount of pollen grains per centimetre square were tested using analysis of variance.

In order to find out the intensity of hermaphrodite flowers in cashew panicle, the following observations were recorded from four trees of BLA-139/1 (air layers).

Plate II. Bamboo poles erected at different distances with acrylic sheets fitted at different heights. (Original length of poles = 4m Distances of the poles from the source = 1, 3, 5, 7, 9, 11, 13, 16, 19 & 22m Heights of acrylic sheets from ground level = 1.2.3 & 4m)

Four panicles, facing different directions, in each of the selected four trees were labelled. By holding a wire frame of 2 cm x 2 cm against the panicle, number of hermaphrodite flowers, opened on that particular day, enclosed by the frame, on a particular plane was counted. This was repeated at 10 different randomly selected areas in each panicle at the rate of four panicles per tree. From the data thus observed the mean number of hermaphrodite flower per square centimetre area of a panicle of a single tree and also the general mean were calculated.

RESULTS

Results of observations recorded from the six year old BLA-139/1 cashew trees (air layers) of Cashew Research Station, Madakkathara on various aspects of flower opening, pollination, fruit set, amount of pollen present in the atmosphere etc, are presented in Tables 1 to 19. The salient features of the results obtained are enumerated below.

Observations on the mean percentage of male flowers opened to the total number of male flowers in a panicle, recorded at bihourly intervals are presented in Table 1.

(Table 1)

The data presented in the above table have revealed that opening of male flowers in cashew commenced after 23 hr and continued upto 15 hr next day. This has been observed to be so uniformly in all the four trees from where the observations were recorded. The pattern of flower opening was also seen to be uniform for all the four trees. There existed two peaks of male flower opening in cashew, one between 1-3 hr and the other between 7-9 hr. However, the first peak was only one third of the second in magnitude.

Observations on the mean percentage of hermaphrodite flowers opened to the total number of hermaphrodite flowers in a panicle, recorded at bihourly intervals are presented in Table 2.

(Table 2)

Table 1. Percentage of male flowers to the total male flowers opened at hihourly intervals (mean of five panicles)

Tree no.	hours of observation											
	1	3	5	7	9	11	13	15	17	19	21	23
2172	4.59	12.35	8.29	11.08	41.46	16.42	4.94	0.91	—	—	—	—
2173	8.02	10.00	10.06	6.64	43.91	15.92	4.86	0.61	—	—	—	—
2174	8.92	15.36	8.82	5.23	42.78	13.54	4.30	1.08	—	—	—	—
2175	5.80	13.38	9.96	6.91	43.30	15.66	3.83	1.18	—	—	—	—
Mean	6.83	12.77	9.28	7.47	42.86	15.39	4.48	0.95	—	—	—	—

Table 2. Percentage of hermaphrodite flowers to the total hermaphrodite flowers opened at hihourly intervals (mean of five panicles)

Tree no.	hours of observation											
	1	3	5	7	9	11	13	15	17	19	21	23
2172	—	1.90	1.04	0.19	26.50	55.31	14.73	0.34	—	—	—	—
2173	0.33	0.79	1.45	0.77	33.13	53.06	9.86	0.63	—	—	—	—
2174	2.73	1.37	0.77	0.46	29.34	53.07	10.29	2.06	—	—	—	—
2175	1.09	2.29	1.46	1.11	20.26	60.87	12.18	0.74	—	—	—	—
Mean	1.04	1.59	1.18	0.63	27.31	55.57	11.77	0.94	—	—	—	—

The data on the pattern of opening of hermaphrodite flowers in cashew have revealed that, like male flowers, hermaphrodite flowers also started opening after 23 hr and continued upto 15 hr next day. The same pattern was observed in all the four trees under observation except in tree 2172, where hermaphrodite flowers started opening only after 1 hr. In general the pattern of flower opening was also seen to be uniform in all the four trees. As in the case of male flowers, hermaphrodite flowers also showed two peaks of flower opening. The first peak, which showed 1.59 percentage of flower opening, was between 1 and 3 hr as in the case of male flowers. But the second peak was shifted to 9-11 hr where 55.57 percentage of hermaphrodite flowers opened. In general opening of hermaphrodite flowers was negligible before 7 hr and that was only 4.44 per cent. The remaining 95.56 per cent of hermaphrodite flowers opened between 7 and 15 hr.

The correlation coefficients between the percentage of flowers opened at hihourly intervals and climatic factors are presented in Table 3.

T (Table 3)

The calculated values of correlation coefficients between the percentage of flowers opened (both male and hermaphrodite flowers) and various climatic factors viz.,

Table 3. Correlation coefficients between the percentage of flowers opened at bihourly intervals and climatic factors.

Sl.no.	Climatic factors	Correlation coefficient 'r'	
		Male flower	Hermaphrodite flower
1.	Temperature	+0.09	-0.07
2.	Sunshine hours	-0.03	+0.17
3.	Relative humidity	+0.09	-0.04
4.	Wind velocity	-0.11	+0.07

temperature, sunshine hours, relative humidity and wind velocity have not revealed any significant relationship between these factors and flower opening.

From the total number of male and hermaphrodite flowers in a panicle, sex-ratio (ratio of hermaphrodite to male flowers) and percentage of hermaphrodite flowers to the total were computed and are presented in Table 4.

(Table 4)

From the table given above the sex-ratio in BLA-139/1 had been found to be 1:2.83 ie for every hermaphrodite flower there are nearly three male flowers. The data had further revealed that there existed variation in sex-ratio even between panicles of the same tree. The highest ratio of male to hermaphrodite flowers recorded was 1:7.04 while the lowest was 1:1.31. The data also showed variation in sex-ratio between trees. Tree 2173 showed the highest mean ratio of male to hermaphrodite flowers of 1:3.72 whereas tree 2175 showed the lowest viz., 1:1.85. The same trend had been reflected in the case of percentage of hermaphrodite flowers to the total flowers in a panicle. Tree 2173 which gave the highest ratio of male to hermaphrodite flowers gave the lowest percentage of hermaphrodite flowers of 23.87. Similarly tree 2175 had the highest percentage of hermaphrodite flowers of 36.30 where the ratio of male to hermaphrodite flowers was lowest viz., 1:1.85. There

Table 4. Flower counts and sex-ratio in cashew

Tree number	Panicle number	Male flowers	Hermaphrodite flowers	Total	Sex-ratio (Hermaphrodite to male flowers)	Percentage of hermaphrodite flowers to total flowers in a panicle
2172	1	179	119	298	1:1.50	39.93
	2	180	36	216	1:5.00	16.67
	3	187	63	250	1:2.97	25.20
	4	189	110	299	1:1.72	36.79
	5	229	41	270	1:5.59	15.19
	Mean	192.8	73.8	266.6	1:3.36	26.76
2173	1	214	69	283	1:3.10	24.38
	2	210	121	331	1:1.74	36.56
	3	212	64	276	1:3.31	23.19
	4	183	26	209	1:7.04	12.44
	5	173	51	224	1:3.39	22.77
	Mean	198.4	66.2	264.6	1:3.72	23.87
2174	1	282	122	404	1:2.31	30.20
	2	165	65	230	1:2.54	28.26
	3	145	68	213	1:2.13	31.92
	4	146	71	217	1:2.06	32.72
	5	191	66	257	1:2.89	25.68
	Mean	185.8	78.4	264.2	1:2.39	29.76
2175	1	235	145	380	1:1.62	38.16
	2	200	153	353	1:1.31	43.34
	3	196	83	279	1:2.36	29.75
	4	287	110	397	1:2.61	27.71
	5	193	143	336	1:1.35	42.56
	Mean	222.2	126.8	349	1:1.85	36.30
General Mean		199.8	86.3	286.1	1:2.83	29.17

'F' value for sex ratio = 1.0813 (Not significant)

existed variation in the percentage of hermaphrodite flowers between panicles of the same tree.

In order to compare the effect of hand pollination over natural pollination, fruit set studies were performed at three distinct stages viz., initial fruit set, fruits reached upto 'pea-nut' stage and fruits reached upto maturity. The data on the initial fruit set (percentage of fruits initially set to the total hermaphrodite flowers) obtained in the naturally pollinated and hand pollinated panicles are given in Table 5.

(Table 5)

Data from the above table have revealed that the initial fruit set was much low in the case of naturally pollinated panicles when compared to hand pollinated panicles which were 11.89 and 66.50 per cent respectively. In other words, there was significant increase in initial fruit set in hand pollinated panicles compared to naturally pollinated panicles.

Observations on the percentage of fruits over total hermaphrodite flowers reached upto 'pea-nut' stage in the naturally pollinated and hand pollinated panicles are given in Table 6.

(Table 6)

According to the above table, a mean percentage of 7.29 fruits reached upto 'pea-nut' stage in naturally pollinated panicles while it was 28.04 in hand pollinated

Table 5. Initial fruit set in the naturally pollinated and hand pollinated panicles

Tree number	Panicle number	Percentage of initial fruit set to the total hermophrodite flowers, obtained in the	
		naturally pollinated panicles	hand pollinated panicles
	1	6.25	60.00
	2	7.25	64.29
2172	3	7.35	71.43
	4	11.69	68.18
	5	11.54	71.05
	6	12.50	71.43
	7	11.70	68.18
2173	8	10.67	63.16
	9	17.31	66.67
	10	9.68	62.00
	11	13.76	65.71
	12	13.16	70.00
2174	13	12.77	52.63
	14	12.05	62.50
	15	13.21	62.07
	16	15.17	65.00
	17	13.33	70.00
2175	18	10.35	62.07
	19	15.00	75.00
	20	13.04	78.57
	Mean	11.89	66.50

t = 37.84*

* Significant at 5 per cent level

Table 6. Fruits reached upto 'pea-nut' stage in the naturally pollinated and hand pollinated panicles

Tree number	Panicle number	Percentage of fruits to the total hermaphrodite flowers, reached upto 'pea-nut' stage in	
		naturally pollinated panicles	hand pollinated panicles
2172	1	—	26.67
	2	4.35	28.57
	3	4.41	14.29
	4	7.79	27.27
	5	7.69	31.58
2173	6	6.25	21.43
	7	9.33	22.73
	8	7.45	36.84
	9	9.62	33.33
	10	3.23	22.00
2174	11	9.17	25.71
	12	10.53	40.00
	13	8.51	22.37
	14	8.43	31.25
	15	7.55	31.04
2175	16	8.70	17.50
	17	8.33	26.00
	18	6.90	24.14
	19	8.75	28.13
	20	8.70	50.00
	Mean	7.29	28.04

t =11.00*

* Significant at 5 per cent level

panicles. This indicated that hand pollination was significantly superior to natural pollination.

Observations on the percentage of fruits reached upto maturity in both naturally pollinated and hand pollinated panicles are given in Table 7.

(Table 7)

From the above table it is clear that, as in the case of initial fruit set and percentage of fruits reached upto 'pea-nut' stage, hand pollination resulted in significantly higher values of the percentage of fruits reached upto maturity compared to natural pollination. The percentages of fruits to the total hermaphrodite flowers reached upto maturity were 5.19 and 19.98 in naturally pollinated and hand pollinated panicles respectively. This indicated that though the number of nuts reached upto maturity was high in hand pollinated panicles, it was not commensurate with the increased initial fruit set obtained by hand pollination.

For a more critical evaluation, percentages of fruits reached upto 'pea nut' stage and maturity over total initial fruit set were calculated for both natural pollination and hand pollination and are represented in Table 8 and Table 9.

(Tables 8 and 9)

From Table 8 it is clear that only 41.74 per cent

Table 7. Fruits reached upto maturity in naturally pollinated and hand pollinated panicles

Tree number	Panicle number	Percentage of fruits to total hermaphrodite flowers reached upto maturity in	
		naturally pollinated panicles	hand pollinated panicles
2172	1	—	21.67
	2	2.90	21.43
	3	4.41	14.29
	4	6.49	18.18
	5	3.85	26.32
2173	6	4.17	21.43
	7	6.67	18.18
	8	5.32	26.32
	9	5.77	20.00
	10	—	18.00
2174	11	7.34	17.14
	12	7.90	20.00
	13	6.38	15.79
	14	7.23	25.00
	15	7.55	24.14
2175	16	6.52	12.50
	17	5.00	15.00
	18	3.45	13.79
	19	6.25	21.88
	20	6.52	28.57
	Mean	5.19	19.98

t = 12.99*

* Significant at 5 per cent level

Table 8. Fruits reached upto 'pea-nut' stage expressed as percentage to the total initial fruit set in naturally pollinated and hand pollinated panicles

Tree number	Panicle number	Percentage of fruits reached upto pea-nut stage over total initial fruit set in the	
		naturally pollinated panicles	hand pollinated panicles
	1	—	44.44
	2	60.00	44.44
2172	3	60.00	20.00
	4	66.67	40.00
	5	66.67	44.44
	6	50.00	30.00
	7	87.50	33.33
2173	8	63.64	58.33
	9	55.56	50.00
	10	33.33	35.48
	11	66.67	39.13
	12	80.00	57.14
2174	13	66.67	42.50
	14	70.00	50.00
	15	57.14	50.00
	16	57.14	26.92
	17	62.50	28.57
2175	18	66.67	38.89
	19	58.33	37.50
	20	66.67	63.64
	Mean	59.76	41.74

t = 3.84*

* Significant at 5 per cent level

Table 9. Fruits harvested, expressed as percentage to the total initial fruit set in naturally pollinated and hand pollinated panicles

Tree number	Panicle number	Percentage of fruits harvested over total initial fruit set in the	
		naturally pollinated panicles	hand pollinated panicles
2172	1	—	36.11
	2	40.00	33.33
	3	60.00	20.00
	4	55.56	26.67
	5	33.33	37.04
2173	6	57.14	30.00
	7	33.33	26.67
	8	62.50	41.67
	9	45.46	30.00
	10	33.33	29.03
2174	11	—	26.09
	12	53.33	28.57
	13	60.00	30.00
	14	50.00	40.00
	15	60.00	38.89
2175	16	42.86	19.23
	17	37.50	21.43
	18	33.33	22.22
	19	41.67	29.17
	20	50.00	36.36
	Mean	42.47	30.13

t = 2.92*

* Significant at 5 per cent level

of initially set fruits reached upto 'pea nut' stage in hand pollinated panicles while 59.76 per cent of initially set fruits reached upto 'pea nut' stage in naturally pollinated panicles. These values exhibited a significant difference. It was interesting to note that 30.13 per cent of initially set fruits reached upto maturity in hand pollinated panicles while 42.47 per cent of initially set fruits reached upto maturity in naturally pollinated panicles as given in Table 9. Here natural pollination was significantly superior to hand pollination both in the percentage of fruits reached upto'pea nut' stage and maturity, over total initial fruit set.

The observations on the total fruit drop in naturally pollinated panicles and hand pollinated panicles over total hermaphrodite flowers are presented in Table 10.

(Table 10)

Data from the above table have indicated that percentage of total fruit drop was high both in naturally pollinated and hand pollinated panicles giving mean values of 94.81 and 80.02 respectively, which showed significant difference. Under natural pollination, in some panicles even 100 per cent drop was recorded. On the other hand, in hand pollinated panicles maximum drop was 87.50 per cent.

Table 10. Total fruit drop in naturally pollinated and hand pollinated panicles (as percentage to total hermaphrodite flowers)

Tree number	Panicle number	Percentage of total fruit dropped over total hermaphrodite flowers in the	
		naturally pollinated panicles	hand pollinated panicles
2172	1	100.00	78.33
	2	97.10	78.57
	3	95.59	85.71
	4	93.51	81.82
	5	96.15	73.68
2173	6	95.83	78.57
	7	93.33	81.82
	8	94.68	73.68
	9	94.23	80.00
	10	100.00	82.00
2174	11	92.66	82.86
	12	92.11	80.00
	13	93.62	84.21
	14	92.77	75.00
	15	92.45	75.86
2175	16	93.48	87.50
	17	95.00	85.00
	18	96.55	86.21
	19	93.75	78.13
	20	93.48	71.43
	Mean	94.81	80.02

t = 12.98*

* Significant at 5 per cent level

For a more critical comparison, fruit drop at different stages viz., hermaphrodite flowers dropped before fruit set, fruits dropped between set and 'pea nut' stage and percentage of fruits dropped after 'pea nut' stage both in natural pollination and hand pollination are presented in Tables 11, 12 and 13 respectively.

(Tables 11, 12 and 13)

The data presented in Table 11 have indicated that in naturally pollinated panicles, heaviest drop of hermaphrodite flowers occurred before set (88.11 per cent) while the drop at this stage was much low in hand pollinated panicles (33.50 per cent). Thus the percentage of hermaphrodite flowers dropped away before set in naturally pollinated panicles was two and a half times greater than that in hand pollinated panicles. But the data presented in Table 12 have revealed that in naturally pollinated panicles, the percentage of fruits dropped between set and 'pea nut' stage over total hermaphrodite flowers was much low when compared to the same in hand pollinated panicles. In hand pollinated panicles 38.76 per cent of fruits dropped between set and 'pea nut' stage while the drop at this stage was only nine times lesser (4.61 per cent) in the case of naturally pollinated panicles, which showed a significant difference. The increased fruit drop in later stages

Table 11. Hermaphrodite flowers dropped before fruit set in naturally pollinated and hand pollinated panicle

Tree number	Panicle number	Percentage of hermaphrodite flowers dropped before fruit set in the	
		naturally pollinated panicles	hand pollinated panicles
2172	1	93.75	40.00
	2	92.75	35.71
	3	92.65	28.57
	4	88.31	31.82
	5	88.46	28.95
2173	6	87.50	28.57
	7	89.33	31.82
	8	88.30	36.84
	9	82.69	33.33
	10	90.32	38.00
2174	11	86.24	34.29
	12	86.84	30.00
	13	87.23	47.37
	14	87.95	37.50
	15	86.79	37.93
2175	16	84.78	35.00
	17	86.67	30.00
	18	89.66	37.93
	19	85.00	25.00
	20	86.96	21.43
	Mean	88.11	33.50

t = 37.85*

* Significant at 5 per cent level

Table 12. Fruit drop between set and 'pea-nut' stage in naturally pollinated and hand pollinated panicles

Tree number	Panicle number	percentage of fruits dropped between set and 'pea-nut' stage over total hermaphrodite flowers in the	
		naturally pollinated panicles	hand pollinated panicles
2172	1	6.25	33.33
	2	2.90	35.71
	3	2.94	57.14
	4	3.90	40.91
	5	3.85	39.47
2173	6	6.25	50.00
	7	1.33	45.46
	8	4.26	26.32
	9	7.69	33.33
	10	6.45	40.00
2174	11	4.59	40.00
	12	2.63	30.00
	13	4.26	30.26
	14	3.62	31.25
	15	5.66	31.03
2175	16	6.52	47.50
	17	5.00	50.00
	18	3.45	37.93
	19	6.25	46.88
	20	4.35	28.57
	Mean	4.61	38.76

t = 17.61*

* Significant at 5 per cent level

Table 13. Fruit drop after 'pea-nut' stage in naturally pollinated and hand pollinated panicles

Tree number	Panicle number	Percentage of fruit drop after 'pea-nut' stage to the total hermaphrodite flowers in the	
		naturally pollinated panicles	hand pollinated panicles
2172	1	—	5.00
	2	1.45	7.14
	3	—	—
	4	1.30	9.09
	5	3.85	5.26
2173	6	2.08	—
	7	2.67	4.55
	8	2.13	10.53
	9	3.85	13.33
	10	3.23	4.00
2174	11	1.84	8.57
	12	2.63	20.00
	13	2.13	6.58
	14	1.21	6.25
	15	—	6.90
2175	16	2.17	5.00
	17	3.33	5.00
	18	3.45	10.35
	19	2.50	6.25
	20	2.19	21.43
	Mean	2.10	7.76

t = 3.76*

* Significant at 5 per cent level

of fruit development in the case of hand pollinated panicles compared to naturally pollinated panicles was further revealed in Table 13. From this table it is clear that only 2.10 per cent of fruits dropped after 'pea nut' stage in the case of naturally pollinated panicles. On the other hand, the fruit drop at this stage was 7.76 per cent in hand pollinated panicles. In general fruit drop after 'pea nut' stage was low both in naturally pollinated and hand pollinated panicles when compared to fruit drop at other stages of fruit development. In natural pollination percentage of fruit drop at this stage was three times less when compared to hand pollinated panicles.

Observations on the fruit set and fruit harvest in completely bagged panicles are given in Table 14.

(Table 14)

From the above table it is found that in majority of completely bagged panicles the fruit set was nil. Only in two panicles out of 20 observed, a low fruit set of 1.70 and 2.90 per cent were observed. It is interesting to note that the fruit drop in these two panicles was nil i.e. all the set fruits reached upto maturity. The mean percentage of initial fruit set and fruits reached upto maturity expressed over total hermaphrodite flowers was much low (0.23).

Table 14. Fruit set and fruit harvest in completely bagged panicles

Tree number	Panicle number	Percentage (expressed over total hermaphrodite flowers) of initial fruit set	Percentage (expressed over total hermaphrodite flowers) of fruit harvest
	1	—	—
	2	—	—
2172	3	—	—
	4	—	—
	5	—	—
	6	—	—
	7	—	—
2173	8	—	—
	9	—	—
	10	—	—
	11	—	—
	12	—	—
2174	13	1.70	1.70
	14	—	—
	15	—	—
	16	—	—
	17	2.90	2.90
2175	18	—	—
	19	—	—
	20	—	—
	Mean	0.23	0.23

Observations on the fruit set and fruit harvest in water sprayed panicles are given in Table 15.

(Table 15)

The data presented in the above table have revealed that the fruit set in water sprayed panicles was negligible (0.05 percentage). Out of 20 panicles observed, only in one panicle one fruit was set which reached upto maturity stage. In the remaining 19 panicles not even a single fruit was set.

The observations on the initial fruit set over total hermaphrodite flowers in naturally pollinated and wind pollinated panicles are given in Table 16.

(Table 16)

From the above table it is found that in naturally pollinated panicles, 11.89 per cent of fruits were initially set while in wind pollinated panicles 7.79 per cent set was observed. Thus naturally pollinated panicles were significantly superior to wind pollinated panicles in initial fruit set.

In order to get an idea about the intensity of cashew pollen in the atmosphere, pollen counts per unit area were made from sticky boards at different heights from ground level and different distances from the source. The observations on this aspect are presented in Table 17

Table 15. Fruit set and fruit harvest in water sprayed panicles

Tree number	Panicle number	Percentage (expressed over total hermaphrodite flowers) of	
		initial fruit set	fruit harvest
2172	1	—	—
	2	—	—
	3	—	—
	4	—	—
	5	—	—
2173	6	—	—
	7	—	—
	8	—	—
	9	—	—
	10	—	—
2174	11	—	—
	12	0.94	0.94
	13	—	—
	14	—	—
	15	—	—
2175	16	—	—
	17	—	—
	18	—	—
	19	—	—
	20	—	—
	Mean	0.05	0.05

Table 16. Initial fruit set in the naturally pollinated and wind pollinated panicles

Tree number	Panicle number	Percentage of initial fruit set to the total hermaphrodite flowers in the	
		naturally pollinated panicles	wind pollinated panicles
2172	1	6.25	7.41
	2	7.25	6.10
	3	7.35	9.38
	4	11.69	9.23
	5	11.54	4.82
2173	6	12.50	4.65
	7	11.70	8.82
	8	10.67	9.09
	9	17.31	6.49
	10	9.68	6.67
2174	11	13.76	7.69
	12	13.16	6.78
	13	12.77	5.26
	14	12.05	9.46
	15	13.21	6.89
2175	16	15.17	10.00
	17	13.33	10.00
	18	10.35	7.14
	19	15.00	12.00
	20	13.04	7.81
	Mean	11.89	7.79

t = 5.46*

* Significant at 5 per cent level

and analysis of variance in Table 18.

(Tables 17 and 18)

From the above tables it is clear that there was no significant variation in the amount of pollen grains present in the atmosphere at different distances viz., 1m, 3m, 5m, 7m, 9m, 11m, 13m, 16m, 19m and 22m away from the source. On an average 2.16 cashew pollen grains per centimetre square area of sticky surface were present at different distances. Similarly at different heights viz., 1m, 2m, 3m, and 4m from ground level, the intensity of cashew pollen was not varying significantly. Here also an average number of 2.16 cashew pollengrains was present per centimetre square area of sticky surface. Further the interaction between heights and distances was also not significant.

Observations on the mean number of hermaphrodite flowers (opened on a particular day) per square cm area of cashew panicle are given in Table 19.

(Table 19)

According to this data given above, on an average 0.098 hermaphrodite flowers or approximately 0.1, was present per square centimetre area of a panicle of BLA-139/1.

Table 17. Intensity of cashew pollen in the atmosphere (No. of fertile pollen grains per cm^2)

Distances from the trees	Heights from the ground level				Mean
	1m	2m	3m	4m	
1m	0.84	0.95	1.60	2.58	1.49
3m	0.73	1.70	1.61	2.58	1.65
5m	2.01	1.68	2.65	3.11	2.36
7m	2.50	2.52	3.19	2.65	2.71
9m	2.49	2.19	1.07	1.62	1.84
11m	2.16	1.85	1.26	1.21	1.62
13m	2.82	2.32	1.83	1.94	2.23
16m	2.22	2.36	2.32	4.00	2.72
19m	2.67	2.88	1.64	2.04	2.31
22m	1.36	4.18	1.95	2.95	2.61
Mean	1.98	2.26	1.91	2.47	2.16

Table 18. Analysis of variance for the effect of heights and distances on the intensity of cashew pollen in the atmosphere

Source	DF	SS	M square	F value
Distance	9	55.65	6.18	1.53
Height	3	13.98	4.66	1.15
Interaction	27	93.49	3.46	0.86
Error	240	968.19	4.034	—
Total	279	1131.31		

Table 19. Intensity of hermaphrodite flowers in cashew panicle

Tree no.	Panicle no.	Mean number of hermaphrodite flowers/square centimetre
2172	1	0.03
	2	0.10
	3	0.10
	4	0.10
	Mean	0.083
2173	1	0.08
	2	0.10
	3	0.13
	4	0.03
	Mean	0.085
2174	1	0.10
	2	0.15
	3	0.10
	4	0.05
	Mean	0.100
2175	1	0.10
	2	0.10
	3	0.15
	4	0.15
	Mean	0.125
General	Mean	0.098

Discussion

DISCUSSION

Observations on the various parameters relating to the different aspects of flower opening, pollination, fruit set etc. of cashew have been critically analysed and presented in the previous chapter. It now remains to discuss the results as a whole so as to draw valid and reliable conclusions from the study. This is attempted in this chapter.

Cashew, although a native of tropical America has become commercially very important in our country as well as some other countries like Brazil, Mozambique, Tanzania, Kenya etc. Because of its hardy and drought resistant nature, it is grown in a wide variety of soils under very low management conditions. Absence of timely plant protection measures, inadequate nutrition, use of genetically poor stock etc. have resulted in very low average yields not only in India but in other cashew growing countries as well. It has been estimated that the average per tree yield of cashewnuts in Mozambique is 4 kg, Kenya 1.5 to 2.5 kg, Brazil 2.2 kg and India 1.6 to 2.2 kg per year. These recorded yield figures are very low as compared to the potential possible yield, a cashew tree can give annually. The genetic potential for raising the ceiling of yield is clear from the reported work of All India Co-ordinated Spices and Cashewnut Improvement

Project sponsored by the ICAR wherein it has been reported that the strain Vengurla-2 has given an annual per tree yield of 43 kg and another genotype BLA-139/1, 34 kg per tree. Thus it is clear that there exists a wide gap between the actual yield realized and the potential yield possible. This gap has to be narrowed to the extent possible and every effort by way of providing research support has to be given in this direction. This is more so in a country like India where the total production is only 25 to 30 per cent of the demand. Thus the need for intensifying agricultural research on cashew cannot be over emphazised.

The obvious solution for the present "cashew crisis" is to increase the indigenous production of raw nuts. It has been officially estimated that India should produce 4.5 lakh tonnes of raw nuts annually if it has to maintain the industry viable (Nambiar, 1979). This indirectly means that our production potential has to be increased three fold. In this context, examination of the factors which lead to the low per tree yield realised in our country is really pertinent and meaningful, so as to enable us for suggesting suitable counter measures for overcoming the situation. It is in this perspective that the present study assumes significance.

Cashew is mainly cultivated for its single seeded nut which is the raw material for industry. The number of nuts produced by a single tree is the tree yield which has to be, as stated earlier, trebled in order to sustain the industry. What are the ways and means by which this is practically feasible? Availability of large number of fertile flowers in a tree, synchronisation of male and female phases in the season, availability of sufficient quantity of viable pollen and also pollinating agents, increased percentage of fruit set and reduced percentage of fruit drop form the chief pre-requisites for realising high yield from a single tree. Let us now examine to what extent the results obtained in the present investigations are capable of unravelling the factors mentioned above.

Cashew inflorescence is a terminal indeterminate polygamomonoecious panicle in which hermaphrodite and male flowers are borne (Rao and Hassan, 1957; Damodharan et al., 1965). Both the type of flowers are essential for fruit production. When male flowers produce male gametes, hermaphrodite flowers produce both male and female gametes. As such, increase in the number of hermaphrodite and male flowers may lead to increase(fruit set. Results of observations recorded in the present investigations have shown that in the type BLA-139/1 under Madakkathara conditions, each panicle on an average possesses 286.1 flowers of

which 199.8 are male and 86.3 hermaphrodite, working out to a sex-ratio of 1:2.83 of hermaphrodite to male flowers. These values are in agreement with the results of previous investigators. Assuming a modest estimate of an average of 50 panicles per tree, there are 50 x 86.3 = 4,315 hermaphrodite flowers possible and if all the flowers after fertilization reach to maturity, a tree may yield 4,315 nuts which may weigh 34.52 kg @ 125 medium sized nuts per kg. However, the actual yield realized is only a portion of the theoretical yield possible. The reason for this, as per the present investigation, cannot be attributed to lack of hermaphrodite flowers produced in a tree. Bigger (1960) also had expressed the same opinion. The reasons for the low average yield in cashew have to be sought elsewhere.

The pre-and post-fertilization drops of hermaphrodite flowers may adversely affect the final yield. The adverse influence of this factor is directly proportional to the magnitude of hermaphrodite flowers shed. As per the results of present study, 88.11 per cent and 33.50 per cent of hermaphrodite flowers are observed to have been dropped before fruit set in the naturally pollinated panicles and in the hand pollinated panicles respectively. In other words out of every 100 hermaphrodite flowers produced in a tree, 88 drop off before fruit set under natural

conditions, leaving only 12 flowers to yield fruits. Lack of pollination or lack of fertilization or other physiological factors may be the reason for the huge amount of early flower drop. However, this will have to be strengthened and confirmed by further studies, and suitable counter measures will have to be chalked out for preventing early flower shedding.

In addition to large number of hermaphrodite flowers, availability of sufficient quantities of fertile pollen at the appropriate time is an important factor for pollination. Results of the present study have shown that each panicle on an average has 199.8 male flowers and a hermaphrodite to male sex-ratio of 1:2.83 which cannot be said to be too low or too high. These facts suggest that derth of male flowers cannot be considered as a limiting factor for low yield in cashew. Further, intensity of fertile cashew pollen is also fairly high in the atmosphere. It has been observed that on an average, there are 2.16 fertile cashew pollen grains per square cm area surrounding the cashew trees to pollinate approximately 0.1 number of hermaphrodite flowers. In other words, there are 21.6 pollen grains to pollinate one flower. As such derth of fertile pollen grains cannot also be considered to be a limiting factor for higher yields in cashew.

The intensity of pollen grains in the atmosphere observed in the present study is fairly uniform for the entire distance of 22 m from the source involving a height of 4 m from the ground level. In other words no significant difference in the pollen count could be observed either at various distances or at various heights in relation to source. As such the isolation distance for cashew cannot be worked out based on the results of the present study. This will have to be worked out by conducting further investigations involving greater distances from the source.

Apart from the availability of large number of hermaphrodite and male flowers in a tree, synchronization of the two phases is also of great significance for higher yields. Cashew is a highly cross pollinated crop and for higher yield, the male phase should necessarily coincide with female phase. In other words liberation of fertile pollen grains should coincide with the period of receptivity of the stigma. It is also necessary that at this time, the climatic conditions should remain conducive for normal pollination and fertilization. The pattern of flower opening as per the results of the present study is essentially the same for both male as well as hermaphrodite flowers. Both the types of flowers start opening after 23 hr and continue to open till 15 hr on the following day with two peaks, one between 1 and 3 hr for both male as well as hermaphrodite flowers and another between 7 and 9 hr for male and

between 9 and 11 hr for hermaphrodite flowers (Fig. 1). No flower is seen to be opening between 15 and 23 hr. This is the picture we get when we consider the distribution of flower opening during the 24 hr period.

When we consider the flowers of a panicle as one unit and trace the time of opening of different types of flowers of that panicle, we find that the male flowers start opening earlier followed by opening of both male and hermaphrodite flowers of that panicle which is again followed by opening of remaining few male flowers. In other words the sequence of flower opening in a single panicle, in general, is that there is an initial male phase followed by mixed phase which is again followed by second male phase (Pavithran and Ravindranathan, 1976). Thus lack of synchronization of flower opening cannot be attributed as a reason for low yield in cashew, based on the results of the present study.

Observations on the relationship of climatic factors like temperature, sunshine hours, relative humidity and wind velocity do not seem to have any significant influence on flower opening. Irrespective of the intensity of expression of these climatic factors, flower opening is observed to be constant at different periods in a day (Fig. 2a, 2b). These findings do not fully agree with the results of Rao and Hassan (1957);

Fig-1 PERCENTAGE OF FLOWERS OPENED AT BIHOURLY INTERVALS IN CASHEW

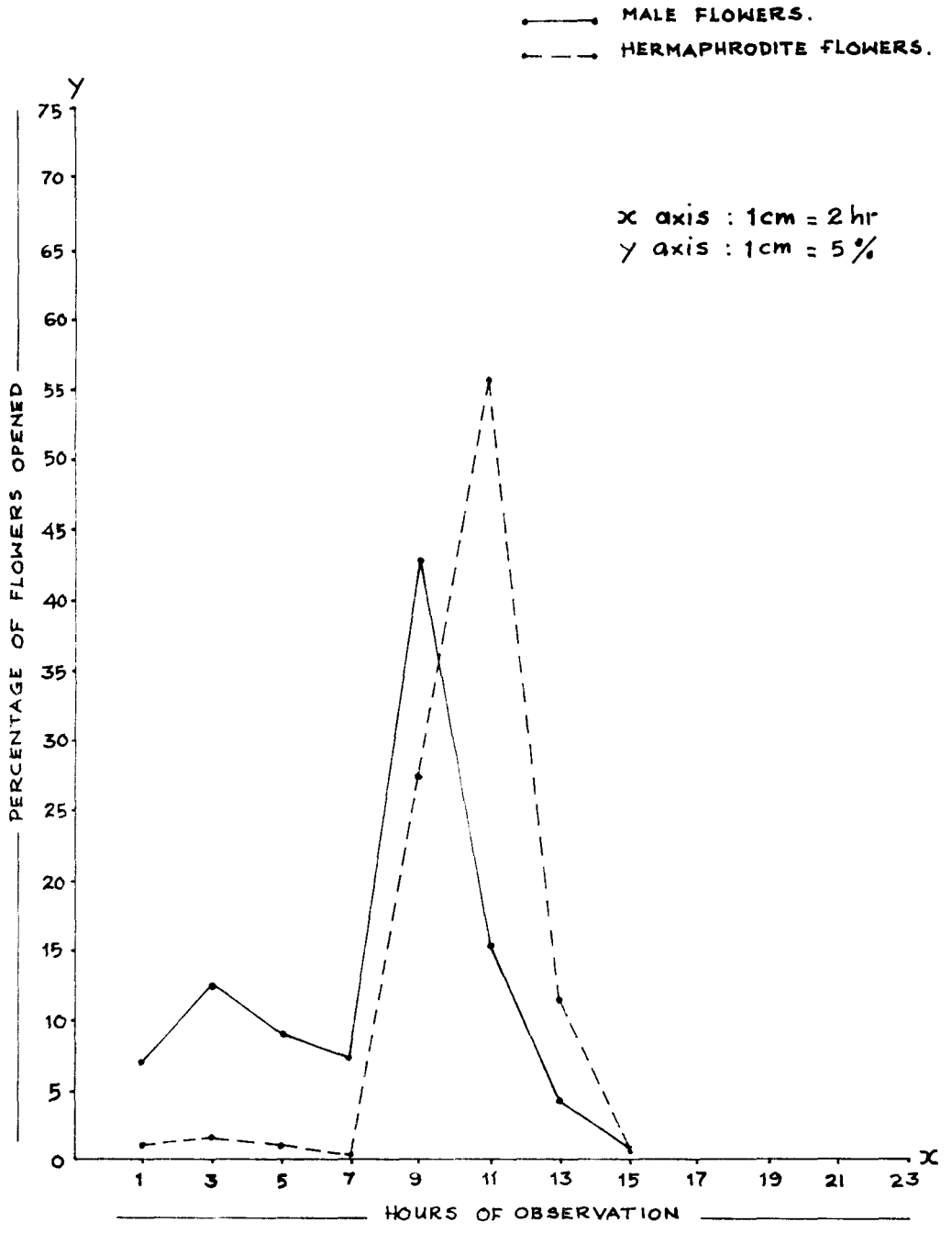


Fig-2a. INFLUENCE OF CLIMATIC FACTORS ON MALE FLOWER OPENING

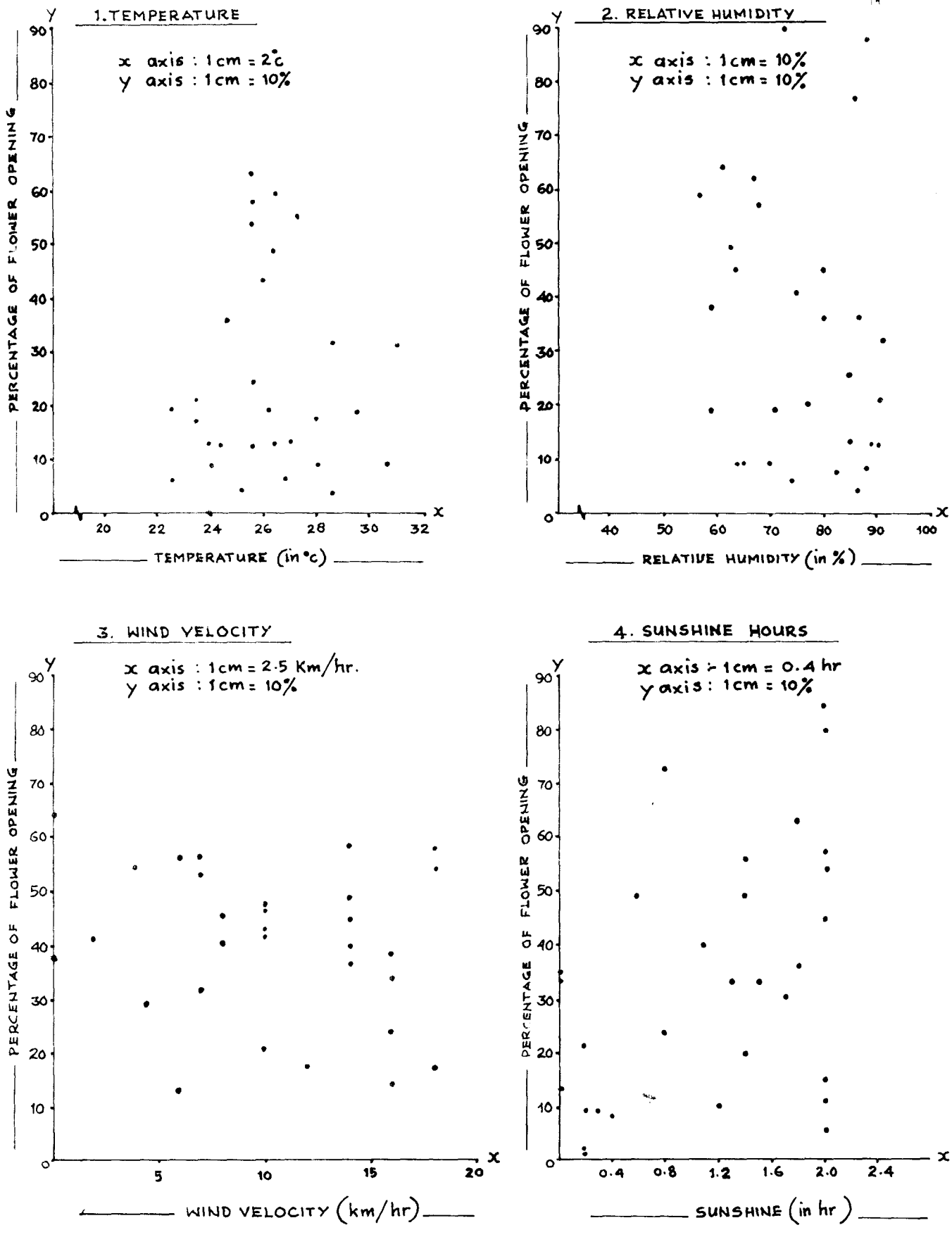
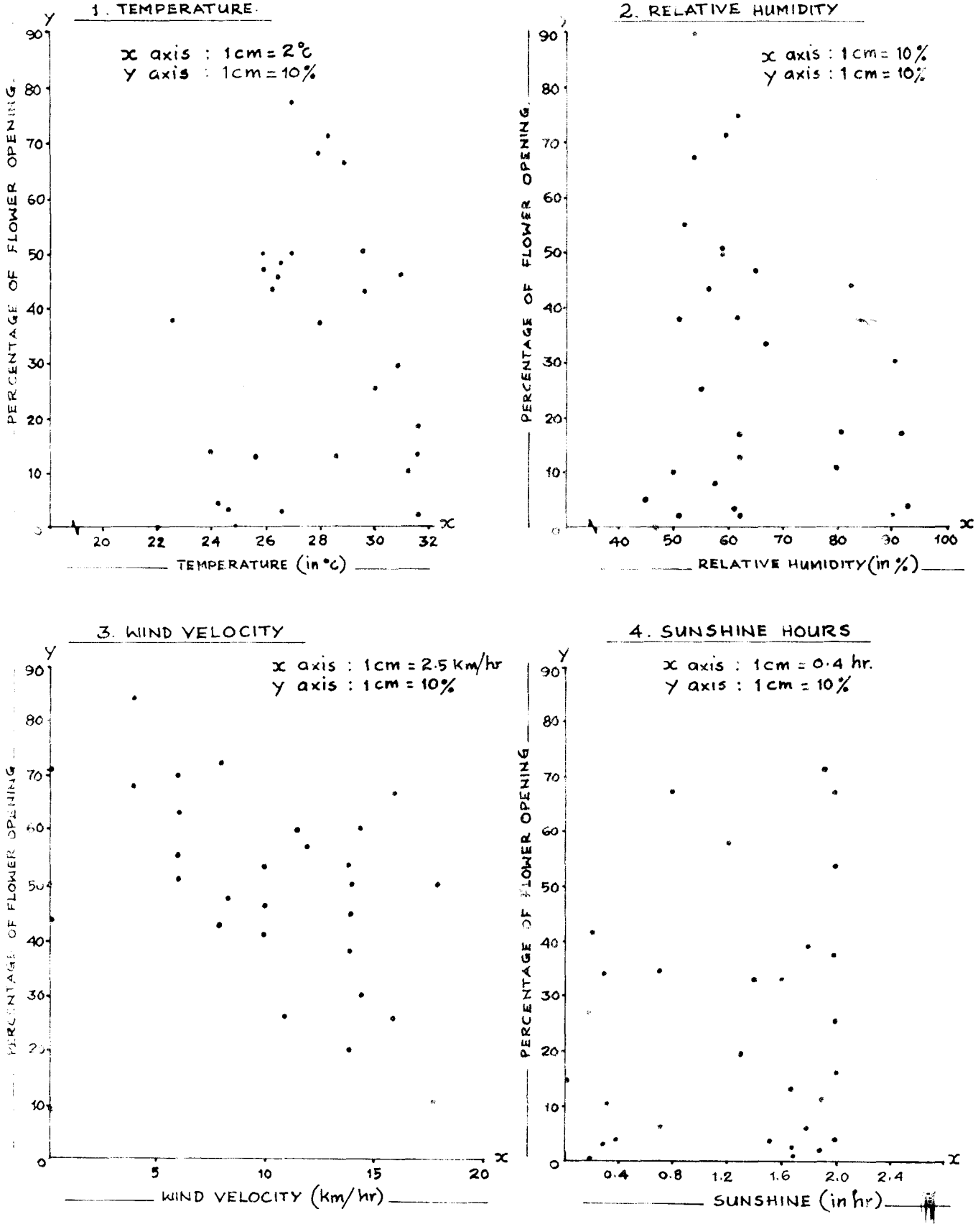


Fig-2b. INFLUENCE OF CLIMATIC FACTORS ON HERMAPHRODITE FLOWER OPENING



Damodaran et al., (1966) and Raju (1979). This may perhaps be due to the abnormal weather conditions prevalent during the cashew flowing season of 1983-84.

From the foregoing discussions it has become evident that cashew possesses the pre-requisites for higher yields such as presence of large number of hermaphrodite flowers, sufficient quantity of fertile pollen, synchronised male and female phases etc. However the fact remains that inspite of presence of all the above factors the yield is low. The reasons for this is to be sought elsewhere.

Cashew being a cross pollinated crop, pollination has to be effected through agents like water, wind, insects etc. Complete absence of fruit set in cashew where the panicles are covered by pollen proof bags throughout the flowering phase (Plate III(1)) fully justifies the cross pollinated nature of the crop for which pollinating agents are, no doubt, essential. Water as a pollinating agent does not seem to have much importance in this crop in so far as practically no fruit set is seen to have occurred in panicles sprayed with water at the time of flower opening (Plate III(4)). Wind has brought a fruit set percentage of 7.79 as against 11.89 per cent under natural pollination (Plates III (3), III(2)). This is indicative of the fact that other than wind, cashew has other

Plate III(1) Completely bagged panicle (Original length of the panicle = 16cm)

Plate III(2) Naturally pollinated panicle (Original length of the panicle = 15.5cm)

Plate III(3) Wind pollinated panicle (Original length of the panicle = 14cm)

Plate III(4) Water sprayed panicle (Original length of the panicle = 12.5cm)

pollinating agents, possibly insects. It has been observed in the present study that insects like black ants, red ants, honey bees and butterflies are frequently visiting cashew flowers. These observations are in agreement with previous reports of Rao and Hassan (1957); Northwood (1966 a); Bhattee (1979) and Rai (1979). The role of these insects as pollinating agents in cashew needs further detailed investigation.

In cashew, the flower structure is conducive for cross pollination, since the developed stamen of the hermaphrodite flower has only a short filament which is only half the length of the style. As stated earlier wind and insects like black and red ants, honey bees, butterflies etc. appear to be chief agencies for pollinating cashew flower. In about 5 to 7 days after pollination the ovary swells up which is an indication that fertilization has already taken place in the flower. In about 15 to 20 days after pollination the ovary attains the size of a pea which is called 'pea nut' stage. In about 50 to 55 days after fertilization, the fruits reach maturity stage and are ready for harvest.

It has been reported by previous workers that assisted pollination improves fruit set considerably in cashew. This has been supported by the findings of present investigations (Plates IV (1), IV (2)) in which assisted pollination by hand has recorded 66.50 per cent

Plate IV (1) Hand pollinated panicle (Original length of the panicle = 17cm)

Plate IV (2) Naturally pollinated panicle (Original length of the panicle = 15.5cm)

of initial fruit set as against 11.89 per cent under naturally pollinated conditions. This vast difference indicates the ineffective functioning of pollinating agents at the proper time. However, this has to be further confirmed by detailed investigations.

A high percentage of initial fruit set need not necessarily end in increased yield. It is quite possible that varying proportions of fruits may drop off from the tree at any time during the developmental stage from fruit set to maturity. In the present study, fertilization as judged by the initial swelling of the ovary is seen to have occurred in 11.89 per cent of the total hermaphrodite flowers in a panicle under natural pollination and 66.50 per cent under assisted pollination. However, only 7.29 per cent under natural pollination and 28.04 per cent under assisted pollination, of the total hermaphrodite flowers are seen to have reached upto 'pea nut' stage and only 5.19 under natural pollination and 19.98 under assisted pollination upto maturity stage (Fig. 3). A considerable proportion of fruits is seen to have been dropped off at various stages of development (Fig. 4). Out of every 100 hermaphrodite flowers produced in cashew panicle, 88 drop off as unfertilized flowers, five between fertilization and 'pea nut', two between 'pea nut' and maturity, leaving only five for harvest. This is

Fig.3. FRUIT-SET AT DIFFERENT STAGES OF NUT DEVELOPMENT IN CASHEW

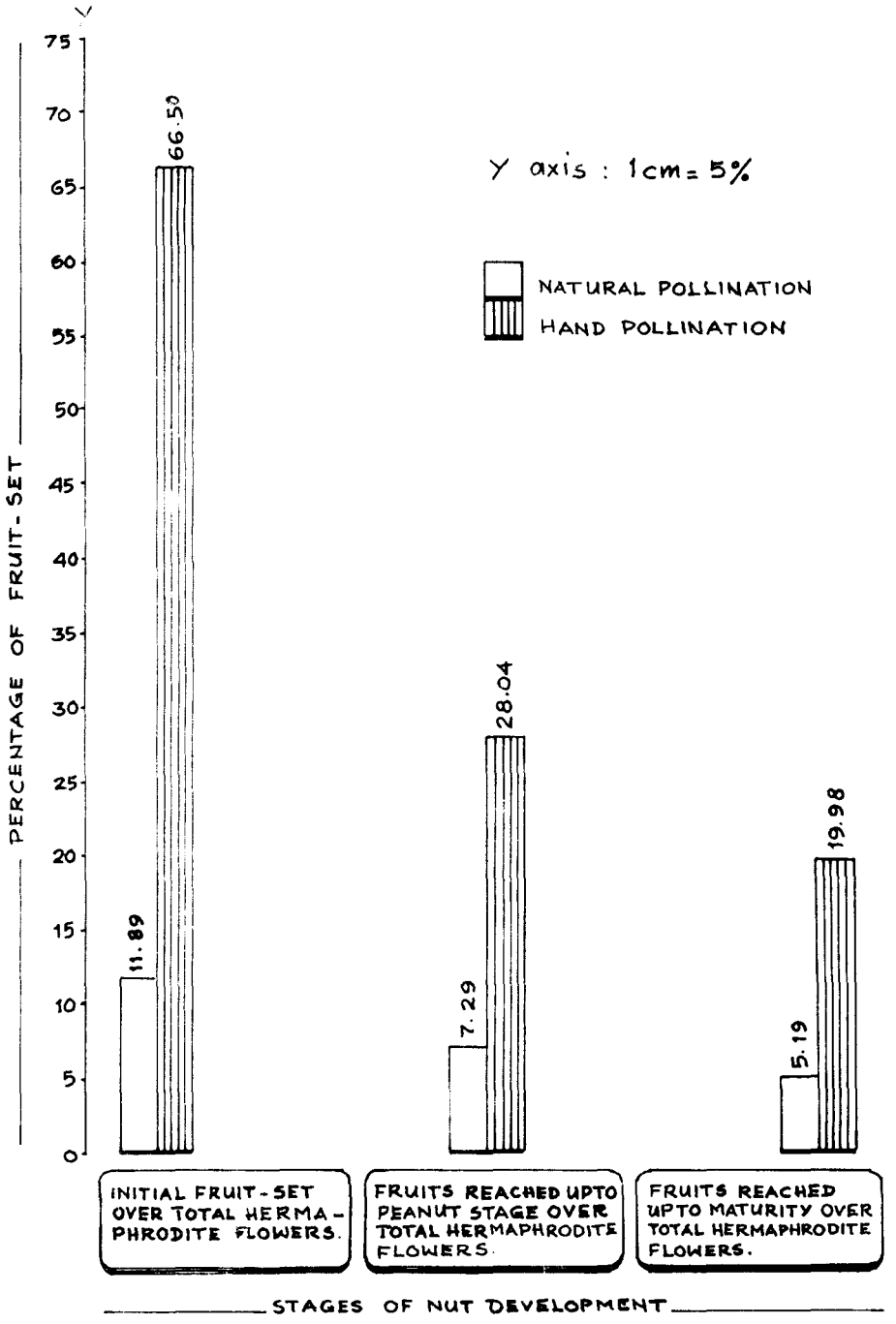
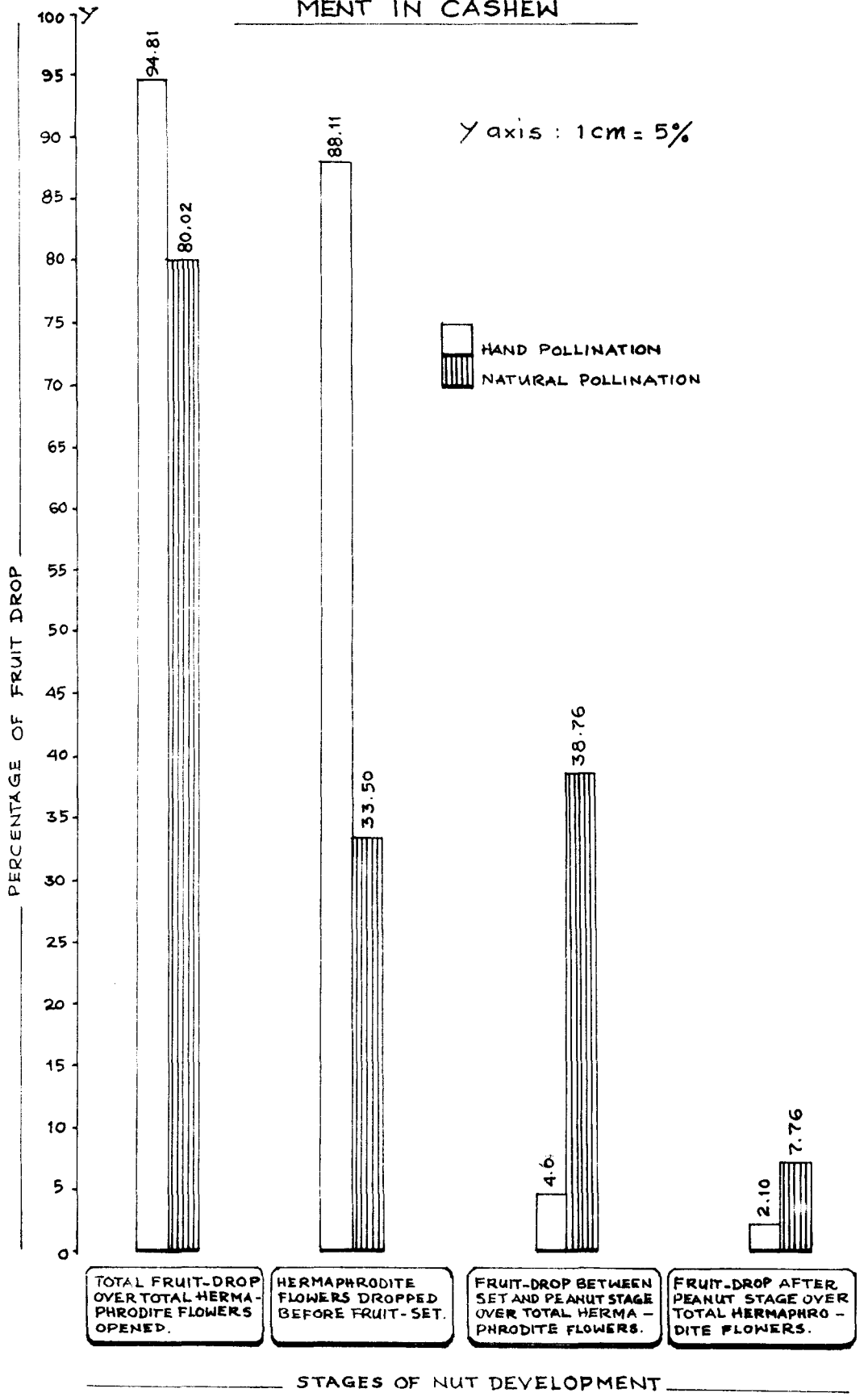


Fig-4. FRUIT-DROP AT DIFFERENT STAGES OF NUT DEVELOPMENT IN CASHEW



These factors may either individually or collectively operate, resulting in large amounts of flowers and fruits to drop, thereby reducing the final yield in cashew. It may be quite possible that genetic constitution of the tree is also involved in this. Each tree may have a total bearing capacity of fruits and this may be decided by the genotype of the tree. Any fruit in excess of this capacity is naturally dropped off by the tree.

Based on the present investigations the following corrective steps are suggested, which, it is hoped, will go a long way in the improvement of yield in cashew.

1. Lack of effective pollinating agents at the proper time appears to be one of the possible reasons for low yield. For this, establishment of bee hives in cashew plantations will be helpful.
2. Early flower and fruit drops have to be prevented. For this, suitable hormonal/growth regulator application will have to be found out, for which investigations in this line will have to be resorted to.
3. Any possible nutritional imbalance will have to be corrected at the appropriate time.
4. Timely control measures have to be resorted to against pest and diseases.
5. Above all, use of genetically superior planting material is very vital.

perhaps one of the vital points for the low yield of cashew. It is interesting to note that out of 11.89 and 66.50 percentages of initial fruit set under natural pollination and assisted pollination, only 42.47 and 30.13 percentages respectively are seen to have reached upto maturity stage. This indicates that post-fertilization drop is more in the case of hand pollination. In other words, even though a high initial fruit set of 66.50 per cent has been obtained in hand pollination, only 19.98 percentage of hermaphrodite flowers has reached upto maturity. Further, comparison of fruit drop at different stages of nut development reveals that most of the fruits drop off in the early stages of development, both in natural and hand pollination. These facts suggest that competitions for nutrients among rapidly growing young fruits and low content of endogenous auxins in the early stages of nut development may account for the premature fruit drop, especially in the early stages. This is in agreement with the reports of Leopold and Kriedeman (1964) and Parameswaran (1979). Besides these factors, defective metabolism and nutritional imbalance (Pillai and Pillai, 1975), pest and disease attack (Pillai and Pillai, 1975) and Parameswaran (1979) and adverse climatic factors are some of the probable reasons for the premature fruit drops in this crop.

These factors may either individually or collectively operate, resulting in large amounts of flowers and fruits to drop, thereby reducing the final yield in cashew. It may be quite possible that genetic constitution of the tree is also involved in this. Each tree may have a total bearing capacity of fruits and this may be decided by the genotype of the tree. Any fruit in excess of this capacity is naturally dropped off by the tree.

Based on the present investigations the following corrective steps are suggested, which, it is hoped, will go a long way in the improvement of yield in cashew.

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3. Any possible nutritional imbalance will have to be corrected at the appropriate time.
4. Timely control measures have to be resorted to against pest and diseases.
5. Above all, use of genetically superior planting material is very vital.

6. Superior, high yielding mother trees will have to be located by conducting regular surveys in the cashew plantations. Progenies of these trees will have to be produced in large numbers preferably through vegetative means. In this process tissue culture technique seems to have tremendous scope.

Summary

SUMMARY

Pollination studies in cashew were undertaken at the Cashew Research Station, Madakkathara and in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period 1983-84. Six year old trees of BLA-139/1 (air layers) which were receiving uniform manurial, cultural and plant protection measures as per the Package of Practices Recommendations of the Kerala Agricultural University, were utilized in the present study. Observations on flower opening, different types of flowers in a panicle, extent of fruit set and fruit drop, role of assisted pollination, influence of different pollinating agents, intensity of cashew pollen in the atmosphere etc. were recorded from the existing, selected trees and the data so collected were subjected to suitable statistical analysis. The important findings are summerised below:

1. Male and hermaphrodite flowers open after 23 hr and continue till 15 hr on the next day. Maximum number of male flowers open between 7 and 9 hr and that of hermaphrodite flowers between 9 and 11 hr. Hence there is overlapping of male and female phases in cashew.

2. Cashew panicle of the type BLA-139/1 has a mean of 286.1 flowers of which 199.8 are male and 86.3 are

hermaphrodite working out to a mean sex-ratio of 1:2.83 of hermaphrodite to male flowers. Hence derth of flowers or sex-ratio cannot be considered as a cause for low yield.

3. Assisted pollination improves initial fruit set considerably. When 11.89 per cent of hermaphrodite flowers set fruits initially under natural conditions, 66.50 per cent of them set fruits under assisted pollination.

4. In the 'pea-nut'stage, 7.29 and 28.04 per cent of hermaphrodite flowers, in the naturally pollinated and hand pollinated panicles respectively, are retained. However, these figures get reduced to 5.19 and 19.98 per cent respectively towards the maturity stage.

5. Taking the initial fruit set as the basis, 59.76 and 41.74 per cent of fruits are retained in the pea-nut stage under naturally pollinated and hand pollinated panicles respectively. The corresponding figures in the maturity stage are 42.47 and 30.13 per cent.

6. Considerable quantity of flowers and fruits drops off at the different stages of maturity both in natural pollination and assisted pollination, especially in the early stages. Of the 94.81 per cent of the total flower/fruit drop in naturally pollinated panicle, 88.11 per cent are before fruit set, 4.61 between set and 'pea-nut' stage and 2.10 between 'pea-nut' and maturity.

In hand pollinated panicles, 33.50 per cent of hermaphrodite flowers drop off before fruit set, 38.76 between set and 'pea-nut' stage and 7.76 after 'pea-nut' stage resulting a total flower/fruit drop of 80.02 per cent. So steps to reduce early flower and fruit drops in cashew will result in higher yields.

7. No fruit is set in completely bagged panicles and hence cross pollinated nature of cashew is further confirmed.

8. In water sprayed panicles also fruits fail to set. Hence water is not a pollinating agent in cashew.

9. Wind pollination results in 7.79 per cent of initial fruit set as against 11.89 under natural pollination which suggest cashew has pollinating agents other than wind.

10. The intensity of pollen in the atmosphere (2.16 fertile pollen grains/square cm) is more or less uniform at different distances and heights from the source.

11. The average number of hermaphrodite flowers per square cm is found to be 0.1.

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Appendix

POLLINATION STUDIES IN CASHEW

By

ELSY, C. R.

ABSTRACT OF THE THESIS

submitted in partial fulfilment of

the requirement for the Degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Agricultural Botany

COLLEGE OF HORTICULTURE

Vellanikara - Trichur

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1985

ABSTRACT

Investigation on the various aspects of pollination viz., flower opening, fruit set and fruit drop under natural pollination and assisted pollination, effect of pollinating agents and intensity of pollen in the atmosphere were undertaken at the Cashew Research Station, Madakkathara and Department of Agricultural Botany, College of Horticulture, Vellanikkara during 1983-84, on six year old BLA-139/1 trees (air layers) under uniform cultural and manurial conditions. The data were subjected to various statistical analyses.

The results have shown that the period of flower opening in both male and hermaphrodite flowers was same, starting after 23 hr and extending upto 15 hr next day. The peak period of flower opening for male flowers was between 7 and 9 hr and for hermaphrodite flowers between 9 and 11 hr. Climatic factors such as temperature, sunshine hours, relative humidity and wind velocity have not shown any significant influence on the magnitude of flower opening.

Type BLA-139/1 has a relatively low sex-ratio of 1:2.83 resulting a higher percentage of hermaphrodite flowers. There is variation in sex-ratio even within the panicles of the same tree.

When compared to natural pollination, assisted pollination resulted in significantly higher initial fruit set indicating the inefficiency or inadequacy of pollinating agents. But the higher initial fruit set was not fully reflected in the percentage of fruits harvested since a major portion of the set fruits dropped at different stages of development. In both cases of natural and hand pollination, fruit drop was more in early stages of nut development. This necessitates the need for improving the initial fruit set and more over reducing post fertilization drop for higher yields in cashew.

In completely bagged panicles no fruit was set, confirming the cross pollinated nature of cashew.

The failure of fruit set in water sprayed panicles rules out the possibility of water as a pollinating agent.

Wind plays a significant role in cashew pollination along with insects like red and black ants, honey bees and butterflies which frequently visit cashew inflorescence.

The intensity of pollen grains on the atmosphere was 20 times higher than that of hermaphrodite flowers in a unit area.