FACTORS AFFECTING YIELD IN CASHEW [*Anacardium occidentale* L.]

BY

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THESIS

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requirements for the degree of

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D E C L A R A T I O N

I, hereby declare that this thesis entitled "Factors affecting yield in oashew (*Anacardium occidentale* L.)" is a bonafide record of research work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
31 December, 1979.

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C E R T I F I C A T E

Certified that this thesis entitled "Factors affecting yield in cashew (*Anacardium occidentale* L.)" is a record of research work done independantly by Sri. M.K. Parameswaran under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

I N T R O D U C T I O N

Cashew (*Anacardium occidentale* L.), a native of tropical belt of Eastern Brazil, was introduced to India in the sixteenth century. It is presumed that cashew was originally introduced to this country, mainly for checking soil erosion. But gradually by virtue of its hardiness and wide adaptability, it established itself as an important commercial crop on the west-coast of peninsular India. The processing of the nut is an important industry, giving employment to over 1½ lakh persons.

Cashewnut is the most popular of the edible nuts and its demand in the world market is on the increase. It is highly nutritious and contains fat (47.0%), protein (21.0%), carbohydrates (22.0%), minerals and vitamins. Cashewnut shell liquid which is a bye-product of the processing industry is an important raw material in paint, chemical and water-proofing industry. Cashew apple, which is practically wasted at present in India (except in Goa) contains about 12 per cent sugar, high amount of Vitamin C (261.5 mg/100 g) and minerals. Studies have shown that it can be utilised for the

production of soft drinks like cashew apple juice, syrup and other products like jams, chutney etc. Alcoholic drinks can also be made out of cashew apple juice.

India is the biggest exporter of cashew kernels in the world market and had the privilege of occupying a monopolistic position in the supply of cashew kernel products till recently. The export of cashewnut and cashew shell liquid fetches over 100 crores of rupees in our export trade.

Cashew is grown over 4.0 lakh hectares in India during 1975-76 with an annual production above 1.7 lakh tonnes of raw nuts (Anon, 1979). Kerala with less than 30 per cent of the area (1,05,940 hectares), accounts for over 70 per cent (1,18,870 metric tonnes) of the total production (Anon, 1979). However the processing industry in the country is dependent on imported raw-nuts for nearly two-thirds of the total requirements. In recent years, it has become more and more difficult to import raw-nuts from other countries because of large mechanical processing plants set up in those countries. Therefore, there is urgent need to increase our raw-nut

production to bridge the gap between the installed processing capacity and the internal production of raw-nuts.

In spite of it's importance in the agricultural, industrial and commercial economy of our country - more particularly of Kerala - little attention is paid by the growers in the culture and management of this crop. Absence of plant protection, inadequate nutrition and above all the poor genetic make-up of the planting material have contributed to the low yields.

Research on cashew, though started nearly three decades back in India, is yet to find solutions for several production problems. There is great variability in the existing population in respect of the different vegetative, floral and fruiting characters, viz., the tree canopy, flowering period, proportion of male and bisexual flowers, percentage of fruit-set, shape and specific gravity of nuts etc.(Anon, 1979). Though some isolated studies on the relationship of some of the above characters and yield have been made in the past, an integrated study to find out the major characters contributing to the yield in cashew have not

been made so far. Present studies were undertaken with the object of identifying the important vegetative as well as flowering and fruiting characters and their relative importance in contributing to the ultimate yield in cashew. These studies will help in fixing the selection criteria based on the above characters and thereby increase the productivity and production of cashew in Kerala State.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Eventhough comprehensive research on the different components contributing to yield in cashew have not been undertaken in India so far, studies on isolated problems which have a bearing on productivity have been carried out in cashew research stations and other institutions. A brief review of the work done so far on these aspects is furnished below.

1. GROWTH FEATURES OF THE TREE AND THEIR RELATIONSHIP WITH YIELD

Galang and Lasa (1936) studied the growth processes of cashew trees of varying ages from 10 to 30 years. They observed that the bearing twigs and floral flushes, either terminal or lateral in the different cardinal directions were longer, more stocky and had a greater total mean leaf area than the corresponding non-bearing parts.

Dasarathi (1958) reported two types of branching in cashew, intensive and extensive. The intensive shoots grew to a length of about 25 to 30 cm and terminated in a panicle. Simultaneously, three to eight laterals arose within 10 - 15 cm of the apex of

the twig. Some of these lateral shoots also terminated in panicles in the same flowering season, repeating the same growth pattern, giving a well-covered bushy appearance to the tree. In the extensive type, the shoot grew to a length of 20 - 30 cm and then remained dormant. A bud sprouting 5 - 8 cm below the apex led to further growth. High yielding trees had more than 60 per cent intensive branches whereas low yielders had less than 10 per cent. Seventy five per cent of the shoots of the intensive types produced flowers as against 12 per cent in extensive types.

Damodaran et al.,(1965) reported that inflorescences in cashew were produced terminally on shoots arising from terminal or lateral fruit buds of mixed types on past season growth. Fruit buds were borne on shoots either terminally or laterally both vegetative and floral parts emerging from the same bud, resulting in mixed panicles. The initial growth that emerged from the growing bud gave rise to normal vegetative leaves, which become smaller and smaller as the extension growth developed into floral panicle.

Argles (1969) reported two or three periods of

growth in a bearing cashew tree, although under favourable conditions stray shoot growth occured almost every month. The pattern of growth of a bearing tree consisted of a generative flower flush and a vegetative flush. The vegetative flush consisted of lateral shoots which developed soon after the main crop had matured. Flowering was terminal and was universally preceeded by the vegetative flush.

Morton (1970) reported that cashew trees exhibiting sprawly growth produced only a tangled mass of base and dead shoots and maximum flowering was seen in trees with erect growing habit.

Chakravarthy et al.,(1972) reported that in cashew, vegetative shoots which appeared in April - May developed panicles in about 92 per cent cases during the next flowering season, while those produced in December - January produced flowers in about 10 per cent shoots only in the same year.

Murthy et al.,(1979) investigated the flowering behaviour and fruit-set in cashew trees by taking ten units of 30 cm square area per tree at different heights

and sides of the tree. Fifteen healthy bearing trees of almost same age group (10 x 15 = 150 units) were studied. Observations per unit area on number of male flowers (1766.04), number of bisexual flowers (61.99), number of fruits set (1.40), percentage of bisexual flowers (4.12), percentage of fruit-set to bisexual flowers (4.57) and number of panicles (flowering shoots) (4.55) were made. They had reported that there was significant correlation between number of panicles and bisexual flowers and between number of bisexual flowers and number of fruits set.

Several studies have been undertaken on the relationship between vegetative characters and yield in related crops like mango.

Khan (1960) found that fruit bearing in mango was closely related to the tree-growth.

Oppenheimer (1960) observed a significant relationship between the tree size and yield in Hadam and Pairi varieties of mango.

Krishnamurthi et al., (1961) reporting on the growth studies in mango have found that there was no

relationship between extension growth, number of nodes, internodal length and flowering in mango. They have also found that leaf area per shoot, leaf size and leaf area per unit length were higher in the flowering shoots as compared to the vegetative shoots.

Teotia et al.,(1970) have reported that there is a significant relationship between the tree spread and yield in mango Var:Dasheri.

2. FLOWERING AND FRUITING CHARACTERS AS RELATED TO YIELD

The main flowering and fruiting characters which have a bearing on yield are the flowering season, pattern of flower opening, sex-ratio, factors affecting pollination, fruit-set, fruit-drop and nut characters.

2.1 Season of flowering

Popenoe (1924) reported August - September as the peak flowering period in Brazil. In Mozambique it was in October and in the Philippines it was in March (Galang and Laso, 1936). Rao (1956) observed that at Anakkayam and Mangalore on the west-coast, peak flowering was in early April. Aiyadurai and Koyama (1957) reported

that in the west-coast of India, flowering in cashew commenced generally in November which extended upto March in individual trees. At Bapatla on the east-coast, peak flowering time was from mid January to mid February (Dasarathi, 1958). Damodaran et al.,(1965) observed that under the climatic conditions of Kottarakkara (Kerala), flower bud emergence in cashew commenced by the middle of September and continued till the end of February the main season being October - November.

Agnoloni and Giulioni (1977) reported that in El Salvador in Central America the flowering period was from December to March with a peak in January - February and in Malagmasy,, the peak period was in March - April. In West Africa also the flowering period was from December to March with a peak period in January - February. In Kenya, there were two flowering periods, one from September to November and the second from December to January.

Dasarathi (1958) reported a striking influence of temperature on growth, flowering and fruiting in cashew. Nambiar (1977) observed that the variation in

the flowering season in cashew in different countries was related to altitude.

2.2 Pattern of flower opening

Many workers observed that in cashew the flowers produced early in a panicle were mostly male (Morada, 1941; Aiyadurai and Koyama, 1957; Rao and Hassan, 1957; Damodaran et al., 1965.).

Pavithran and Ravindranathan (1974) observed three distinct phases in the flower opening in cashew panicles.

i. The first male phase with 19 to 100 per cent male flowers; ii. the mixed phase with nil to 60 per cent male flowers and nil to 20 per cent hermaphrodite flowers and iii. the second male phase with nil to 6.7 per cent male flowers. The trees showed considerable variation in the duration of different phases. The mean duration of flowering was recorded as 85.2 days in which the duration of first male phase was 2.4 days, mixed phase 69.4 days and second male phase 13 days.

2.3 Sex-ratio

Sex-ratio has been reported as an important factor

controlling yield in cashew. Morada (1941) has reported that 90 - 99 per cent of the flowers in a paniole were staminate, while Rao and Hassan (1957) observed the percentage of staminate flowers to be 96. Bigger (1960) noted that the ratio of staminate to perfect flowers was 6 : 1 and only 10.2 per cent of the perfect flowers produced mature fruits. Damodaran et al.,(1965) reported that the proportion of perfect flowers varied from as low as 0.45 per cent to 24.9 per cent in different trees. They had also observed a weak positive correlation between the number of hermaphrodite flowers and yield of cashew trees. Rao (1974) found a positive correlation between yield and percentage of hermaphrodite flowers in cashew and attributed the high percentage of male flowers as one of the reasons for poor yield in many trees.

Naik and Mohan Rao (1943) reported a high positive relationship between the percentage of perfect flowers and the number of fruits carried to maturity in mango. Singh (1954) reported a positive correlation between the percentage of hermaphrodite flowers and the fruit-set in mango. Similar relationship was reported by Singh (1962) and Singh (1964).

2.4 Factors affecting pollination

2.4.1 Extent of pollination under natural conditions

Studies on pollination have indicated that high proportion of perfect flowers do not get pollinated under natural conditions and that it was one of the major reasons for poor fruit-set in cashew. Damodaran et al., (1966) observed that only 13 - 17 per cent of the perfect flowers set fruits out of which only 6.4 per cent were carried to maturity. Eventhough precise information about the cause for the drop of the vast majority of perfect flowers was not known it was presumed that, a majority of drop prior to mustard stage may be due to lack of pollination. This is based on the high proportion of fruit-set obtained by hand pollination.

Northwood (1966) observed that there was no fruit-set when inflorescences were bagged. Rao (1974) suggested that pollination in nature was inadequate since he obtained 55 per cent fruit-set by hand pollination whereas Kumaran et al., (1976 a) obtained 61.3 per cent fruit-set by artificial cross-pollination.

2.4.2 Period of receptivity

Rao and Hassan (1957) reported that the flowers of cashew opened between 9 A.M. and 2 P.M. and that the staminate flowers opened earlier than the bisexual flowers. According to Aiyadurai and Koyamu (1957), the male flowers opened between 9 and 11 A.M. while bisexual flowers opened between 2 and 4 P.M. Rao and Hassan (1957) observed that the stigma remained receptive only on the day of anthesis. Damodarn et al., (1966) reported that stigma was receptive even the day before opening and continued to be so for about forty eight hours after anthesis at least in some flowers. According to Northwood (1966) most of the flowers opened between 11 A.M. and 12.30 P.M. The stigma was receptive as soon as the flowers opened.

2.4.3 Assisted pollination

Artificial pollination with the object of increasing the set of fruits was carried out in several other economic crops and methods have been described by several workers.

Wixon (1951) and Alexander (1952) have described

the methods of assisted pollination adopted in dates (*Phoenix dactylifera*). The method described by the former consisted of either keeping male strands in between female flower clusters, or a more economic method in dusting dry pollen on cotton and placing the cotton so dusted in between the strands of female flowers. The latter described the pollination as being done with a blow pollinator by which dry pollen is blown from ground level on to the female flowers. Purvis (1953) reported that artificial pollination of the oil palm was carried out on large scale in Nigeria, Malaya, Indonesia, Belgian Congo and French Africa and obtained high yields. He described such a pollination which was done in an unprotected bunch as a means of aiding natural pollination as "assisted pollination". Liyanage (1954) has explained the method of controlled pollination in coconut palms as carried out in Ceylon by means of a blower in which the pollen grains were collected and blown on to the female flowers. Ochse *et al.*, (1961) in reviewing the methods of pollination as adopted in oil palms reported that pollination was done by dusting the pollen by means of

an atomiser or brush on the stigmatic surface. Shama Bhat (1965) reported a method of supplementing natural pollination in arecanut by spraying pollen grains held in suspension in an aqueous solution of sucrose. Roberts (1956) reported that sugar sprays during flowering encouraged pollination by attracting honey bees in plums.

Rao and Hassan (1957) reported increased fruit-set in cashew by spraying the trees in bloom with water at intervals of six days. Smith (1958) suggested that in cashew, bees may be used to promote greater pollination. The occurence of strong scented flowers and sticky pollen grains of cashew emphasised the importance of insects over wind as pollinating agents. In a study conducted to find out the role of honey bees in the pollination of cashew it was found that the open panicles 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 nets (Anon, 1978).

2.5 Fruit-set

Damodaran *et al.*, (1966) reported that fruit-setting in cashew became evident after about seven days

of pollination as indicated by the swollen ovary being visible above the corolla cup. Large number of flowers dropped before the 'pea' stage. This was attributed to lack of pollination or natural drop. Shedding was also found to occur during the various stages of development. Northwood (1966) reported that the production of hermaphrodite flowers and the efficiency of pollination were generally sufficient to secure optimum yields. He also observed that when the inflorescences were bagged they failed to produce nuts in the absence of hand pollination.

2.6 Fruit-drop

Damodaran et al., (1966) reported that only four to six per cent of the hermaphrodite flowers were carried to maturity, the remaining flowers being shed before or after fertilisation. Those fruits which were shed did so at various stages of development. They found that the number of fruit-set per panicle was slightly higher in the case of a tree with higher sex-ratio as compared to the tree with low sex-ratio. However the difference was not fully reflected in the ultimate number of fruits per panicle carried to maturity.

The intensity of drop was heaviest before the fruits attained a length of 5 mm. Northwood (1966) attributed fruit-drop in cashew during the early stages of development to physiological reasons. Dasarathi (1971) reported 55 per cent fruit-drop at the 'mustard' stage and 22 per cent at the 'peanut' stage. Pillai and Pillai (1975) reported maximum shedding (more than 40 per cent) at 'mustard' stage, 20 per cent at 'peanut' stage and 20 per cent at later stages. They further observed that insect attack also played an important role in immature fruit-drop, apart from physiological causes.

Naik and Rao (1943) reported that the first two weeks after fruit-set to be the most important period from the point of view of fruit shedding in mango. Singh (1960) studied the extent of fruit drop in mango varieties - Dasheri and Langra. Fruit-drop per panicle varied from 95.49 to 97.6 per cent and 98.1 to 99.08 in the two varieties respectively. Fruit shedding was heavy during the first three weeks of fruit-set and continued upto the 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 occuring in the first three weeks after fruit-set. Rey et al.,(1963) suggested that there was strong varietal difference in relation to fruit-drop in mango.

Chadha and Singh (1964 a) reported that 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 length and breadth. Chadha and Singh (1964 b) observed that the heaviest crop losses were caused by the May drop and only solitary fruits fell afterwards. There was little difference in the rate of fruit drop between 10 and 20 year old trees. The drop during day hours was nearly double that during night hours.

2.7 Nut characters

Considerable variation in nut size and weight was observed by Northwood (1966) in a population of 128 three-year old trees. He also observed that trees

which produced a large number of nuts had small nuts unsuitable for cashew trade. Anon (1966) observed that heavy yielding trees were more likely to bear medium sized nuts (120 - 130 nuts/kg) and hence medium sized nuts should be preferred in selection.

MATERIALS AND METHODS

MATERIALS AND METHODS

These studies were carried out on five year old cashew trees planted in 1973 at the main campus of the Kerala Agricultural University. All the trees included in the studies were receiving uniform manurial and cultural treatments, besides the plant protection measures to control the major pests and diseases of the crop. The weather and seasonal conditions were more or less normal during the period of study from November 1978 to April 1979.

Representative samples were taken for different studies. The following investigations were carried out, adopting the procedures indicated against the different items.

The main factors which contributed to the yield in cashew may be grouped under two categories namely (1) Vegetative characters (2) Flowering and fruiting characters.

The main vegetative characters contributing to the yield are:

1.1 The proportion of flowered and non-flowered shoots in a unit area of the tree canopy and

1.2 Growth parameters of the tree represented by height and spread.

Under flowering and fruiting characters, the main factors contributing to yield are:

2.1 Pattern of flower opening.

2.2 The proportion of bisexual flowers.

2.3 Factors affecting pollination.

2.4 Percentage of fruit-set.

2.5 Percentage of fruit-drop.

2.6 Mean weight of nuts harvested.

1. VEGETATIVE CHARACTERS CONTRIBUTING TO YIELD

1.1 <u>Proportion of flowered and non-flowered shoots in unit area of the tree canopy</u>

Twenty trees were selected before flower-bud emergence and on each of these trees, four samples of half metre square were marked on four sides of the tree, using a wooden frame. All the shoots in the marked area were tagged. After flower-bud emergence,

the number of flowered and non-flowered shoots were counted and recorded. The proportion of these were worked out. The total number and weight of nuts harvested from each sample, as also from the whole tree were recorded.

2.2 Growth parameters of the tree and their relationship to yield

Height and spread of the individual trees were measured. Spread of the tree was calculated by the formula Πr^2 where 'r' is the radius of the crown of the tree. Radius of the crown was found out by measuring the maximum spread in north-south and east-west direction and by working out the means.

The linear regression lines of yield (Y), on percentage of flowered shoots per unit area of tree canopy (X_1), tree spread (X_2) and height (X_3), were calculated. The linear correlation coefficients (r) of yield with the above three vegetative characters were calculated separately. The significance of these correlation coefficients were tested with the help of Statistical Tables (Fisher and Yates, 1963).

To assess the relative contributions of X_1, X_2

and X_5 on Y, multiple regression equation was worked out. The partial regression coefficients were tested for significance, using the Student's 't' test as suggested by Snedecor and Cochoran (1967). The standardised partial regression coefficients were calculated to assess the relative contribution of the above characters on yield, independent of the units of measurement. Goodness of multiple regression equations were tested by 'F' test.

2. FLOWERING AND FRUITING CHARACTERS CONTRIBUTING TO YIELD

2.1 Pattern of flower opening

The total number of male and bisexual flowers which opened during each week from the commencement to completion of flowering were worked out and the pattern of opening of the male and bisexual flowers during the entire flowering period was also worked out. This was done to find out the different phases namely the male phase and mixed phase of flower opening in the trees and their relationship to fruit-set and yield.

2.2 Proportion of bisexual flowers

Ten panicles were selected at random and tagged before the commencement of flower opening on each of the above twenty trees and the number of male and bisexual flowers that opened on each day were recorded. The male flowers were removed after counting in order to avoid congestion of opened flowers as the flowering advanced. The hermaphrodite flowers were retained in order to study the extent of fruit-set, fruit-drop and ultimate number of nuts harvested.

2.3 Factors affecting pollination

2.3.1 Extent of pollination under natural conditions

To estimate the percentage of bisexual flowers getting pollinated under natural conditions, fifteen panicles were tagged at random in each of the seven trees selected. These panicles were grouped into three and the number of bisexual flowers that opened on a single day in each of the groups were recorded. The panicles in the first group were bagged six hours after opening. Bisexual flowers that opened in the second group of panicles were bagged 24 hours after

opening and those opened in the third group of panicles were bagged 48 hours after opening. All the flower buds and opened flowers except those under study were removed before the initial recording of the number of bisexual flowers. Bags were removed after four to five days and the number of bisexual flowers that set fruits in each group were recorded and percentages worked out. Those flowers in which there was no swelling of the ovary within five days after opening were treated as 'not pollinated'.

2.3.2 Effect of hand pollination

Bisexual flowers that opened on each day were hand-pollinated to find out the extent of fruit-set when pollination was ensured. Five panicles were selected in each of the seven trees and the bisexual flowers opened were hand pollinated by brushing the stigmatic surface with mature pollen collected from male flowers. Deposition of the pollen grains on the stigma was confirmed by examining with a field lens. The male and the unopened bisexual flowers were pinched off after the observations were recorded. Another set of five panicles in each tree were kept as control to compare with the former.

2.3.3 Period of receptivity of stigma

Artificial pollination was carried out in a random number of bisexual flowers at different time intervals after opening viz., immediately after opening, three hours, six hours, 24 hours, 48 hours and 72 hours. Number of fruit-set obtained under each stigmatal age group were recorded and the period of receptivity of stigma was worked out.

2.3.4 Assisted pollination

This study was made with the object of finding out whether the fruit-set can be enhanced by better pollination by spraying pollen suspensions or by spraying with different attractant solutions for pollinating by insects.

The experiment was laid out in randomised block design with six treatments and seven replications. The following treatments were tried.

Treatments:-

1. Spray the panicles with jaggery solution (20%).
2. Spray the panicles with sweet toddy (Neera).
3. Spray the panicles with pollen suspension in coconut water.

4. Spray the panicles with cashew apple juice.

5. Spray the panicles with pollen suspension in water.

6. Control - No spray.

Spraying was done with an atomiser on alternate days during a period of one week. Number of fruit-set was recorded. Observations were also made whether the above treatments attracted pollinating insects and if so for how long.

2.4 Fruit-set

To find out the relationship between the extent of fruit-set and yield, observations on these aspects were made on the same trees chosen for the sex-ratio studies. The bisexual flowers on the panicles chosen for sex-ratio studies, which showed definite swelling of the ovary (within five to seven days after opening) were treated as set. The total set was recorded and the percentage was worked out.

2.5 Total fruit-drop and extent of drop at different stages of maturity

Fruits dropped in the immature stages of development on selected panicles for sex-ratio studies were collected

in bags kept in suitable positions of the trees. Total fruit-drop was recorded and the percentage was worked out. These fruits were then grouped into different categories based on size viz., mustard, pea and marble stages and the total drop under the above groups were also worked out.

2.5.1 Causes of immature fruit-drop

To find out the causes of immature fruit drop, such fruits, collected from the selected panicles were carefully examined to see whether there was any visible symptom of injury due to insect attack, incidence of diseases etc. Those which could not be attributed to any of the above causes were treated as due to nutrient deficiency or other physiological causes. Six trees were selected for taking these observations.

2.6 Relationship between yield and mean weight of nuts harvested

The total number and weight of nuts harvested from each of the above twenty trees were recorded. Mean weight of nuts was worked out and the relationship with yield was found out.

The linear regression lines of yield (Y) on the important flowering and fruiting characters viz., percentage of perfect flowers (X_1), percentage of fruit-set (X_2), percentage of fruit-drop (X_3) and mean weight of nuts (X_4) were calculated. The linear correlation coefficients (r) of yield with the above four flowering and fruiting characters were also calculated. The significance of these correlation coefficients were tested.

Relative contributions of X_1, X_2, X_3 and X_4 on Y were assessed by working out a multiple regression equation.

RESULTS

R E S U L T S

The results of the investigations carried out to identify the major factors contributing to the yield in cashew are presented below:

1. RELATIONSHIP BETWEEN VEGETATIVE CHARACTERS OF THE TREE AND YIELD

1.1 Simple correlation analysis

The mean values relating to the yield, the percentage of flowered shoots per $(\frac{1}{4}\ m)^2$ area of the tree canopy, tree spread and tree height are given in Table 1.

The calculated values of correlation coefficients and the regression equations are given in Table 2.

The results indicated significant positive correlation between yield and the percentage of flowered shoots per unit area. Correlation between yield and tree spread was significant (Fig.1) but no statistical relationship could be established between tree height and yield. The regression equation was used to estimate the expected average yield of cashew trees for known values of vegetative characters. The regression equation

Table 1. Yield per tree in relation to vegetative characters

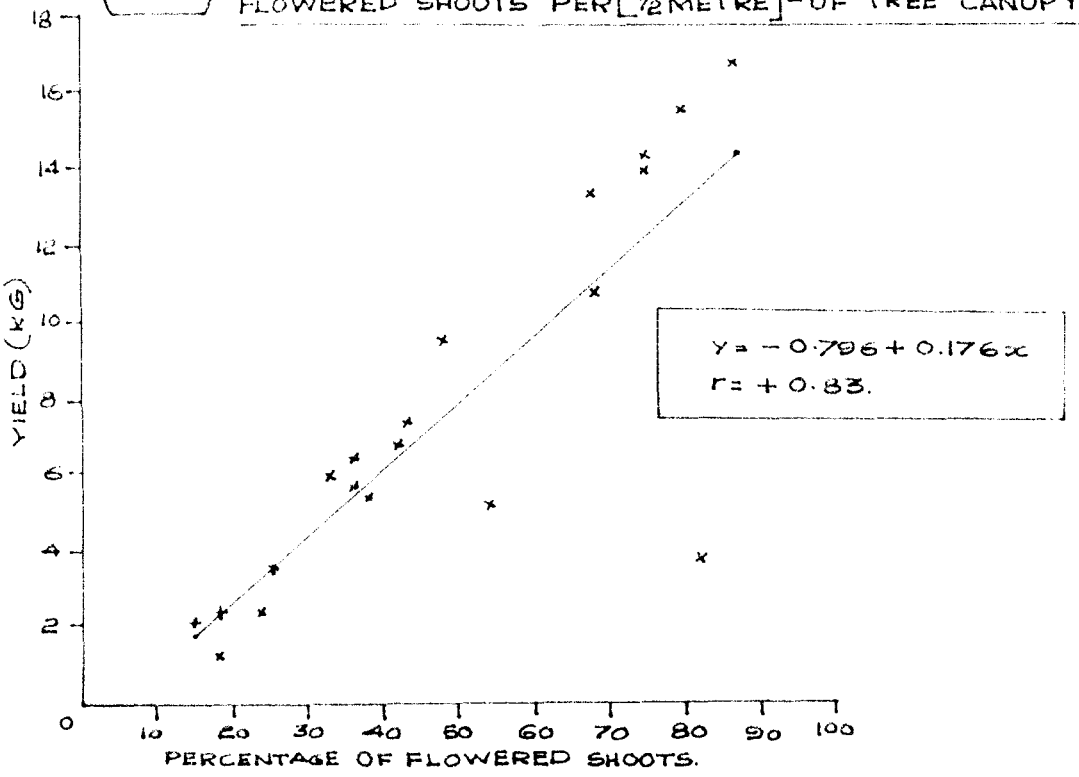
Tree No.	Yield per tree in kg	Mean percentage of flowered shoots per $(\frac{1}{4}\ m)^2$ area of tree canopy	Spread of the tree in sq. m.	Height in metres
1.	6.48	36.36	50.24	5.15
2.	6.042	32.65	68.77	5.85
3.	5.476	38.09	47.52	7.45
4.	2.534	24.32	42.06	5.85
5.	2.194	18.18	35.02	5.05
6.	6.791	41.67	53.04	5.2
7.	14.54	75	63.59	4.85
8.	16.772	86.96	67.31	5.15
9.	14.32	75	73.56	6.35
10.	2.045	14.82	38.25	5.75
11.	9.692	47.83	35.02	5.55
12.	5.566	36.17	47.76	4.5
13.	13.441	66.67	64.72	5.25
14.	15.725	79.55	47.75	5.6
15.	3.565	25.53	52.53	5.55
16.	7.518	43.48	42.76	5.15
17.	10.842	67.57	55.13	5.55
18.	1.213	17.86	44.87	5.55
19.	5.274	54.35	56.72	5.85
20.	3.859	81.48	48.49	5.85

Table 2. Correlation coefficients and regression equations of different vegetative characters with yield

Sl. No.	Characters	Correlation coefficient 'r'	Regression equation ($Y = a + bx$)
1.	Percentage of flowered shoots per ($\frac{1}{4}$ m)^2 area of tree canopy (X_1)	+ 0.83**	$- 0.795 + 0.176X_1$
2.	Tree spread (X_2)	+ 0.6**	$- 6.188 + 0.268X_2$
3.	Height (X_3)	- 0.14	

** Significant at 1 per cent level

FIG-1 RELATIONSHIP BETWEEN YIELD AND PERCENTAGE OF FLOWERED SHOOTS PER [½ METRE]^2 OF TREE CANOPY.



RELATIONSHIP BETWEEN YIELD AND TREE SPREAD.

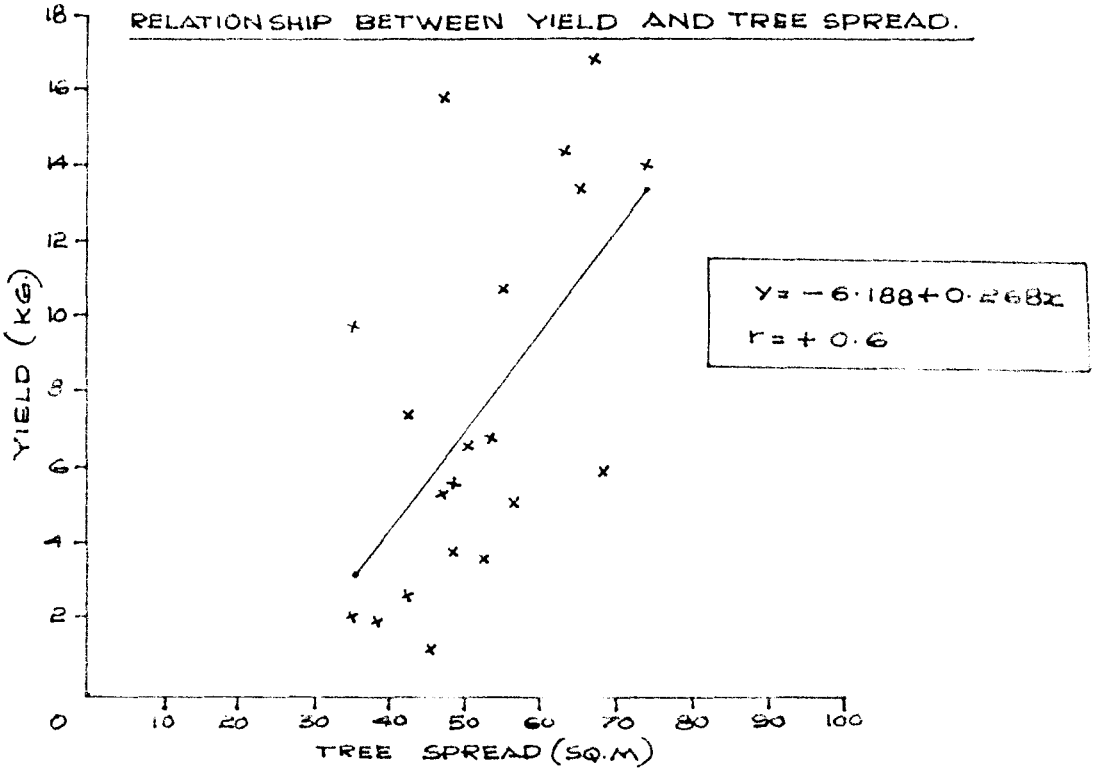
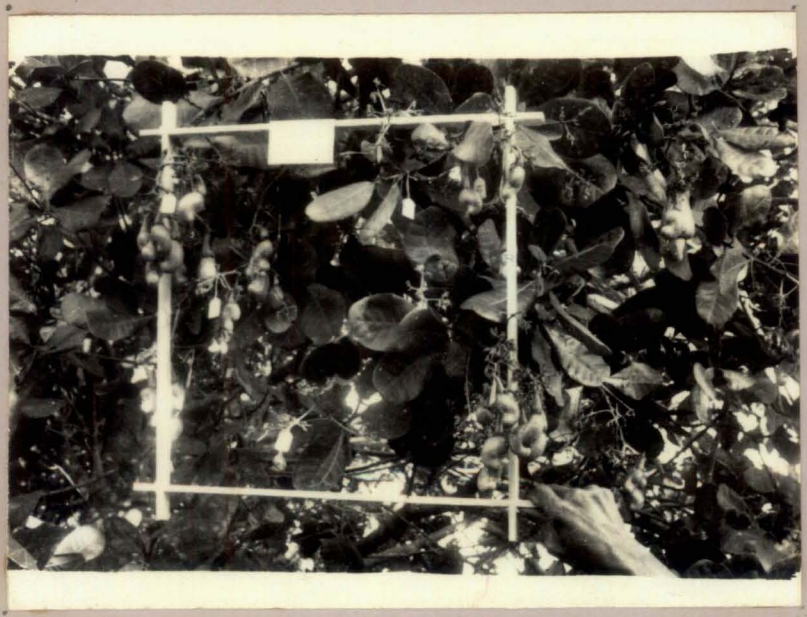


Plate I $(\frac{1}{4}\ m)^2$ canopy area of a high yielding tree.

Plate II $(\frac{1}{4}\ m)^2$ canopy area of a low yielding tree.




Tree No. 1308
Sample No. 4
No of flowered stock - 6
No of non flowered stock - 84

for height is not given as the correlation was not statistically significant.

1.2 Multiple regression analysis

To assess the relative contribution of the three characters mentioned above viz., percentage of flowered shoots per $(\frac{1}{4}\ m)^2$ area of tree canopy, tree spread and height to the yield, multiple regression equation was fitted. The partial regression coefficients were tested for significance. Standardised partial regression coefficients were also worked out to assess the relative importance of the various characters, independent of units of measurement. The results are presented in Table 3.

The partial regression coefficient of percentage of flowered shoots per unit area $(\frac{1}{4}\ m)^2$ on yield was found to be significant. The partial regression coefficients of tree spread and height on yield were not statistically significant. The multiple regression equation of yield on percentage of flowered shoots per unit area $(\frac{1}{4}\ m)^2$ of tree canopy, tree spread and height is $Y = 1.6265 + 0.1514\ X_1 + 0.0892\ X_2 - 1.0524\ X_3$.

Table 3. Multiple regression relationship of vegetative characters with yield

Characters	Partial regression coeffi-cients (bi)	Standardi-sed partial regression coefficients (bi`)	't' value
Percentage of flowered shoots per $(\frac{1}{4}\ m)^2$ area of tree canopy	0.1514	0.717	4.588**
Tree spread (sq.m.)	0.0892	0.201	1.2845
Tree height (m.)	- 1.0524	- 0.131	- 1.0163

** Significant at 1 per cent level

The coefficient of determination was found to be 73.89 per cent. Thus the equation gives a satisfactory fit to the data. Expected tree yield can be predicted from the equation, after substituting for the parametric values.

2. RELATIONSHIP BETWEEN THE FLOWERING AND FRUITING CHARACTERS OF THE TREE AND YIELD

2.1 Pattern of flower opening

In order to find out whether there was any definite pattern in the opening of male and bisexual flowers, the total flowering period of selected panicles on the twenty trees were categorised as first male phase, followed by a mixed phase and the second male phase. The duration of these phases varied from tree to tree and the twenty trees included in the study were grouped into two on the basis of yield - those below the median yield and those above it. The data are presented in Tables 4 and 5.

It may be seen from the data presented that there was considerable variation among the trees in the pattern of flower opening. While there was distinct male phases (I and II) and mixed phases in some trees above the median

Table 4. Pattern of flower opening as related to yield

Trees yielding above median						Trees yielding below median					
		Mean duration of flowering (days)	Mean duration of different phases (days)					Mean duration of flowering (days)	Mean duration of different phases (days)		
Tree No.	Yield (kg)		I Male phase	Mixed phase	II Male phase	Tree No.	Yield (kg)		I Male phase	Mixed phase	II Male phase
1.	16.772	87.7	4.6	73.9	9.2	1.	6.042	88.8	12.3	57.5	19
2.	15.725	51.8	0	37.7	14.1	2.	5.566	71.4	3	66.7	1.7
3.	14.54	75.9	0	75.9	0	3.	5.476	116	7	106	3
4.	14.32	72.1	6.2	62.3	3.6	4.	5.274	105.7	22.5	68	15.2
5.	13.441	53.6	6	45.3	2.3	5.	3.899	109.8	19.2	75	15.6
6.	10.842	101.8	11.8	73.4	16.6	6.	3.565	124.9	18.2	77	29.7
7.	9.692	92.2	6.3	84.5	1.4	7.	2.534	93.6	11.2	73	9.4
8.	7.518	117.2	0	117.2	0	8.	2.194	119.4	8	106.7	4.7
9.	6.791	68.5	3.8	64.7	0	9.	2.045	86.6	20	42.4	24.2
10.	6.48	116	7.2	105.3	3.5	10.	1.213	111.1	12.6	86.5	12
Mean	11.612	83.7	4.6	74.0	5.1	Mean	3.775	102.7	13.4	75.9	13.4

Table 5. Mean duration of male phase and percentage of male phase over total duration of flowering for trees above and below the median yield

	Above median group	Below median group
Male phase (days)	9.65	26.8
Percentage of male phase over total duration of flowering	10.31	26.14

Student's 't' for comparing mean duration of male phase for the two groups = 2.498*

* Significant at 5 per cent level

yield, the first male phase was practically nil in some others of the same group. Two of the trees in this group showed complete absence of the male phases (both I & II) and the entire flowering period was a mixed phase.

The three distinct phases were observed in all the trees below the median yield (Fig.2).

Mean duration of flowering of the trees above the median yield was 83.7 days while it was 102.7 days in the trees below the median yield.

The proportion of male phase over the total duration of flowering was significantly lower in the trees above the median yield than the trees below the median yield.

2.2 Relationship between percentage of bisexual flowers and yield

The mean values relating the yield with the percentage of bisexual flowers are given in Table 6, and the calculated value of correlation coefficient is given in Table 7.

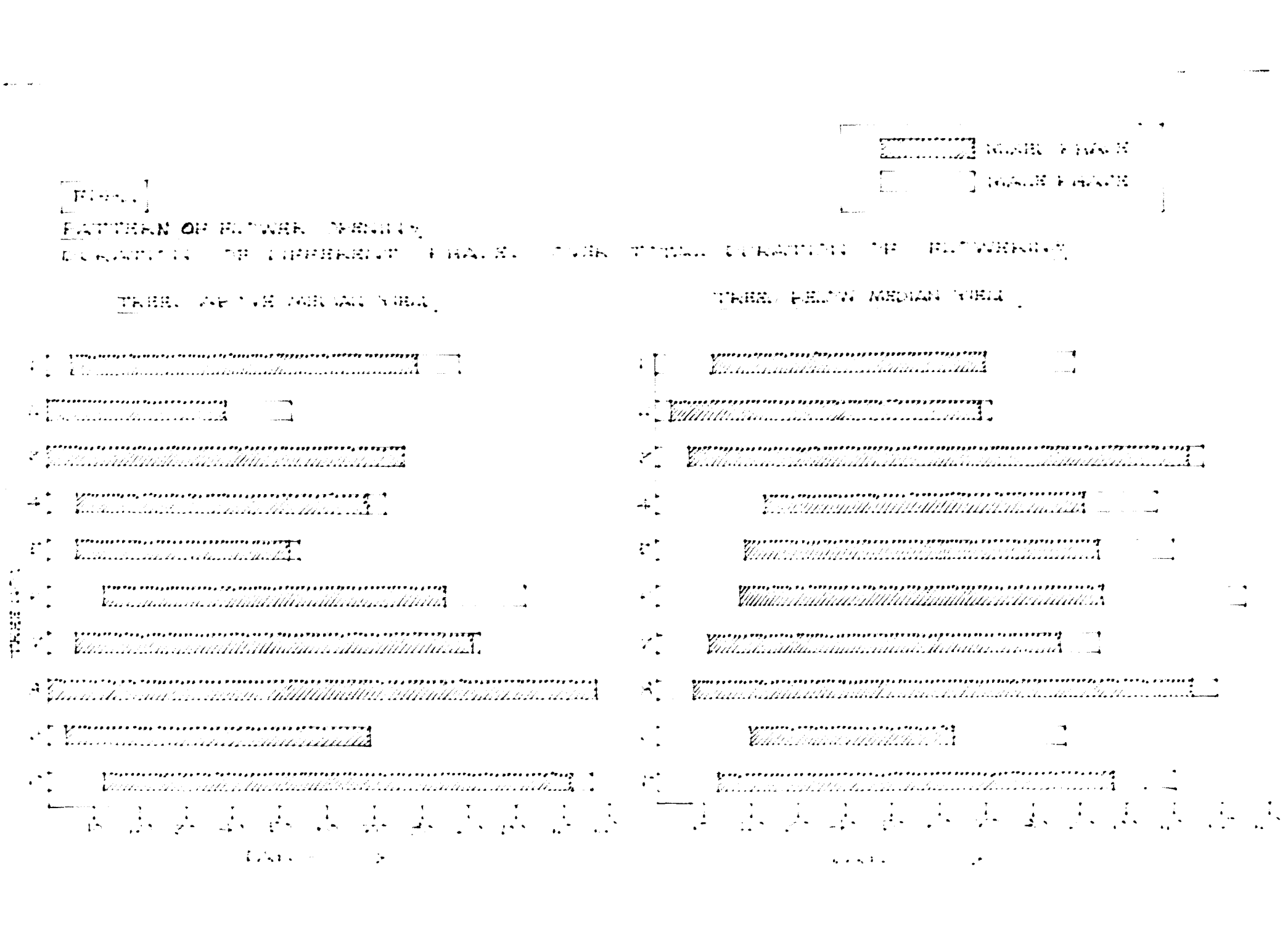


Table 6. Yield per tree in relation to percentage of bisexual flowers

Tree No.	Yield per tree in kg	Percentage of bisexual flowers (Mean)
1.	6.48	5.78
2.	6.042	3.05
3.	5.476	7.79
4.	2.194	13.49
5.	2.534	8.94
6.	6.791	20.15
7.	14.54	17.57
8.	16.772	12.75
9.	14.32	8.87
10.	2.045	3.75
11.	9.692	40.79
12.	5.566	19.71
13.	13.441	21.47
14.	15.725	15.09
15.	3.565	1.31
16.	7.518	6.41
17.	10.842	5.63
18.	1.213	2.49
19.	5.274	1.87
20.	3.839	7.19

Table 7. Correlation coefficient and regression equation of percentage of bisexual flowers with yield

Character	Correlation coefficient 'r'	Regression equation (Y = a + bx)
Percentage of bisexual flowers	+ 0.396*	$Y = 5.371 + 0.207 X_1$

*Significant at 10 per cent level for the two-tailed 't' test

On the assumption that the correlation coefficient of yield with percentage of bisexual flowers would be positive one-tailed 't' test was applied to assess the significance of the character. Results showed significant positive correlation between tree-yield and percentage of bisexual flowers (Fig. 5).

2.3 Factors affecting pollination

2.3.1 Extent of pollination under natural conditions

A number of bisexual flowers opened on a day were examined at different time intervals viz., six hours, 24 hours and 48 hours after opening and the extent of fruit-set under each of the groups were recorded and the data are given in Table 8.

It may be seen from the table that only a small percentage of perfect flowers were pollinated under natural conditions. In the first group, where the flowers were examined six hours after opening, the percentage of fruit-set obtained was only 1.89. But in the second group of flowers examined 24 hours after opening, the percentage of fruit-set was higher ie., 8.55 per cent. In the third group where the flowers

(FIG-3) RELATIONSHIP BETWEEN YIELD AND PERCENTAGE OF BISEXUAL FLOWERS.

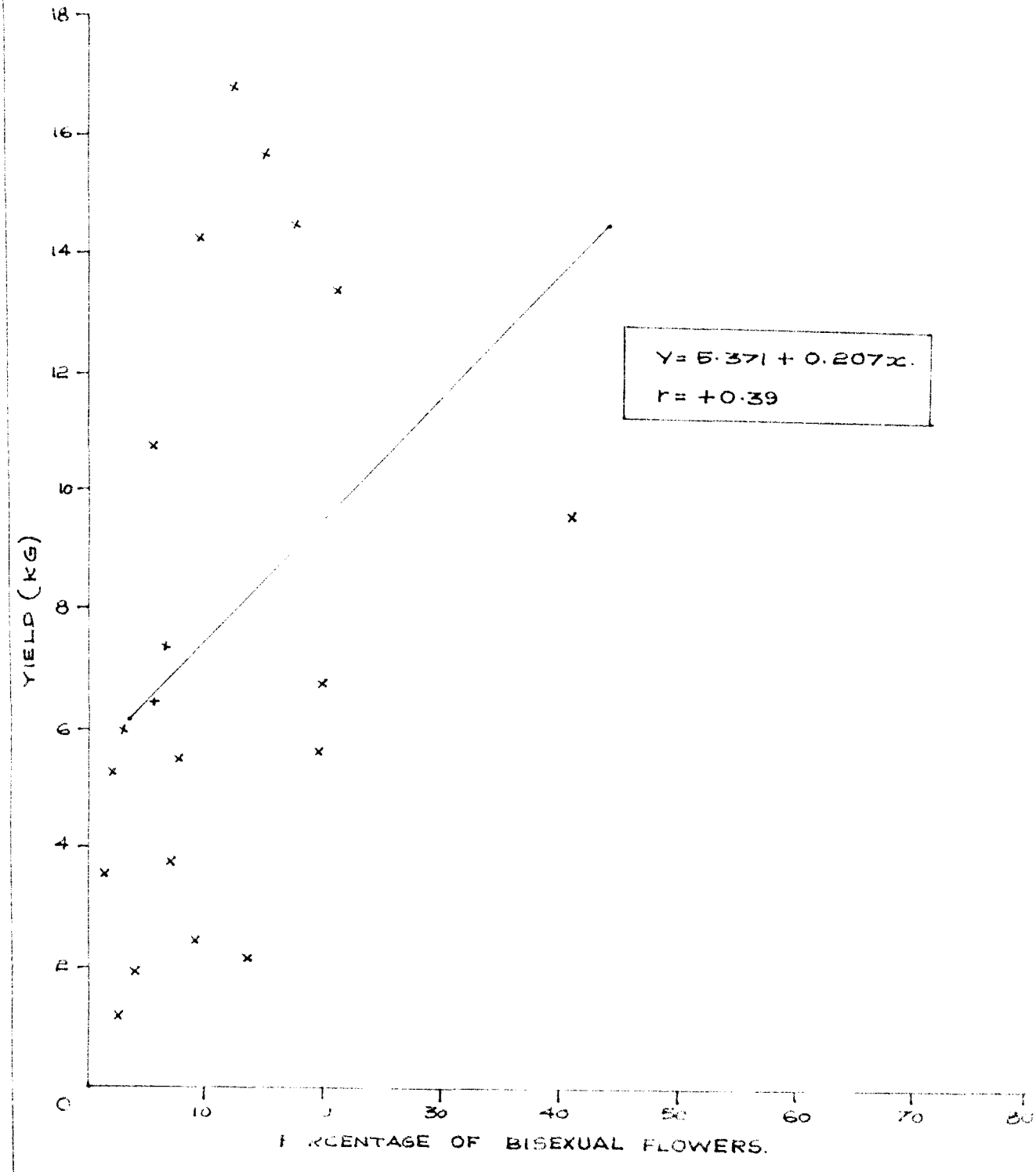


Table 8. Percentage of bisexual flowers getting pollinated in the natural conditions at different intervals after opening

No. of flowers examined six hours after opening	No. of fruits set as seen by swelling of ovary	Percentage of fruit-set	No. of flowers examined 24 hours after opening	No. of fruits set as seen by swelling of ovary	Percentage of fruit-set	No. of flowers examined 48 hours after opening	No. of fruits set as seen by swelling of ovary	Percentage of fruit-set
159	3	1.89	117	10	8.55	181	18	9.95

were examined after 48 hours of opening the percentage of set was slightly higher. It was clear from the above data that a large number of perfect flowers remained unpollinated in nature due to one cause or other.

2.3.2 Effect of hand pollination on fruit-set

In order to find out whether the poor fruit-set in cashew was due to lack of pollination, hand pollination was done on selected panicles and the fruit-set was recorded and the same is presented in Table 9.

It may be seen from the table that when pollination was ensured, there was significant increase in initial fruit-set. The percentage of bisexual flowers carried towards full maturity in hand pollinated inflorescences and the inflorescences which were allowed to get pollinated in the natural conditions is presented in Table 10.

2.3.3 Receptivity of stigma

Perfect flowers were artificially pollinated at different time intervals after opening and were kept under observation for fruit-set. Results obtained is presented in Table 11.

Table 9. Fruit-set obtained in the hand pollinated panicles and in the naturally pollinated panicles

Tree No.	Percentage of fruit-set obtained in the hand pollinated panicles	Percentage of fruit-set in the naturally pollinated panicles	Difference
1.	86.63	5.42	81.21
2.	88.73	19.15	69.58
3.	95.29	17.77	77.52
4.	89.02	17.29	71.73
5.	83.59	7.32	76.27
6.	83.17	5.67	77.5
7.	81.69	17.72	63.97

:: Student's 't' = 23.48**

** Significant at 1 per cent level

(:: 't' test was applied after subjecting the data to angular transformation)

Table 10. Percentage of bisexual flowers carried to full maturity in hand pollinated panicles and in the naturally pollinated panicles

Tree No.	Hand pollinated panicles	Naturally pollinated panicles	Difference
1.	7.45	0.86	6.57
2.	5.39	3.19	2.2
3.	8.12	3.01	5.11
4.	12.17	3.01	9.16
5.	3.15	0.3	2.85
6.	0.72	0	0.72
7.	31.37	8.86	22.51

:: Student's 't' = 4.943**

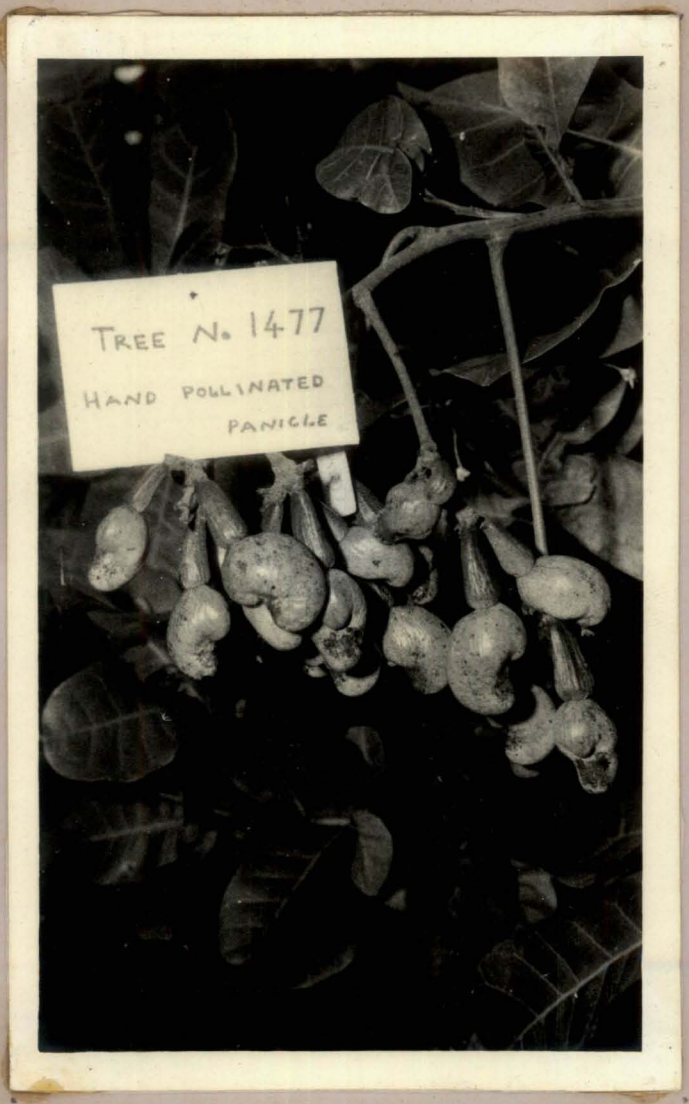
** Significant at 1 per cent level

(:: 't' test was applied after subjecting the data to angular transformation)

Effect of hand pollination on cashew panicles

Plate III Hand pollinated panicle.

Plate IV Naturally pollinated panicle.


TREE No. 1477
HAND POLLINATED
PANICLE


TREE No 1477
NATURALLY POLLINATED
PANICLE

Table 11. Period of receptivity of stigma of ceshew flowers after opening

Stigmatal age group	No.of bisexual flowers pollinated	No. of fruit-set	Receptivity of stigma (%)
At the time of flower opening	92	92	100
Three hours after opening	115	115	100
Six hours after opening	108	102	94.44
24 hours after opening	101	59	58.42
48 hours after opening	75	28	37.33
72 hours after opening	104	0	0

It may be seen that receptivity of the stigma decreased progressively with advance in the age of open flower. Best results were obtained when hand pollination was done within 24 hours of their opening (93 - 100%). But the receptivity was continuing upto 48 hours since the hand pollination resulted in nearly 37.33 per cent fruit-set when made two days after flower opening.

2.3.4 Assisted pollination

Results obtained from the assisted pollination trials conducted by spraying with attractant solutions and pollen suspensions in different media are presented in Tables 12 & 13.

It may be seen from the tables that spray treatments had significant effect on fruit-set. Sprays with neera (T_2), jaggery solution (T_1) and cashew apple juice(T_4) resulted in increased fruit-set. This may be due to the increase in pollination through house-flies and honey-bees which were found to be attracted by these spray solutions.

Table 12. Effect of assisted pollination on fruit-set in cashew

	R_1	R_2	R_3	R_4	R_5	R_6	R_7
T_1	*24.42 (29.6)	17.18 (24.5)	34.61 (36.03)	49.31 (44.6)	28.57 (32.83)	15.47 (23.19)	34.42 (35.91)
T_2	36.98 (37.5)	47.16 (43.39)	41.81 (40.28)	40.47 (39.52)	38.75 (38.53)	45.11 (42.19)	28.08 (32.01)
T_3	43.47 (41.27)	32.96 (35.06)	24.13 (29.4)	33.33 (35.24)	25.92 (30.59)	25.39 (30.26)	44.66 (41.96)
T_4	46.66 (43.11)	46.47 (42.99)	55.12 (47.93)	16.66 (24.12)	16.85 (24.27)	36.43 (37.7)	12.98 (21.13)
T_5	26.92 (31.24)	34.02 (35.67)	53.44 (46.95)	32.36 (34.7)	31.16 (33.96)	41.53 (40.11)	50 (45)
Control	2.5 (9.1)	10.112 (18.53)	11.71 (20)	12.5 (20.7)	13.79 (21.81)	0 (0)	5.13 (13.05)

* Percentage of fruit-set obtained

The figures in the parentheses indicate the angular transformed values

Table 13. Analysis of variance for spray treatments

Source	Sum of squares	Degrees of freedom	Mean squares	'F'
Total	4693.4	41	114.47	
Block	229.29	6	38.21	0.689 NS
Spray treatments	2801.4	5	560.28	10.109**
Error	1662.7	30	55.42	

** Significant at 1 per cent level

NS - Not significant

Increased fruit-set obtained in the other two treatments ie., spray with pollen suspension in coconut water (T_3) and in water (T_5) may be due to the increased pollination effected by these sprays.

2.4 Percentage of fruit-set, fruit-drop and mean weight of nuts harvested as related with tree yield.

The mean values relating the yield with percentage of fruit-set, percentage of fruit-drop and weight of nuts harvested are given in Table 14.

The calculated values of correlation coefficients are given in Table 15.

From the table, it can be seen that there is a significant negative relationship between percentage of fruit-drop and yield (Fig. 4). On the assumption that the correlation coefficient of yield with percentage of fruit-set would be positive one-tailed 't' test was applied to assess the significance of this character. Results showed significant positive relationship between tree yield and percentage of fruit set (Fig.4). Results did not show any significant relationship between yield and mean weight of nuts harvested.

Table 14. Yield per tree in relation to fruiting characters

Tree No.	Yield per tree (kg)	Percentage of fruit-set (Mean)	Percentage of fruit-drop (Mean)	Weight of nuts (g) (Mean)
1.	6.48	14.24	95	7.29
2.	6.042	13.42	100	7.22
3.	5.476	19.69	88.09	6.38
4.	2.194	8.81	94.92	5.44
5.	2.534	34.88	99.39	7.02
6.	6.791	45.63	93.49	3.96
7.	14.54	32.49	94.27	7.93
8.	16.772	30.77	90.13	7.98
9.	14.32	38.9	73.97	7.85
10.	2.045	21.08	99.59	6.09
11.	9.692	28.85	95.14	5.94
12.	5.566	30.85	94.91	8.93
13.	13.441	29.48	89.17	5.65
14.	15.725	31.99	83.92	8.56
15.	3.565	28.74	76	8.42
16.	7.518	25.51	95	6.99
17.	10.842	25.07	77.17	6.81
18.	1.213	30.25	100	5.69
19.	5.274	26.72	91.43	6.44
20.	3.839	20.9	97.73	7.06

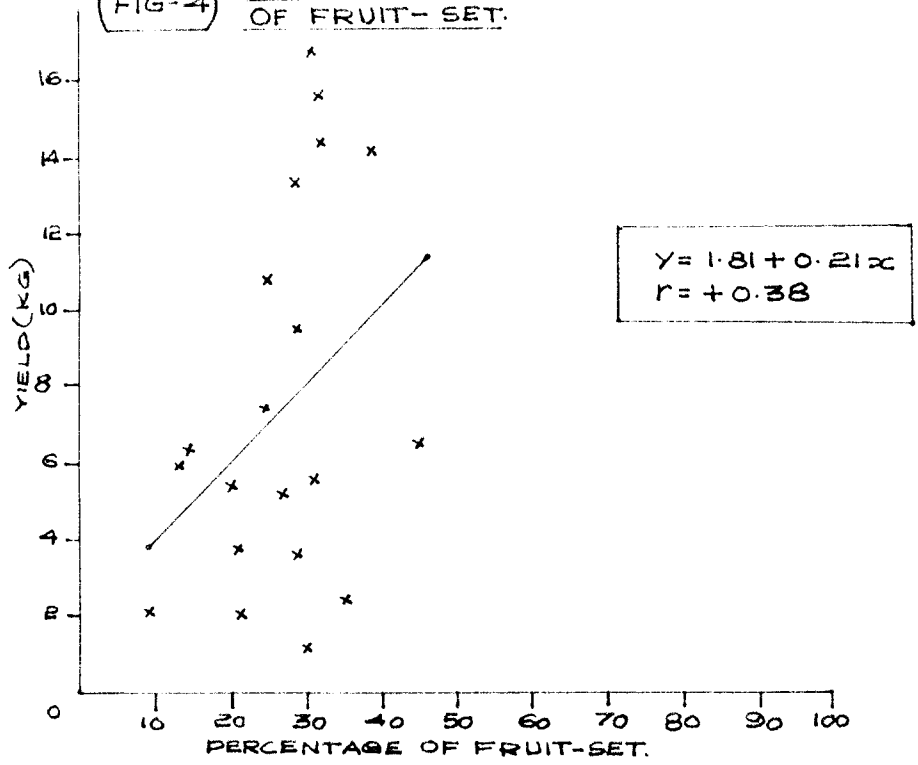
Table 15. Correlation coefficients and regression equations of different fruiting characters with yield

Sl. No.	Character	Coefficient of correlation 'r'	Regression equation (Y = a + bx)
1.	Percentage of fruit-set (X_2)	+ 0.38[x]	$Y = 1.81 + 0.21 X_2$
2.	Percentage of fruit-drop(X_3)	- 0.48*	$Y = 35.01 - 0.298X_3$
3.	Mean weight of nuts (X_4)	+ 0.34	

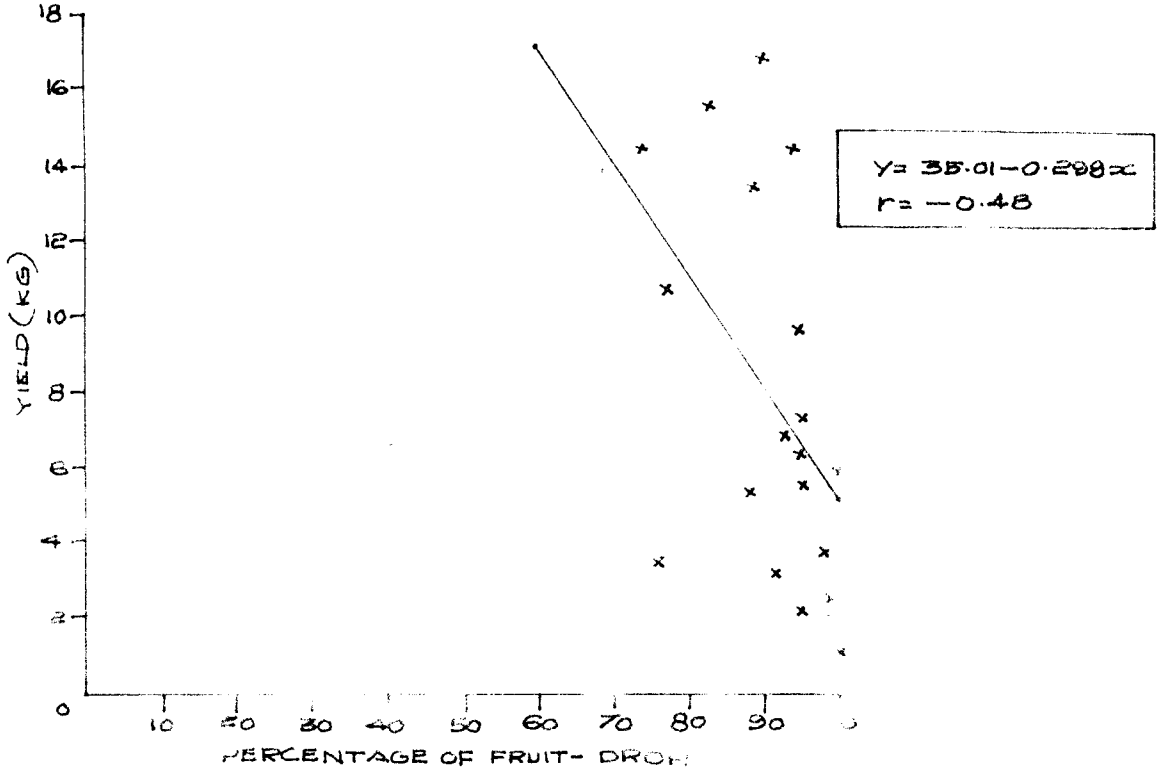
x: Significant at 10 per cent level for the two-tailed 't' test

*: Significant at 5 per cent level for the two-tailed 't' test

FIG-4 RELATIONSHIP BETWEEN YIELD AND PERCENTAGE OF FRUIT-SET.



RELATIONSHIP BETWEEN YIELD AND PERCENTAGE OF FRUIT-DROP.



2.4.1 Stages of fruit-drop

Extent of fruit-drop at different stages of development is presented in Table 16.

It can be seen from the table that only seven to eight per cent of the initial fruit-set was carried towards full maturity. Remaining 92 - 93 per cent of the fruits were dropped due to one cause or other at different stages of development. When the dropped fruits were classified based on their size, they were found to be coming under three groups.

1. Fruits having a length less than 5 mm were included under 'pinhead' or 'mustard' stage of development.

2. Fruits having a length in between 5 - 10 mm were included under 'pea' stage of development.

3. Fruits having a length above 10 mm were included under 'marble' stage of development.

Among these three stages, 'mustard' stage accounted for the maximum fruit-drop. Only small proportions of fruits were found to drop in the later two stages.

Table 16. Fruit-drop at different stages of development

Tree No.	No. of flowers opened	Percentage of bi-sexual flowers	Percentage of fruit-set	Fruits dropped at different stages *(percentage)			*Percentage of fruits retained upto full maturity
				'Mustard' stage	'Pea' stage	'Marble' stage	
1.	189.6	21.47	29.48	75.83	12.5	0.8	10.83
2.	296.1	15.09	31.99	81.82	2.1	0	16.08
3.	662.4	1.31	28.74	76	0	0	24
4.	317.6	20.15	45.63	93.49	0	0	6.5
5.	336.4	17.57	32.49	88.54	5.2	0.52	5.73
6.	387.6	12.75	30.77	87.5	0	2.63	9.87
7.	496.7	13.49	8.81	93.22	0	1.7	5.08
8.	529.4	8.94	34.88	99.39	0	0	0.61
9.	485.5	5.78	14.24	82.5	12.5	0	5
10.	488.6	3.05	13.42	95	5	0	0
11.	821.2	7.79	19.69	84.13	3.96	0	11.91
12.	258.2	19.71	30.85	85.35	5.7	3.82	5.09
13.	611.5	6.41	25.51	92	2	1	5
14.	651.7	5.63	25.07	70.65	5.4	1.09	22.83
15.	652	2.49	30.25	100	0	0	0
16.	701.1	1.87	26.72	91.43	2.9	0	8.57
17.	585	7.19	20.9	97.73	0	0	2.27
18.	422.8	8.87	38.9	73.97	7.5	0.68	26.03
19.	307.4	3.75	21.08	100	0	0	0
20.	471.6	40.79	28.85	95.14	1.08	0	4.86

* Expressed as percentage of initial fruit-set

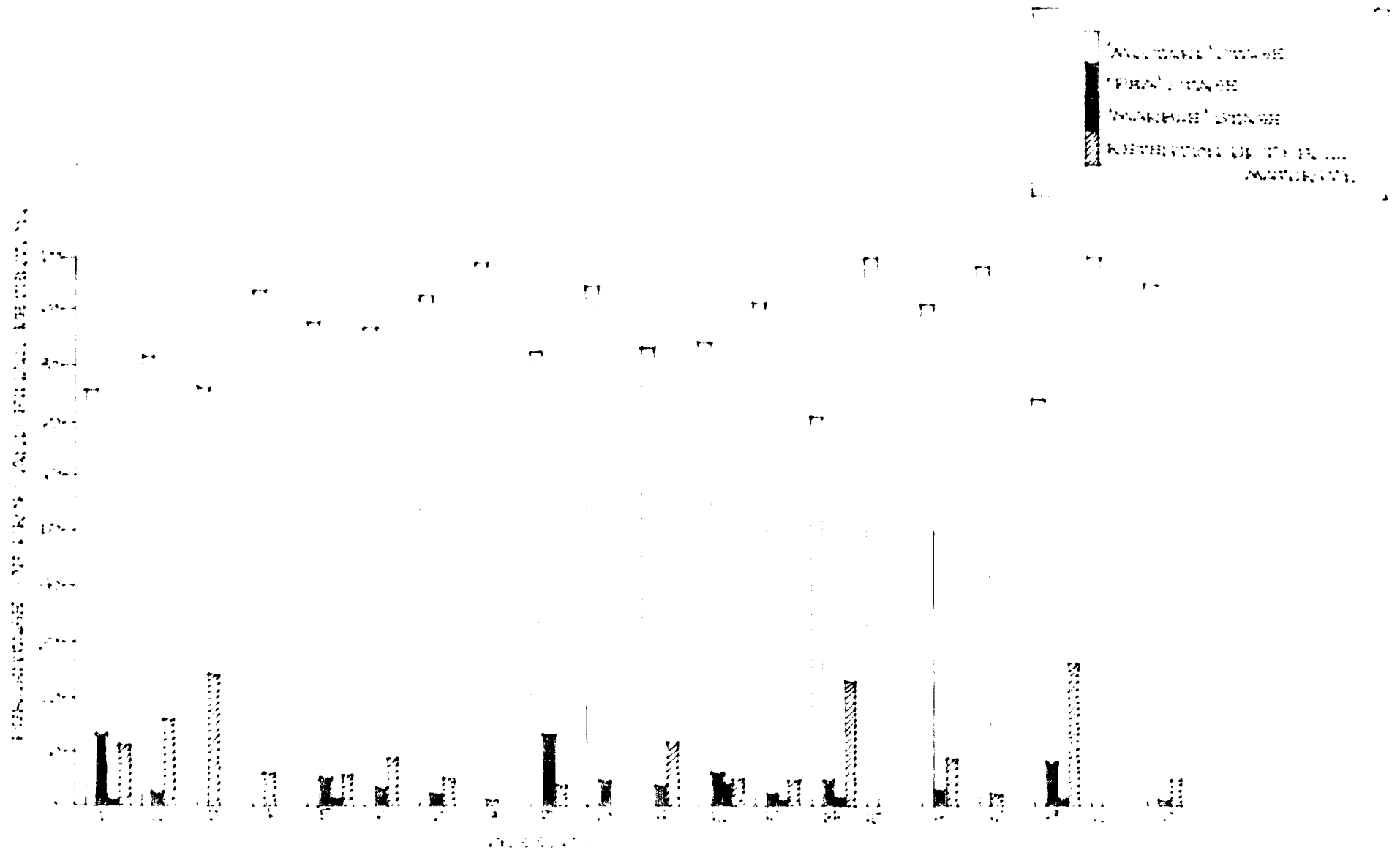
Plate V Fruit-drop at different stages of development.

DROP AT DIFFERENT ST[illegible]

DEVELOPMENT

MUSTARD STAGE PEA STAGE MARBLE STAGE

(Fig. 6) PERCENTAGE OF FRUITLINGS AT DIFFERENT STAGES OF DEVELOPMENT AND RETENTION OF THE FULL MATURITY.



2.4.2 Causes of fruit-drop

The fruits dropped at the different stages were examined to find out the possible causes. The causes that could be identified were those resulting from the attack of insects like Tea mosquito bug (*Helopeltis antonii* sign) and the apple and nut borer (*Thylocaptila panrosema* Meyr). The extent of the drop due to these factors are furnished in Table 17.

Among these pests Tea mosquito bug accounted for more than 10 per cent of the total fruit-drop. Apple and nut borer was found to be causing fruit-drop upto five per cent. Remaining 80 - 85 per cent of the fruit-drop was due to unknown factors. One of these may be the strong wind prevalent during the period of study. Other unknown causes of fruit-drop may range from nutritional imbalance to defective metabolism.

2.4.3 Multiple regression analysis

Relative contribution of these flowering and fruiting characters viz., percentage of bisexual flowers, percentage of fruit-set, percentage of fruit-drop and mean weight of nuts harvested, on tree yield was assessed

Table 17. Extent of fruit-drop due to different factors

Tree No.	Total No. of flowers opened	Percentage of bi-sexual flowers	Percentage of fruit-set	Causes of fruit-drop*		
				Tea mosq-uito bug (%)	Apple and nut borer (%)	Unknown factors (%)
1.	336.4	17.57	32.49	9.38	2.6	82.29
2.	387.6	12.75	30.77	10.53	4.61	75
3.	189.6	21.47	29.48	10.83	3.33	74.17
4.	611.5	6.41	25.51	9	2	89
5.	651.7	5.63	25.07	21.74	4.35	51.09
6.	422.6	8.87	38.9	8.9	3.43	61.64

* Fruit drop expressed as percentage of initial fruit-set

by fitting a multiple regression equation. The partial correlation coefficients were tested for significance. Standardised partial regression coefficients were also worked out. The results are presented in Table 18.

The partial regression coeffieient of percentage of bisexual flowers on yield was found to be significant. The partial regression coefficients of percentage of fruit-set, fruit-drop and mean weight of nuts were not found to be significant. The multiple regression equation of yield on percentage of bisexual flowers, fruit-set, fruit-drop and mean weight of nuts was $Y = 19.571 + 0.244\ X_1 + 0.028\ X_2 - 0.255\ X_3 + 1.156\ X_4$. The coefficient of determination was found to be 49.59 per cent.

Table 18. Multiple regression relationship of flowering and fruiting characters with yield

Characters	Partial regression coefficients (bi)	Standardised partial regression coefficients (bi`)	't' value
Percentage of perfect flowers	0.244	0.465	2.338*
Percentage of fruit-set	0.028	0.049	0.241
Percentage of fruit-drop	- 0.255	- 0.411	- 1.987
Mean weight of nuts	1.156	0.29	1.444

*Significant at 5 per cent level

DISCUSSION

D I S C U S S I O N

Successful crop production is dependent up on the proper understanding of the different factors influencing the yield of the crop. Such studies have been carried out in most of the crops, but no such studies have been made in a systematic manner in the case of cashew, eventhough the relationship between some characters like sex-ratio and yield have been studied in the past. A study of the different factors influencing yield and the extent of contribution made by these factors in the ultimate yield obtained in cashew was undertaken in the present case. Results of these investigations are discussed below.

VEGETATIVE CHARACTERS AS RELATED TO YIELD

From the simple correlation analysis between yield and individual vegetative characters, it was found that tree yield in cashew was significantly correlated with the percentage of flowered shoots per unit area of the tree canopy and also to the spread of the tree but not to the height. The multiple regression coefficients of tree yield on the three vegetative

characters indicated above showed that the percentage of flowered shoots per unit area of tree canopy and the spread of the tree mainly contributed to the yield.

Multiple regression coefficients were worked out to find out the effect of independent variable (X) on the dependent variable (Y) eliminating the effects of other variables involved in the production process.

The standardised multiple regression coefficient of yield on the percentage of flowered shoots per unit area of tree canopy was 0.717 and that of yield on tree spread was 0.201. Among the three vegetative characters, the percentage of flowered shoots per unit area of tree canopy was the most important factor contributing to yield. Results from these studies showed that trees with profuse flowering could be expected to give high yield as compared to those trees with a sparse flowering habit. This may be due to the fact that the profuse flowering habit of the tree resulted in the production of more number of bisexual flowers per unit area of the tree canopy as compared to that of the trees with sparse flowering habit.

Eventhough there was high variation among the trees in respect of the proportion of bisexual flowers, the flowering habit of the tree - profuse or sparse - has a definite bearing on it's yield potential. These results conform to the findings of Murthy et al., (1979), who reported significant correlation between number of panicles (flowering shoots) and number of bisexual flowers in cashew.

Present investigation also indicated the influence of tree spread on yield which is in agreement with the findings in mango by Khan (1960), Oppenheimer (1960) and Teotia et al., (1970). But Dasarathi (1958) and Morton (1970) have reported that cashew trees with spreading habit produced only a tangled mass of base and dead shoots and that maximum flowering was seen in trees with erect growing habit. However, Dasarathi (1958) has reported that intensive branching contributed to higher yields in cashew. The present studies confirm these findings. It may be pointed out that the trees included in these studies are only five years old and it is difficult to classify them as erect growing or spreading. The number of shoots per unit area was therefore taken as the index of vegetative growth.

FLOWERING AND FRUITING CHARACTERS AS RELATED TO YIELD

Pattern of flower opening

Results from the present studies indicated that the opening of flowers in cashew panicles was taking place in three phases - the first male phase, mixed phase followed by a second male phase. But the duration of the male phases was found to be very short in the case of trees yielding above the median and the mixed phase was longer than in the trees yielding below the median. Two trees in the above median group showed complete mixed phase over the entire period of flowering. High yielding behaviour of the trees of above median group may be primarily due to the high proportion of bisexual flowers in the panicles but it was also indicative of the influence of long mixed phase resulting in better pollination and fruit-set.

A number of workers have reported that in cashew the flowers produced early in a panicle are mostly male. Pavithran and Mavindrenathan (1974) reported three distinct phases in the flower opening in cashew panicles. Results from the present studies are in conformity with these findings.

Percentage of bisexual flowers

Simple correlation analysis between yield and percentage of bisexual flowers indicated a positive correlation.

The standardised partial regression coefficient of yield on percentage of bisexual flowers was comparatively higher than those of other fruiting characters. So, among the flowering and fruiting characters, tree yield in cashew was found to be influenced more by this character ie., the proportion of bisexual flowers opened during the flowering period - than others.

Damodaran et al., (1965) have reported that there was a positive correlation between the percentage of bisexual flowers and yield in cashew. Rao (1974), Murthy et al., (1979) also have made similar observations. In mango, Naik and Mohan Rao (1943), Singh (1954), Singh (1962), Singh (1964) have reported similar results.

Factors affecting pollination:-

Extent of pollination under natural conditions

Preponderence of staminate flowers over bisexual

flowers was reported as one of the reasons for low fruit-set in cashew (Rao, 1974). But, the extent of pollination taking place under natural conditions is undoubtedly an important factor governing fruit-set in cashew. In the present studies, a random number of perfect flowers were examined at different intervals after opening to find out whether the flowers have been pollinated. The results clearly indicated that a large proportion of bisexual flowers remained unpollinated. So even in trees producing a fairly high proportion of bisexual flowers, it may not be fully reflected on the ultimate yield. These observations are in conformity with the findings of Damodaran et al., (1966), Rao (1974) who had reported lack of adequate pollination in nature as one of the reasons for poor fruit-set in cashew.

Effect of hand pollination on fruit-set

Hand pollination studies in the present investigations resulted in 80 - 95 per cent initial fruit-set. Eventhough the ultimate fruit retention till maturity on the hand pollinated panicles were significantly higher in number than that on the naturally pollinated

panicles, the increase was not commensurate with the increased fruit-set. Increased fruit-set in cashew from hand pollination has been reported by Rao (1974), Kumaran et al., (1976 a).

Period of receptivity of stigma

In the present observations, it was found that the receptivity of stigma of cashew flowers continued upto 48 hours, after opening. Optimum stigmatic receptivity was observed during the first six hours of opening. A steady decline in receptivity was observed as the age of opened flowers advanced further. These results are in conformity with the findings of Damodaran et al., (1966) in cashew.

Assisted pollination

In the present investigation, the panicles sprayed with pollen suspensions in water and coconut water recorded an increased fruit-set than the control. This may be due to the better pollinations facilitated by the pollen sprays.

Rao and Hassan (1957) have reported increased fruit-set in cashew by spraying the trees in bloom

with water at intervals of six days. Bhasma Bhat (1965) has reported increased fruit-set in arecanut by spraying pollen grains held in suspension in an aqueous solution of sucrose.

Fruit-set in the panicles sprayed with different attractant solutions, in the present investigations, was also significantly greater than that in the control. A lot of house flies and honey-bees were observed to be visiting these sprayed panicles. Increased fruit-set obtained in these treatments was possibly due to the increased pollination by the activity of these insect visitors. Roberts (1956) has reported that sugar sprays during flowering could encourage pollination by attracting honey-bees in plums.

Present investigations indicated that insect pollinators like honey-bees can be successfully used to supplement the natural pollination in cashew orchards. Smith (1958) has also suggested that in cashew, bees may be used to promote greater pollination. But spraying with attractant solutions will not be economic and practical for large scale adoption. But, keeping bee-hives at different locations of the orchard during

the flowering period may be beneficial. This practice not only serves in better pollination and fruit-set in the cashew trees but also helps in getting higher quantity of honey.

Fruit-set, fruit-drop and mean weight of nuts as related to yield

Simple correlation analysis between yield and other important fruiting characters indicated a positive correlation between yield and percentage of fruit-set and a negative correlation between yield and percentage of fruit-drop. No significant correlation could be found between yield and mean weight of nuts.

The standardised partial regression coefficient of yield on percentage of fruit-drop was found to be negative and higher than that of fruit-set. Thus 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.

Present investigations on the extent of fruit-drop at different stages of maturity indicated that 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 - 95 per cent length and breadth.

Several workers have reported that severe shedding of young fruits was one of the reasons for poor yield in cashew (Damodaran et al., 1966, North Wood, 1966., Dasarathi, 1971., Pillai and Pillai, 1975). Similarly Naik and Mohan Rao (1943), Singh (1960), Srivasthava (1961), Roy et al., (1963), Chadha and Singh (1964 a & b) have reported such findings in mango. Results from the present studies are in conformity with these findings.

The causes of fruit-drop that could be identified in the present studies were those resulting from the attack of insect pests like Tea mosquito bug (Helopeltis antonii Sign) and the Apple and nut borer (Thylocaptila porrocoma Meyr) and certain physiological factors like inadequate nutrition etc. It was observed that these pests accounted for 10 - 15 per cent of the fruit-drop

occuring in all the three stages. Remaining 85 - 90 per cent could be attributed to other factors like the competition for nutrients among the rapidly growing young fruits, hot dry winds blowing in this part of the year etc. Examination of the dropped fruits did not show any fungal infection and they contained kernels free from abnormal symptoms of decay and deformity.

Northwood (1966) attributed fruit-drop in cashew during the early stages of development to physiological reasons. Pillai and Pillai (1975) observed that insect attack also played an important role in immature fruit-drop apart from physiological causes. Results from the present observations generally conformed to these findings. Further studies are required on this aspect to findout the different factors which are responsible for the dropping of immature fruits.

The present studies revealed that higher proportion of flowering shoots per unit area, bushy growth, longer period of the mixed phase in flowering higher proportion of perfect flowers, better pollination contributing to higher fruit-set and factors helping to

reduce fruit-drop are the main factors contributing to yield in cashew. While some of these factors like the proportion of flowering branches per unit area, sex-ratio serve as selection indices, others like fruit-set, fruit-drop etc., which can be manipulated by better nutrition, application of plant regulators etc., are important in increasing the productivity of this important crop.

SUMMARY

S U M M A R Y

Studies on different factors affecting yield in cashew were undertaken on five year old trees at the main campus of Kerala Agricultural University at Vellanikkara during the period from November 1978 to April 1979. The results of these studies are summarised below:

1. Among the vegetative characters, percentage of flowered shoots per unit area of the tree canopy was found to be the most important factor contributing to yield.

2. Tree spread was also found to have a positive correlation with yield. The influence of this character on yield was not direct but indirect through the former character.

3. There was no significant correlation found between yield and height of the tree.

4. Pattern of flower opening in cashew panicles was found to have three phases viz., the first male phase, followed by a mixed phase which is again followed by a second male phase. The duration of these three

phases was found to be varying in the different trees. It was found that some trees had only the mixed phase throughout and that trees yielding above the median had a longer mixed phase as compared to those yielding below the median.

5. A positive correlation was found between yield and percentage of bisexual flowers in the tree. Among the flowering and fruiting characters affecting yield, this factor was found to influence yield much more than any other character.

6. Examination of a random number of bisexual flowers revealed that a large proportion of bisexual flowers remained unpollinated in nature. So lack of pollination was found to be one of the reasons for poor fruit-set and yield in cashew. This was further confirmed from the high fruit-set obtained in hand-pollinated panicles.

7. Receptivity of stigma was found to be continuing upto 48 hours after flower opening and hence it was not a limiting factor for securing high yield.

8. Supplementing the natural pollination with

the help of insect pollinators like house-flies and honey-bees met with some success. Keeping bee-hives in the orchards during flowering season is therefore advisable for facilitating better pollination.

9. Data on fruit-set and yield indicated that there was positive correlation between yield and percentage of fruit-set. But the yield increase was not commensurate with increase in the fruit-set due to the heavy drop of young fruits before reaching maturity.

10. The intensity of fruit-drop was found to be high in the early stages of development and it declined as the fruits approached maturity.

11. The causes of fruit-drop that could be identified were those resulting from the attack of insect pests like Tea mosquito bug (Helopeltis antonii Sign) and Apple and nut borer (Thylocoptila paurosema Meyr) accounting for 10 - 15 per cent of the total dropped fruits. The other important factors involved in the fruit-drop are yet to be identified.

12. There was no significant relationship between yield and mean weight of nuts harvested.

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APPENDIX

Appendix - I. Weather data (monthly average) for the period from March 1978 to March 1979

Month	Temperature (°C)	Relative humidity (%)	Wind-speed (km/hr)	Total rainfall (mm)	Sunshine (hrs./day)
1978					
March	29.80	60.0	10.9	5.2	9.5
April	30.45	69.5	6.4	19.9	9.0
May	29.85	71.5	7.2	287.5	7.5
June	26.15	83.0	5.3	848.5	3.9
July	25.55	84.0	7.9	790.4	5.6
August	25.80	85.0	9.0	679.5	3.1
September	26.25	79.0	6.4	68.3	8.2
October	27.50	79.5	7.7	114.1	7.6
November	25.20	67.0	11.4	284.2	9.5
December	26.95	70.5	18.3	43.9	8.9
1979					
January	26.35	67.0	21.2	nil	9.3
February	28.35	66.5	13.7	22.0	9.0
March	29.50	67.0	12.4	3.2	9.2

Source: 'B' Class Observatory, Mammathy.

FACTORS AFFECTING YIELD IN CASHEW [*Anacardium occidentale* L.]

BY

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ABSTRACT OF A THESIS

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COLLEGE OF HORTICULTURE

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A B S T R A C T

Investigations on the different vegetative, flowering and fruiting characters, influencing yield in cashew, were undertaken at the main campus of Kerala Agricultural University at Vellanikkara. These studies were made during the period from November 1978 to April 1979.

Important vegetative characters studied were the percentage of flowered shoots per unit area of tree canopy and the growth parameters of the tree represented by spread and height.

The major flowering and fruiting characters studied were the pattern of flower opening, percentage of bisexual flowers, factors affecting pollination, fruit-set, fruit-drop and the mean weight of nuts harvested.

The results showed that among the vegetative characters, percentage of flowered shoots per unit area of tree canopy was found to be the most important factor, contributing to yield. Tree-spread was also found to have a positive correlation with yield. The

influence of this character on yield was not direct but indirectly through the former character. There was no significant correlation between yield and height of the tree.

Pattern of flower opening in cashew panicles was found to have three phases viz., the first male phase followed by a mixed phase which is again followed by a second male phase. The duration of these three phases was found to be varying in the different trees. It was found that some trees had only the mixed phase throughout and those trees yielding above the median had a longer mixed phase as compared to the trees yielding below the median.

A positive correlation was found between yield and percentage of bisexual flowers in the tree. Among the flowering and fruiting characters affecting yield, this factor was found to influence yield much more than any other character.

Examination of a random number of bisexual flowers revealed that a large proportion of bisexual flowers remained unpollinated in nature. So, lack of

pollination was found to be one of the reasons for poor fruit-set and yield in cashew. This was further confirmed from the high fruit-set obtained in the hand pollinated panicles. Receptivity of the stigma was found to be continuing up for 48 hours after flower opening and hence it was not a limiting factor for securing high yield.

Supplementing the natural pollination with the help of insect pollinators met with some success. Keeping bee-hives in the orchards during flowering season is advisable for facilitating better pollination.

A positive correlation could be observed between yield and percentage of fruit-set but the ultimate yield was found to be adversely affected by the severe shedding of young fruits before reaching maturity.

The intensity of fruit-drop was found to be high in the early stages of development but it declined during the later stages. The causes of fruit-drop that could be identified were those resulting from the attack of insect pests, adverse climatic conditions etc.

Studies did not reveal any significant correlation between yield and mean weight of nuts harvested.