GENETIC VARIABILITY AND CORRELATIONS IN NINE DIVERGENT VARIETIES OF COCONUT

(Cocos nucifera **L.)**

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled '**Genetic variability and correlations in nine divergent varieties of coconut (*Cocos nucifera* L.)**' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled '**Genetic variability and correlations in nine divergent varieties of coconut (*Cocos nucifera* L.)**' is a record of research work done independently by **Ms.P. Sindhumole**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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EXTERNAL EXAMINER

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P. Sindhumole

Dedicated to
my beloved
Ammamma

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ABBREVIATIONS

ANOVA	- Analysis of variance
VHC-1	- Veppankulam Hybrid Coconut-1
VHC-2	- Veppankulam Hybrid Coconut-2
GV	- Genotypic variance
PV	- Phenotypic variance
TMS	- Treatment mean square
EMS	- Error mean square
r	- Number of replications
GCV	- Genotypic coefficient of variation
PCV	- Phenotypic coefficient of variation
Cov.	- Covariance
df	- Degree of freedom
CD	- Critical difference
NA	- Not applicable
SE	- Standard error
SD	- Standard deviation
CV	- Coefficient of variation
TH	- Trunk height
TG	- Trunk girth
PL	- Petiole length
LL	- Leaf length
SY	- Spadices year^{-1}
FF	- Female flowers spadix^{-1}
FS	- Fruit set
CY	- Copra yield
OC	- Oil content (%)
OY	- Oil yield
NY	- Nut yield

Introduction

INTRODUCTION

Coconut (*Cocos nucifera* L.), known as 'Kalpa Vriksha', is a versatile species providing food, drink, shelter, oil and several other useful products. India, with an area of 1.8 million ha under coconut and production of 14 billion nuts, ranks second in the world (George, 1997). Of this, Kerala, 'the land of coconuts', accounts for 55 per cent of the area and 42 per cent of the production. Coconut has an integral role in the economic, social and cultural lives of the people of our state. Productivity shows a declining trend while there is growing demand for coconut in the country and abroad as a source of vegetable oil as food and for chemical industries. Crop improvement has a major role in achieving higher productivity. Pioneering research in coconut had been conducted in India leading to the development of the first coconut hybrid (Patel, 1937). Breeding works carried out in Kerala and elsewhere till date have identified several high yielding cultivars and developed superior hybrids for commercial cultivation.

Intervarietal and intravarietal variability had been reported in coconut for several characters (for eg. Louis, 1981; Gopimony, 1982). Considerable variation among hybrids of various parental combinations exists for leaf and nut characters as well as yield (Satyabalan, 1982; Rajamony *et al.*, 1983; Balakrishnan and Kannan, 1991). Total phenotypic variation is conditioned by the joint action of genes and environment. Response to selection is governed by the proportion of genetic variation.

In coconut, inflorescences are produced at intervals of about one month (Menon and Pandalai, 1960). Although each bunch is influenced by a 12-month weather cycle, the environmental conditions encountered by different bunches at similar stages of their development will be different. Inflorescence characters, therefore, vary even within the same variety from season to season (Marechal, 1928; Patel, 1938).

Economic characters, such as yield, are low in heritability and composite in nature. Therefore, variability in component characters and their influence on yield are also important in the formulation of breeding strategies. Significant correlation with yield has been reported for a number of vegetative and reproductive characters in coconut (Satyabalan *et al.*, 1972; Abeywardena, 1976; Kutty and Gopalakrishnan, 1991). Works carried out in coconut on variability and correlation are mostly restricted to phenotypic level with data being based on single variety or unreplicated varietal trials. But a more meaningful relationship would be provided by correlation operating at a genetic level among characters.

Multiple regression models for crop yield provide information on the relative importance of component characters in determining the yield. Such information will help the breeder to plan the breeding programmes in a time and resource efficient manner. Yield prediction models, using multiple regression, were worked out by Kutty and Gopalakrishnan (1991) on characters like leaf number and leaf length. Functional leaves, spikelets with nuts and leaflets have positive direct effects on coconut yield (Ramanathan, 1984).

The present study was undertaken with the following major objectives:

1) to estimate genetic variability for yield and component characters in coconut from a set of nine divergent varieties including three hybrids;

2) to find out seasonal and season x genotype effects on certain reproductive characters;

3) to determine genetic correlation among component characters as well as that of component characters with yield;

4) to estimate dependence of yield on various characters using simple and multiple regression models;

5) to find out direct and indirect effects of component characters on yield.

Review of Literature

REVIEW OF LITERATURE

2.1 Variability

2.1.1 Vegetative characters

Tall x Dwarf hybrid was intermediate for trunk girth but higher for leaf production than its parental types (Bhaskaran and Leela, 1964). Krishnan and Nambiar (1972) reported that among the four Tall x Dwarf hybrids, Tall x Laccadive Dwarf had the maximum number of leaves and leaflets.

Functional leaves, leaflets and leaf length varied among nine Tall x Choughat Dwarf Orange hybrids (Bavappa *et al.*, 1973). Kannan and Nambiar (1974) reported that superiority of Laccadive Ordinary x Gangabondam for annual leaf production among the hybrids of six tall varieties with Gangabondam.

Thampan (1975) compared tall, dwarf green and tall x dwarf varieties at Nileshwar for trunk girth and leaf production. Girth was maximum for tall x dwarf and minimum for dwarf whereas the highest total leaf production was in dwarf and the lowest in tall.

Chan (1979) compared hybrids between various Malayan dwarf and tall varieties and reported that Malayan Dwarf x Malayan Tall hybrids had taller and thicker trunks, and fronds which were longer and high in number, compared to Malayan Dwarf x Rennel Tall hybrids. Malayan Dwarf x West African Tall was similar to Malayan Dwarf x Malayan Tall in leaf length, but superior in leaf production.

Louis (1981) studied genetic variability among 25 varieties and two hybrids and reported that varieties Fiji, Federated Malayan States and San Ramon bore large number of leaves. High genotypic coefficient of variation was observed for leaf length and leaves produced per year.

West Coast Tall x Niyorgading and West Coast Tall x Choughat Dwarf Green produced the highest number of leaves among fifteen hybrid combinations under rainfed conditions (Rajamony *et al.*, 1983).

Dwarf x Tall hybrids in Indonesia produced 19 to 22 per cent more leaves than their respective male (tall) parents (Liyanage *et al.* as quoted by Ohler, 1984).

Balakrishnan and Namboodiri (1987) reported that 24 tall cultivars of exotic and indigenous origin showed variability for trunk girth and leaf number.

Half sib families from various West Coast Tall mother palms pollinated by a common Choughat Dwarf Orange pollen parent showed considerable variation for trunk girth, internodal distance, number of functional leaves, annual leaf production, leaf length, petiole length and number, length and width of leaflets (Sreelatha, 1987). Among these characters, genotypic and phenotypic coefficients of variation were maximum for internodal distance and minimum for number of leaflets.

Exotic and indigenous collection of 31 cultivars showed variation for trunk height, leaf length and number of leaflets (Louis and Chopra, 1989).

Raveendran *et al.* (1989) reported that among four parents and their direct and reciprocal hybrids, hybrids in general had higher number of functional leaves and leaf scars per metre. Malayan Dwarf yellow among the parents and Malayan Dwarf Yellow x East Coast Tall and its reciprocal among the hybrids had higher leaf number than other varieties.

VHC-2 was superior in trunk girth and leaves to its parents viz., East Coast Tall and Malayan Yellow Dwarf (Ramachandran *et al.*, 1990). Performance of Tall x Dwarf hybrids was better than Dwarf x Tall in leaf production (Balakrishnan and Kannan, 1991).

Between Tall and Dwarf varieties, marked difference was observed for stem girth, leaf number and petiole length (Pillai *et al.*, 1991).

Shylaraj *et al.* (1991) reported the superiority of Komadan over West Coast Tall for trunk girth and functional leaves. In another study, West Coast Tall had thicker trunk and more and bigger leaves than Laccadive Ordinary (Joseph *et al.*, 1992).

Ramanathan *et al.* (1992) reported that seven varieties and three hybrids under semidry condition varied for trunk height, trunk girth at stem and petiole length, but not for trunk girth at crown, functional leaves and leaf length.

2.1.2 Reproductive characters

The varieties Philippines and Straits Settlements Green produced high female flowers among various exotic varieties and West Coast Tall (Ratnam and

Satyabalan, 1964). Bavappa *et al.* (1973) reported that parental combinations of Tall x Choughat Dwarf Orange differed in female flower production and fruit set.

Nambiar and Ravindran (1974) compared open pollinated and inbred progenies of twelve coconut varieties and reported that substantial difference existed among varieties and also between open pollinated and inbred progenies of the same variety, for female flowers per spike.

Satyabalan and Pillai (1977) compared eight exotic varieties and West Coast Tall and observed that wide variation existed for yield attributes viz., spadix production, female flowers and setting percentage. Generally, exotic varieties produced more spadices and female flowers whereas West Coast Tall had relatively high fruit set.

Malayan Dwarf x West African Tall hybrids were characterised by early flowering and higher female flowers and fruit set than hybrids of Malayan Dwarf with Malayan Tall and Rennel Tall (Chan, 1979).

Among eight coconut varieties grown in red loam, West Coast Tall had high female flowers and setting percentage (Potty *et al.*, 1980).

Louis (1981) reported that among 25 varieties and two hybrids, Laccadive Small and Spicata produced high number of spadices per year. Ayiramkachi had the largest number of female flowers whereas Ordinary Tall had the highest setting percentage. Maximum phenotypic coefficient of variation was recorded for number of female flowers, followed by setting percentage.

Number of inflorescences produced annually varied between tall and dwarf varieties in Philippines (Balingasa and Carpio, 1983).

Rajamony *et al.* (1983) compared fifteen coconut hybrids among which West Coast Tall x Laccadive Dwarf had taken least period for first flowering. Annual female flower production was high in West Coast Tall x Choughat Dwarf Green and West Coast Tall x Niyorgading whereas the highest setting percentage was for Gangabondam x Laccadive Ordinary.

Fifteen exotic varieties of coconut were evaluated along with local cultivars, in Orissa, by Panda *et al.* (1985). The varieties differed for flowering habit, female flowers and percent fruit set. Cochin China and New Guinea were grouped as late, Orissa Selection-1 and West Coast Tall as medium and the other exotics including Tall x Dwarf as early types. Variety Spikeless produced maximum female flowers per year but had minimum fruit set whereas the highest fruit set was for Strait settlements.

Balakrishnan and Namboodiri (1987) reported considerable variation among 24 tall cultivars of exotic and indigenous origin for number of inflorescences, female flowers per rachis and female flowers per inflorescence. West Coast Tall x Choughat Dwarf Orange hybrids with common male parent and different mother palms varied for number of spadices, branches per spadix, female flowers and number of buttons set (Sreelatha, 1987). Maximum genotypic and phenotpyic coefficient of variation were for female flowers and number of buttons set respectively.

Comparison of four parents with their direct and reciprocal hybrids, showed that the hybrids produced the highest number of bunches, spikelets and length of spikelets but had moderate fruit set (Raveendran *et al.*, 1989).

Ramachandran *et al.* (1990) observed that VHC-2 produced high number of bunches, spikelets and spikelets with buttons, compared to its parents and VHC-1. Pillai *et al.* (1991) reproted variability among 18 cultivars of exotic and indigenous origin for number of inflorescences, spikelets and spikelet length.

Komadan produced more spadices and female flowers per spadix than West Coast Tall (Shylaraj *et al.*, 1991). Similarly Laccadive Ordinary was superior to West Coast Tall for bunches, female flowers and setting percentage (Joseph *et al.*, 1992). Komadan produced more spadices than West Coast Tall, but these cultivars did not vary for female flowers per spadix and percent fruit set (Vanaja, 1993).

Highest number of spadices were produced by direct and reciprocal hybrids of Malayan Yellow Dwarf and East Coast Tall among various hybrids and their parents (Vijayaraghavan *et al.*, 1993).

2.1.3 Economic characters

Compared to West Coast Tall, the exotic varieties New Guinea, Cochin China, Fiji and Federated Malayan States had high copra content per nut (Ratnam and Satyabalan, 1964). Nut of Tall x Dwarf Orange hybrid had larger size and higher copra content than that of Tall x Dwarf Green hybrid (Satyabalan *et al.*, 1968).

Performance of eight germplasm introductions and West Coast Tall revealed that the varieties had wide variation for nut and copra characters (Satyabalan and Pillai, 1977). Zanzibar, British Solomon Islands and West Coast Tall were better for copra outturn.

Chan (1979) reported that Malayan Dwarf x West African Tall hybrids produced the highest number of nuts per palm. But their copra outturn was poorer than Malayan Dwarf x Rennel Tall hybrids.

Superiority of West Coast Tall for nut yield among eight coconut varieties was reported by Potty *et al.* (1980). Reddy *et al.* (1980) reported that hybrids had heavier nuts among eleven coconut cultivars, but maximum oil content was seen in Laccadive Ordinary. High genotypic and phenotypic coefficients of variation for nut yield was reported among 25 varieties and two hybrids by Louis (1981). Oil content was high in tall, moderate in tall x dwarf and low in dwarf varieties (Louis and Ramachandran, 1981).

Among various coconut varieties in Philippines, Tagnanan exhibited the heaviest nut components whereas per cent copra recovery was the highest for Magtoud and Makilala (Santos *et al.*, 1981). Marked differences were observed between West African Tall and Polynesian varieties for weight of nut, husked nut, husk, nut water, shell, endosperm and copra (Meunier *et al.*, 1982). Balingasa and Carpio (1983) reported that the highest copra content per nut was possessed by Tagnanan and Baybay varieties, among various coconut populations in Brazil.

Performance of fifteen hybrids along with West Coast Tall revealed that all the hybrids were superior to West Coast Tall (Rajamony *et al.*, 1983). Among the hybrids, West Coast Tall x Niyorgading and West Coast Tall x Choughat Dwarf Green were superior in copra content and nut yield whereas West Coast Tall x Gangabondam had maximum oil content.

East Coast Tall x Malayan Dwarf Yellow was better than its reciprocal for yield of copra and nut (Ramanathan and Louis, 1983). Satyabalan and Rajagopalan (1983) reported that Malayan Dwarf and Choughat Dwarf varieties differed for nut yield. Medium to high genotypic and phenotypic coefficients of variation were observed for weight of unhusked nut, husked nut and meat (Mathew *et al.*, 1984).

Higher nut size and copra content were observed in varieties New Guinea, Jawa, Philippines and Fiji and Laccadive Micro produced smallest nut size and copra content (Panda *et al.*, 1985). Varieties Jawa, Laccadive Small, Laccadive Micro, Cochin China, Philippines and Tall x Dwarf had higher copra yield and oil recovery than the local types.

Balakrishnan and Namboodiri (1987) reported variation among twenty four exotic and indigenous cultivars for nuts per bunch, weight of unhusked nut, weight of meat per nut, thickness of meat, copra content and percent oil content.

East Coast Tall x Dwarf Green produced the highest nut and copra yield but, copra weight per nut was maximum in East Coast Tall x Choughat Dwarf Orange (Ramanathan and Nallathambi, 1988). Though dehusked nut weight was higher in Choughat Dwarf Orange x Tall than in other hybrids, the highest copra content was in Tall x Choughat Dwarf Orange (Rao and Nair, 1989).

Ramachandran *et al.* (1990) reported higher nuts per bunch for VHC-1 than East Coast Tall, Malayan Dwarf Yellow and VHC-2. Five varieties and their hybrids when compared, Laccadive Ordinary and West Coast Tall among the parents and Laccadive Ordinary x Gangabondam among the hybrids had the highest oil content (Nambiar and Rao, 1991).

West Coast Tall x Malayan Dwarf Yellow and West Coast Tall x Choughat Dwarf Green were superior among fifteen hybrids for nut and copra yield (Balakrishnan and Kannan, 1991). Nut yield of West Coast Tall x Choughat Dwarf Green was higher than that of West Coast Tall (Rao, 1991). All the hybrid combinations except West Coast Tall x Gangabondam gave higher cumulative yield than West Coast Tall (Rao *et al.*, 1991).

Komadan was superior to West Coast Tall for annual nut yield (Shylaraj *et al.*, 1991). Taffin *et al.* (1991) reported that Dwarf x Tall hybrids were superior to West African Tall for nut yield and copra content.

Laccadive Ordinary had higher yield than West Coast Tall whereas Laccadive Ordinary x Gangabondam was superior to West Coast Tall x Gangabondam (Joseph *et al.*, 1992). Manju (1992) reported the superiority of Komadan over West Coast Tall for all nut characters except oil content. High genotypic and phenotypic coefficients of variation were observed for nuts per bunch and nuts per palm.

Among seven varieties and three hybrids, West Coast Tall x Malayan Dwarf Yellow and its reciprocal produced maximum annual nut yield (Ramanathan *et al.*, 1992).

Komadan exhibited superiority over West Coast Tall for nuts per bunch, annual nut yield, kernel weight, copra content, embryo weight and nut water volume (Vanaja, 1993).

Nut weight and water volume of immature and mature Srilankan Green nuts were low and those of Malayan Green were high (Islam *et al.*, 1994). Among the five coconut hybrids assessed in Brazil, PB 111, PB 141 and PB 123 were precocious and high yielding while PB 123 had the best nut composition (Siqueira *et al.*, 1995).

2.2 Heritability

Lakshmanachar (1959) reported heritability in broad sense as 62 per cent for nut yield based on 24 palms at CPCRI, Kasaragod. Using parent offspring regression method in 14 mother palms and their open pollinated progenies, heritability in narrow sense was estimated as 49 per cent. Liyanage and Sakai (1960) reported high heritability for husked nut weight and copra yield, intermediate for nut yield and low for flowering period in the progenies of high yielding tall mother palms. Heritability based on parent progeny regression was low for bunches and spikes but high for other characters (Nambiar *et al.*, 1970).

Heritability was high for nut yield (Bavappa *et al.*, 1973). High heritability was reported for annual production of leaves and spadices in 25 varieties and two hybrids by Louis (1981).

Copra content and oil content had high heritability in West Coast Tall (Bavappa and Sukumaran, 1983). Heritability for copra content and oil content was higher than that for nut yield in Tall x Tall and Dwarf x Tall hybrids (Meunier *et al.*, 1984).

Among the various vegetative and floral characters studied in West Coast Tall x Choughat Dwarf Orange hybrids, relatively high heritability was observed for internodal distance, trunk girth, leaf length and female flowers (Sreelatha, 1987). Mathew and Gopimony (1991) reported high heritability for weight of unhusked nut, husked nut and meat in West Coast Tall.

2.3 Seasonal effects

Female flower production was high during November to March in dwarf palms in Fiji (Marechal, 1928). Maximum production of spadices occurred during March at Nileshwar and during April at Kasaragod (Patel, 1938). At both places spadix production was low during October to January. High spadix abortion happened during July to October. High and low female flower production occurred during March to May (highest in May) and September to January respectively. Also, there was a variation for yield, nut characters, copra and oil content among seasons. In West Coast Tall copra volume and weight were maximum in May and minimum in October, whereas oil content was high during November to February.

Narayana (1940) and Menon and Pandalai (1960) reported that nuts harvested during February to May were bigger and with large quantity of meat. Aiyadurai (1962) reported that the production of best quality nuts was during February to May in the West Coast and during March to June in the East Coast.

Seasonal variations for yield, nut characters and copra content were observed in some exotic varieties (Pillai and Satyabalan, 1960). The highest yield was obtained during summer and the lowest during north-east monsoon period. In West Coast Tall larger nuts and maximum copra content were obtained during summer.

Vijayalakshmi *et al.* (1962) reported that copra content and weight and volume of unhusked and husked nuts were higher in those inflorescences which reached stigmatic receptivity during summer months. Unfavourable seasonal factors coinciding with the active period of nut development affected the growth rate, final nut size and copra content adversely (Nambiar *et al.*, 1969).

Under East Coast conditions, high female flower production and low percent fruit set were observed from February to June (Muhammed *et al.*, 1970). Nambiar *et al.* (1970) reported that instability in production was due to seasonal differences within each year.

Abeywardena (1971) reported yield variations in Ceylon, among six bimonthly harvests. The first harvest (January-February) had the highest copra out-turn but the lowest setting percentage and bunches. The third harvest (May-June) was the highest in number of bunches, percent fruit set and nut yield. The highest number of female flowers was observed in the fourth harvest (July-August). The poorest crop was the sixth (November-December) which also had the lowest number of female flowers per bunch.

Louis and Annappan (1980) reported variation for nut yield among different seasons of the year, the maximum yield being obtained during the summer months. The female flowers produced was the highest during March to April (Bai and Ramadasan, 1982).

Bhaskaran and Leela (1983) reported that spadices, female flowers, nut yield, size and weight of whole and dehusked nut, kernel thickness and copra content were maximum during hot weather period in Tall x Dwarf and West Coast Tall. Nut and copra characters of bunches harvested during different months of the year exhibited variation in West Coast Tall (Satyabalan and Mathew, 1984).

The higest nut yield was obtained during South West monsoon for East Coast Tall palms at Veppankulam (Vijayaraghavan *et al.*, 1988). Nuts harvested during April or May were bigger and had higher copra content whereas those harvested during December or January were smaller but with higher oil content (Nambiar and Govindan, 1989).

Rao and Nair (1989) studied monthly variation in the nut development of three coconut hybrids at Pilicode. All the three hybrids recorded higher nut weight and copra content in summer. Nambiar and Rao (1991) reported that oil content recorded for five coconut cultivars was maximum during post monsoon period, followed by winter and minimum during summer.

Production of spadices and female flowers in West Coast Tall x Choughat Dwarf Orange hybrid was high during March to May and absent during October to December (Sreelatha and Kumaran, 1991). Low pollen fertility and viability were during April to May but low fruit set was observed during rainy months.

Stepwise multiple regression was done for the coconut productivity on monthly rainfall based on data during 1956-57 to 1989-90 in Kerala State (Babu *et al.*, 1993). The analysis assuming that the monthly rainfall influenced the coconut productivity three years later showed that March and May rains had a positive contribution to yield, whereas rains during January and November had a negative influence.

Nut characters viz., copra content, kernel weight, nut size and husked nut weight were maximum for nuts harvested during summer months in both West Coast Tall and Komadan (Vanaja, 1993). Vijayaraghavan *et al.* (1993) reported maximum opening of spadices during April to September.

The highest proportion of the annual yield was obtained during the hot weather period i.e., March to May (Satyabalan, 1994).

2.4 Correlation

2.4.1 Among vegetative characters

Positive association was observed in 26 tall and four dwarf cultivars among trunk height, trunk girth, total leaves, functional leaves, leaf length, leaf breadth and leaflets except between leaf length and leaf breadth (Ramanathan, 1984). Trunk girth had positive genotypic correlation with functional leaves, annual leaf production, leaf length, petiole length, leaflets, leaflet length and leaflet width in West Coast Tall x Choughat Dwarf Orange hybrid (Sreelatha, 1987).

2.4.2 Among reproductive characters

In West Coast Tall x Choughat Dwarf Orange hybrid, fruit set had high positive genotypic correlation with spadices and female flowers (Sreelatha, 1987).

Kalathiya and Sen (1991) reported correlation in Dwarf Green variety for spadices positively with spadix length and fruit set, and negatively with spadix production interval. Positive association was observed between spikelets and spikelet length. Female flowers had positive correlation with spadices, spadix length and spikelets having female flowers.

Manju *et al.* (1992) reported that number of spadices was positively associated with female flowers in five coconut types.

2.4.3 Among economic characters

Pieris (1934) reported high correlation for nut yield with copra weight. Varieties with heavy husked nuts had higher copra content also (Harland, 1957).

Genotypic correlation between nut yield and copra yield was high and positive in tall variety (Liyanage and Sakai, 1960). Vijayalakshmi *et al.* (1962) reported high positive association between weight and volume of husked nut, weight and volume of unhusked nut and also husked nut weight and unhusked nut weight.

In West Coast Tall, nut yield was positively correlated with annual outturn of both copra and oil but negatively with copra content per nut (Satyabalan, 1982). Similar result that nut yield showed positive and negative association with oil yield and copra content per nut respectively was reported by Bavappa and Sukumaran (1983) in the same variety.

Satyabalan and Mathew (1984) reported that in West Coast Tall, irrespective of the month of harvest, correlation existed in respect of weight between unhusked nut and husked nut, unhusked nut and husk, husked nut and kernel, husked nut and shell, husked nut and copra, kernel and copra and shell and copra.

Balakrishnan and Vijayakumar (1988) reported positive association for copra content with equatorial diameter of nut and unhusked, husked and split nut weight. Manju *et al.* (1992) reported positive correlation between nuts per bunch and annual nut yield in five coconut types.

2.4.4 Between vegetative and reproductive characters

Sreelatha (1987) reported that trunk girth, functional leaves, petiole length, leaf length, leaflets and leaflet length had high positive association with fruit set in West Coast Tall x Choughat Dwarf Orange hybrid. Leaf number was positively associated with spadices in variety Dwarf Green (Kalathiya and Sen, 1991).

2.4.5 Between vegetative and economic characters

Number of opened leaves, old leaves and leaf age were associated positively with nut yield (Patel, 1937). Trunk height was also correlated positively with nut yield (Patel, 1938). Narayana and John (1942) reported that total leaves and trunk girth were positively associated with nut yield.

In West Coast Tall, correlation for trunk height and total leaves with nut yield was high and positive (Satyabalan *et al.*, 1972). Ramanathan (1984) reported positive association for trunk height, trunk girth, functional leaves, total leaves, leaflets and leaf length with nut yield in four dwarf and 26 tall cultivars.

Total leaves and leaf length had positive association with nut yield in West Coast Tall (Kutty and Gopalakrishnan, 1991). Mathew and Gopimony (1991) reported that total leaves had positive correlation with number of bunches in the same variety.

2.4.6 Between reproductive and economic characters

High positive correlation existed for female flowers with nut yield (Pieris, 1934 and Johns, 1938). Spadices, female flowers and fruit set had positive association with nut yield (Patel, 1938). Narayana and John (1942) reported positive correlation for female flowers with nut yield.

Negative genotypic correlation existed between copra yield and flowering period in mother palms of tall variety (Liyanage and Sakai, 1960). High yield was associated with abundant female flowers and high setting percentage (Menon and Pandalai, 1960).

Positive correlation was observed between female flower production and nut yield in tall variety (Satyabalan *et al.*, 1969). Balingasa and Carpio (1983) reported that percent fruit set varied inversely with female flowers in six tall and two dwarf coconut populations of Philippines.

In Dwarf Green variety, positive association for spadices and duration of female phase with nut yield was reported by Kalathiya and Sen (1991). Manju *et al.* (1992) reported positive correlation for spadices with annual nut yield in five coconut types.

2.5 Multiple regression

Liyanage (1962) proposed the inclusion of characters viz., number of bunches produced per year, number of nuts per bunch, weight of husked nut, number of female flowers per bunch and setting percentage in the index for mother palm selection. Criteria for copra production were earliness in bearing, nut yield and nut weight.

Abeywardena and Mathes (1980) evolved an index for selecting mother palms in coconut based on trunk girth, number of opened inflorescences including mature bunches, number of nuts per bunch and number of fronds present at a given time.

Component characters which influenced yield directly were the number of female flowers, number of functional leaves and internodal distance (Sukumaran *et al.*, 1981).

Indirect selection for nut yield based on component characters viz., leaves, female flowers and fruit set was suggested by Louis (1981) and Ohler (1984).

Functional leaves, spikelets with nuts and leaflets had positive direct effects on yield in East Coast Tall coconut (Ramanathan, 1984).

Discriminant function was adopted to formulate selection indices for number of nuts and copra content against seventeen component characters (Louis and Chopra, 1989). Both indices had three common characters with positive role and two common characters with negative role.

Rao and Nair (1989) worked out quadratic regression equations based on heat units during the second phase of nut development. They had multiple correlation coefficients of 0.87 for Choughat Dwarf Orange x Tall, 0.84 for Tall x Choughat Dwarf Orange and 0.80 for Choughat Dwarf Orange x Laccadive Ordinary.

Balakrishnan *et al.* (1991) formulated selection indices by discriminant function analysis technique for 15 hybrids and West Coast Tall. The component characters used were total leaves, leaves $year^{-1}$, nuts $year^{-1}$ and cumulative nut production since first flowering.

An experiment conducted in Indonesia revealed that selection process for improved yields from every generation could be based on total leaf width on each generative phase, leaf scars, bunches and female flowers (Darwis, 1991).

Louis and Chopra (1991) assessed the cause and effect relationship of the contributory factors on copra content. Kernel weight, petiole length and shell thickness had positive direct effect whereas pre-flowering period and kernel thickness had negative direct effects on copra weight.

Kumar *et al.* (1993) worked out the direct and indirect effects of kernel weight, kernel thickness, shell thickness, number of nuts, petiole length, leaves per crown, length of pre-flowering period and leaflets.

Oil production was markedly influenced by nuts per tree, nut weight, mesocarp weight, copra weight, fruit quality value and oil content of which considerable direct effects were shown by the former three characters (Pamin and Asmono, 1993).

Vanaja (1993) studied the direct and indirect effects of various nut characters on copra content and oil content. On copra content, maximum direct effect (positive) was by weight of split nut. But only limited amount of variability in oil content was explained by the nut characters of which weight of split nut had maximum direct (positive) effect.

Materials and Methods

MATERIALS AND METHODS

The present experiment was conducted at Instructional Farm, College of Horticulture, Vellanikkara during 1995-96 on coconut palms planted in 1976 in a Randomised Block Design. All the palms have been maintained under average management as per KAU Package of Practices Recommendations.

3.1 Materials

The nine coconut varieties used in the study were as hereunder:

i) West Coast Tall x Choughat Yellow Dwarf
ii) West Coast Tall x Gangabondam*
iii) Laccadive Ordinary x Gangabondam**
iv) West Coast Tall
v) Philippines
vi) Jawa
vii) Cochin China
viii) New Guinea
ix) Laccadive Ordinary

* released as `Keraganga' by Kerala Agricultural University
** released as `Lakshaganga' by Kerala Agricultural University

3.2 Methods

3.2.1 Design

The experiment on nine varieties as the treatments was conducted in Randomised Block Design with three replications and three palms per plot. The analysis was done on plot means.

3.2.2 Characters

a) Trunk height

The trunk height of each palm was measured from the ground level to the point just below the crown.

b) Trunk girth

Trunk girth was measured at one metre above the ground level.

c) Total leaves

Fully opened functional leaves (ie., leaving the unopened and senile leaves) were recorded as total leaves.

d) Leaves $year^{-1}$

The unopened spindle leaf was marked at the beginning of the experiment, ie., in March 1995. The number of leaves since produced till the completion of one year ie., February 1996 were recorded as leaves $year^{-1}$.

e) Leaf length

Length of rachis of the fourteenth leaf from the unopened spindle leaf was measured as the leaf length.

f) Petiole length

Petiole length of the fourteenth leaf was measured from the base to the point of emergence of leaflets.

g) Spadices year^{-1}

The number of spadices produced per palm during the study period was counted.

h) Spadix length

Length of spadices produced during each month was measured from the base to the tip.

i) Branches spadix^{-1}

Number of branches in the spadices were counted during each month.

j) Female flowers spadix^{-1}

Female flowers in spadices produced during every month were counted.

k) Fruit set (%)

Fruit set was calculated as below:

$$\frac{\text{Number of buttons set}}{\text{Number of female flowers}} \times 100$$

This was done in the spadices produced during each month.

l) Copra yield (kg $palm^{-1}$)

One nut per plot was made into copra during February 1996. Weight of the copra per nut was multiplied by the number of nuts produced per year per palm to get copra yield $palm^{-1}$.

m) Oil content (%)

Percent oil content was estimated by Cold percolation method (Kartha and Sethi, 1957).

n) Oil yield (kg $palm^{-1}$)

Oil yield (kg $palm^{-1}$) was estimated as below:

$$\frac{\text{Copra yield (kg palm}^{-1}\text{) x Oil content (\%)}}{100}$$

o) Nut yield (no. $palm^{-1}$)

The number of nuts produced per palm during the four years from 1992-93 to 1995-96 were recorded and divided by four to estimate nut yield (no. $palm^{-1}$).

3.2.3 Statistical analysis

3.2.3.1 Variability

i) Analysis of variance

Analysis of variance was done as per routine methods. Varietal means were compared using critical difference at 5 per cent level.

ii) Genotypic and phenotypic variances

Variability existing in the various characters was estimated (Burton, 1952) as hereunder:

a) Genotypic variance (GV) $= \dfrac{TMS - EMS}{r}$

b) Phenotypic variance (PV) $= GV + EMS$

c) Genotypic coefficient of variation (GCV) $= \dfrac{\sqrt{GV}}{\text{Overall mean}} \times 100$

d) Phenotypic coefficient of variation (PCV) $= \dfrac{\sqrt{PV}}{\text{Overall mean}} \times 100$

where TMS, EMS and r are the treatment mean square, error mean square and the number of replications respectively in the ANOVA.

e) Heritability (broad sense) $= \dfrac{GV}{PV} \times 100$

iii) Seasonal variability

Seasonal variability was studied for four reproductive characters viz., spadix length, branches spadix^{-1}, female flowers spadix^{-1} and fruit set.

ANOVA as applicable to factorial RBD revealed non-significant Variety x Season interaction. Therefore, seasonal effects were studied based on the overall performance by all the varieties instead of individual performance and variability estimated as standard deviation and coefficient of variation. Overall performance under various months for the various characters is represented as histograms.

3.2.3.2 Correlation and regression analyses

Characters viz., total leaves, leaves $year^{-1}$, spadix length and branches $spadix^{-1}$ (for all of which the level of significance for varietal mean square exceeded 20%) were eliminated from correlation and regression analyses.

In regression analysis, copra yield, oil content, oil yield and nut yield were taken as dependent characters and others as independent characters. Variances and covariances used in regression analysis were estimated on plot means.

i) Simple correlation coefficients

Genotypic, environmental and phenotypic correlation coefficients were calculated as suggested by Singh and Choudhary (1985).

$$\text{Correlation coefficient } ({}^{r}x_1x_2) = \frac{\text{Cov. } x_1x_2}{\sqrt{V(x_1).V(x_2)}}$$

where variances and covariances are genotypic, phenotypic or environmental depending on the kind of correlation coefficient.

ii) Simple regression coefficients

Simple regression coefficients of independent characters on dependent characters were calculated as the ratio of covariance between the characters to the variance of independent character.

iii) Multiple regression

Step-down regression was done using SPAR-1 computer programme. First, multiple regression on dependent character was worked out based on all independent characters. At each step-down, the character that had the least 't' value was eliminated and multiple regression worked out. The step-down process was repeated until the 't' value of the character, that showed the least value, exceeded the table 't' value.

iv) Direct and indirect effects

Direct and indirect effects of component characters on economic characters were estimated as per Singh and Choudhary (1985).

Results

RESULTS

4.1 Variability

4.1.1 Comparison of varieties

4.1.1.1 Vegetative characters

Analysis of Variance and data on vegetative characters are furnished in Tables 1 and 2 respectively.

(i) Trunk height

Varieties did not show significant difference for trunk height at conventional levels of probability (but significant at 6%). Variety Cochin China was the tallest (9.53 m) and the hybrid West Coast Tall x Gangabondam, the shortest (7.57 m).

(ii) Trunk girth

No significant difference was observed among varieties for trunk girth. However, the maximum girth (0.96 m) was recorded in variety Jawa and minimum (0.81 m) in hybrid Laccadive Ordinary x Gangabondam.

(iii) Total leaves

There was no significant difference among varieties for the number of total leaves, which showed a narrow range of 39.7-41.4 per palm.

Table 1. ANOVA (Mean squares) for vegetative characters in nine coconut varieties

Source	df	Mean squares					
		Trunk height (m)	Trunk girth (m)	Total leaves	Leaves year^{-1}	Petiole length (m)	Leaf length (m)
Block	2	2.521* (0.04)	0.000 (0.92)	8.412* (0.04)	1.646 (0.24)	0.002 (0.64)	0.262 (0.10)
Variety	8	1.649 (0.06)	0.008 (0.11)	1.078 (0.85)	0.387 (0.92)	0.021** (0.01)	0.254* (0.05)
Error	16	0.667	0.004	2.240	1.053	0.005	0.098

* Significant at 5% level
** Significant at 1% level

Values in parentheses show the level of significance

Table 2. Vegetative characters of the nine coconut varieties

Sl. No.	Varieties	Characters					
		Trunk height (m)	Trunk girth (m)	Total leaves	Leaves year^{-1}	Petiole length (m)	Leaf length (m)
1	West Coast Tall x Choughat Yellow Dwarf	8.37	0.82	40.7	11.2	1.31^{bc}	6.71^{bcd}
2	West Coast Tall x Gangabondam	7.57	0.88	40.7	11.4	1.33^{bc}	6.37^{abc}
3	Laccadive Ordinary x Gangabondam	7.64	0.81	41.4	12.0	1.37^{c}	7.01^{d}
4	West Coast Tall	7.62	0.86	39.7	10.9	1.19^{a}	6.47^{abc}
5	Philippines	7.96	0.95	40.9	11.3	1.28^{abc}	6.26^{ab}
6	Jawa	9.32	0.96	39.7	11.4	1.24^{ab}	6.80^{cd}
7	Cochin China	9.53	0.91	39.9	11.7	1.34^{bc}	6.54^{abcd}
8	New Guinea	8.94	0.92	40.7	11.8	1.49^{d}	6.70^{bcd}
9	Laccadive Ordinary	8.71	0.88	40.3	11.0	1.32^{bc}	6.07^{a}
CD (5%)		NA	NA	NA	NA	0.12	0.54

Values having any common superscript are not significantly different from one another

(iv) Leaves $year^{-1}$

Leaves produced during the year did not differ significantly among varieties, which had a narrow range of 10.9-12.0.

(v) Petiole length

Varieties showed significant difference for petiole length. The longest petiole (1.49 m) was in the variety New Guinea. West Coast Tall had the shortest petiole (1.19 m) which was on par with the varieties, Philippines and Jawa. The three hybrids produced petioles of moderate size that ranged from 1.31 to 1.37 m.

(vi) Leaf length

Significant difference was present for leaf length among the varieties. Longest leaf (7.01 m) was produced in the hybrid Laccadive Ordinary x Gangabondam, which was on par with the varieties Jawa, Cochin China, New Guinea and West Coast Tall x Choughat Yellow Dwarf. Relatively short leaves were observed in the varieties Laccadive Ordinary, Philippines, West Coast Tall and West Coast Tall x Gangabondam.

4.1.1.2 Reproductive characters

Analysis of variance and data on reproductive characters are furnished in Tables 3 and 4 respectively.

Table 3. ANOVA (Mean squares) for reproductive characters in nine coconut varieties

Source	df	Mean squares				
		Spadices $year^{-1}$	Spadix length (cm)	Branches $spadix^{-1}$	Female flowers $spadix^{-1}$	Fruit set (%)
Block	2	0.593 (0.47)	749.082** (0.00)	11.619 (0.34)	427.933** (0.00)	185.972 (0.12)
Variety	8	1.694 (0.07)	82.580 (0.49)	10.131 (0.47)	101.462 (0.09)	131.616 (0.17)
Error	16	0.736	54.277	10.124	47.952	76.969

** Significant at 1% level

Values in parentheses show the level of significance

Table 4. Reproductive characters of the nine coconut varieties

Sl. No.	Varieties	Characters				
		Spadices year^{-1}	Spadix length (cm)	Branches spadix^{-1}	Female flowers spadix^{-1}	Fruit set (%)
1	West Coast Tall x Choughat Yellow Dwarf	11.11	74.75	33.86	36.17	57.70
2	West Coast Tall x Gangabondam	11.44	66.27	32.49	23.12	58.21
3	Laccadive Ordinary x Gangabondam	11.56	69.33	34.87	30.24	55.17
4	West Coast Tall	11.78	72.57	34.74	30.63	61.73
5	Philippines	11.78	72.87	34.15	24.19	52.89
6	Jawa	9.56	62.31	29.50	17.19	39.73
7	Cochin China	11.67	71.71	34.83	26.41	57.44
8	New Guinea	10.78	72.66	32.10	25.42	50.02
9	Laccadive Ordinary	12.00	75.11	35.04	28.07	60.91

Note: None of the characters showed significance

(i) Spadices $year^{-1}$

Though no significant difference was observed among varieties for the number of spadices at conventional levels of probability, it was significant at 7 per cent. Laccadive Ordinary produced the highest number of spadices annually (12.00) and Jawa the lowest (9.56). Spadix production was moderate in the three hybrids (11.11 to 11.56).

(ii) Spadix length

Varieties showed no significant difference for spadix length. However, the longest spadix (75.11 cm) was in Laccadive Ordinary and the shortest spadix (62.31 cm) in Jawa.

(iii) Branches $spadix^{-1}$

There was no significant difference among the varieties for this character. However, the highest and the lowest number of branches were recorded in varieties Laccadive Ordinary (35.04) and Jawa (29.50) respectively.

(iv) Female flowers $spadix^{-1}$

Difference for the number of female flowers per spadix among varieties was significant, not at 5% level, but at 9%. Female flowers were the highest in West Coast Tall x Choughat Yellow Dwarf (36.17) and the lowest in Jawa (17.19).

(v) Fruit set (%)

No significant difference was exhibited by the varieties for fruit set. The highest fruit set was however in West Coast Tall (61.73%) and the lowest in Jawa (39.73%).

4.1.1.3 Economic characters

Analysis of variance and data on economic characters are furnished in Tables 5 and 6 respectively.

(i) Copra yield

The varieties did not differ significantly for copra yield. However, the highest yield was recorded in the hybrid West Coast Tall x Choughat Yellow Dwarf (18.47 kg) and the lowest in New Guinea (8.49 kg).

(ii) Oil content (%)

Significant difference was observed among the varieties for oil content. The variety with the highest oil content was Jawa (74.13%) whereas the lowest oil content was in the hybrid Laccadive Ordinary x Gangabondam (35.07%). Laccadive Ordinary also was characterised by high oil content (73.40%).

(iii) Oil yield

No significant difference was observed among varieties for oil yield. The highest (10.21 kg) and the lowest (4.08 kg) yields of oil were recorded for Laccadive Ordinary and Laccadive Ordinary x Gangabondam respectively.

Table 5. ANOVA (Mean squares) for economic characters in nine coconut varieties

Source	df	Mean squares			
		Copra yield (kg palm^{-1})	Oil content (%)	Oil yield (kg palm^{-1})	Nut yield (no. palm^{-1})
Block	2	0.976 (1.00)	46.381 (0.68)	0.809 (1.00)	0.212 (1.00)
Variety	8	30.978 (0.19)	404.387* (0.02)	12.417 (0.19)	853.090* (0.02)
Error	16	18.742	117.184	7.567	248.260

* Significant at 5% level

Values in parentheses show the level of significance

Table 6. Economic characters of the nine coconut varieties

Sl. No.	Varieties	Characters			
		Copra yield (kg $palm^{-1}$)	Oil content (%)	Oil yield (kg $palm^{-1}$)	Nut yield (No. $palm^{-1}$)
1	West Coast Tall x Choughat Yellow Dwarf	18.47	53.72^{ab}	9.78	84.36^{d}
2	West Coast Tall x Gangabondam	11.72	60.40^{bc}	6.92	58.36^{abcd}
3	Laccadive Ordinary x Gangabondam	11.72	35.07^{a}	4.08	74.45^{bcd}
4	West Coast Tall	13.12	64.20^{bc}	8.37	75.44^{cd}
5	Philippines	10.78	64.00^{bc}	6.98	55.47^{abc}
6	Jawa	9.34	74.13^{c}	6.95	45.47^{a}
7	Cochin China	16.26	59.27^{bc}	9.45	58.33^{abcd}
8	New Guinea	8.49	63.07^{bc}	5.63	36.67^{a}
9	Laccadive Ordinary	14.07	73.40^{c}	10.21	83.86^{d}
CD (5%)		NA	18.74	NA	27.27

Values having any common superscript are not significantly different from one another

(iv) Nut yield

Varieties differed significantly for nut yield. The best yielder was the hybrid, West Coast Tall x Choughat Yellow Dwarf with 84.36 nuts which was on par with that of Laccadive Ordinary, Cochin China, West Coast Tall and the other hybrids namely West Coast Tall x Gangabondam and Laccadive Ordinary x Gangabondam.

4.1.2 Genotypic and phenotypic variability

Genotypic and phenotypic, variances and coefficients of variation for vegetative, reproductive and economic characters are presented in Table 7.

Vegetative characters, in general, showed low variability with the highest genotypic and phenotypic coefficients of variation for trunk height (6.79 and 11.84% respectively). Higher variation was observed for reproductive characters, than for vegetative characters, with female flowers having the highest genotypic and phenotypic coefficients of variation (15.76 and 30.27% respectively). Economic characters had the highest genotypic and phenotypic variability. Genotypic coefficients of variation ranged from 15.95 (copra yield) to 22.32 (nut yield) whereas phenotypic coefficient of variation ranged from 24.00 (oil content %) to 39.90 (oil yield).

4.1.3 Heritability

Heritability for vegetative, reproductive and economic characters are furnished in Table 7.

Table 7. Genotypic and phenotypic variability and heritability for the various characters

Sl. No.	Characters	Variance		Coefficient of variation (%)		Heritability (%)
		Genotypic	Phenotypic	Genotypic	Phenotypic	
	Vegetative characters					
1	Trunk height (m)	0.327	0.994	6.79	11.84	32.9
2	Trunk girth (m)	0.001	0.005	4.06	8.21	24.5
3	Total leaves	*	1.853	0.00	3.37	0.0
4	Leaves $year^{-1}$	*	0.831	0.00	7.98	0.0
5	Petiole length (m)	0.005	0.010	5.51	7.68	51.5
6	Leaf length (m)	0.052	0.150	3.48	5.91	34.7
	Reproductive characters					
7	Spadices $year^{-1}$	0.319	1.055	5.00	9.09	30.2
8	Spadix length (cm)	*	53.71	0.00	10.35	0.0
9	Branches $spadix^{-1}$	0.002	10.13	0.14	9.50	0.0
10	Female flowers $spadix^{-1}$	17.84	65.79	15.76	30.27	27.1
11	Fruit set (%)	18.22	95.18	7.77	17.77	19.1
	Economic characters					
12	Copra yield (kg $palm^{-1}$)	4.079	22.82	15.95	37.73	17.9
13	Oil content (%)	95.73	212.92	16.09	24.00	45.0
14	Oil yield (kg $palm^{-1}$)	1.616	9.183	16.76	39.90	17.6
15	Nut yield (no. $palm^{-1}$)	201.61	449.87	22.32	33.35	44.8

* Calculated genotypic variance was negative, but treated as zero for calculation of coefficient of variation and heritability

Heritability was absent for characters related to leaf production but high for leaf characters i.e., 51.5 per cent and 34.7 per cent for petiole length and leaf length respectively. In reproductive characters, though heritability was absent for spadix length and branches spadix^{-1}, comparatively high levels were exhibited by spadices year^{-1} (30.2%) and female flowers spadix^{-1} (27.1%). Heritability was high for oil content (45.0%) and nut yield (44.8%) among economic characters but relatively low for copra yield (17.9%) and oil yield (17.6%).

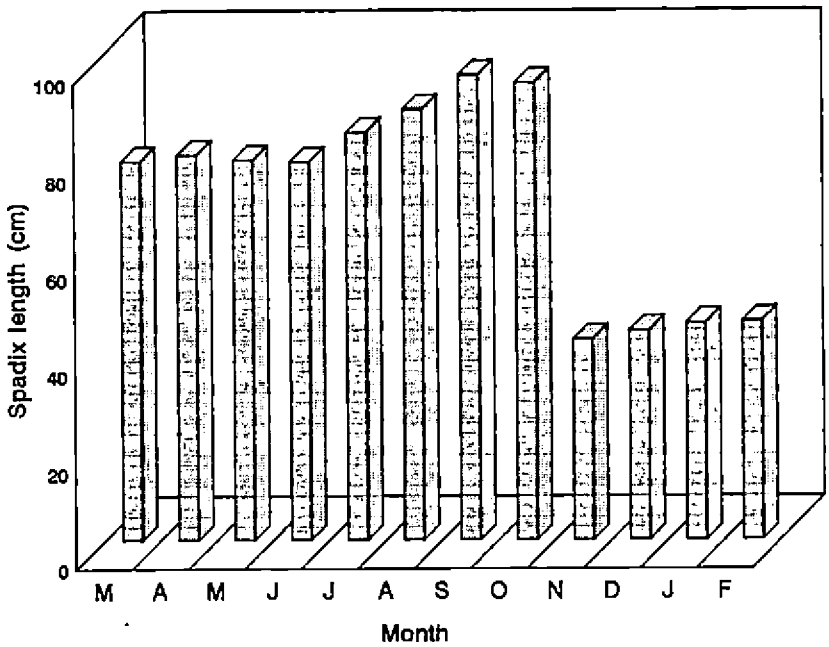
4.1.4 Seasonal variability for the reproductive characters

Seasonal effects on the four reproductive characters studied during twelve-month period (Table 8) are depicted in histograms (Fig. 1). They show seasonal performance averaged over the nine varieties since interaction was absent between varieties and months (see Appendix 1).

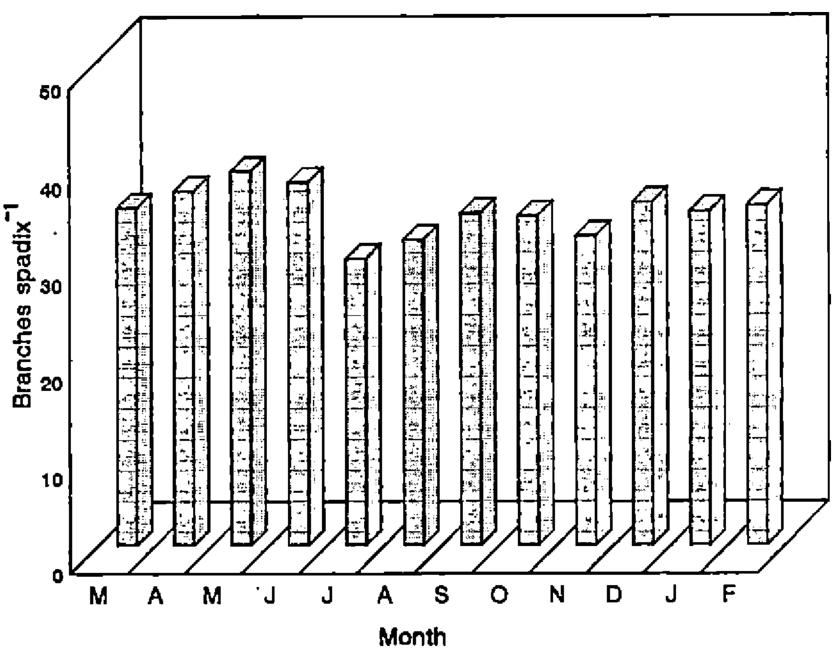
Spadices opened during March-June maintained constant length, but thereafter showed slight enhancement during July-October before finally declining during subsequent months (Fig. 1a). In contrast, no appreciable seasonal variation was evident in branches spadix^{-1} with the number ranging from 27.52 to 38.64 (Fig. 1b). Female flower production was low during the rainy season (13.54 to 17.58 flowers spadix^{-1} during June-November). It picked up during the winter months (December and January) and attained high production during summer months (Fig. 1c). Compared to female flower production, seasonal effect on fruit set was less pronounced and the trend less clear. However, fruit set was generally low during the rainy season. (Fig 1d).

Table 8. Seasonal variability for the reproductive characters

Sl. No.	Months	Spadix length (cm)	Branches spadix^{-1}	Female flowers spadix^{-1}	Fruit set (%)
1	March 95	78.12	34.93	45.05	36.21
2	April 95	79.30	36.61	44.04	58.18
3	May 95	78.24	38.64	37.54	71.74
4	June 95	77.86	27.52	14.64	41.75
5	July 95	83.98	29.61	15.03	42.16
6	August 95	88.70	31.58	14.80	50.50
7	September 95	95.77	34.30	16.30	54.54
8	October 95	94.14	34.04	13.54	52.52
9	November 95	41.33	31.95	17.58	46.04
10	December 95	43.09	33.40	20.62	54.29
11	January 96	44.66	34.47	29.32	77.16
12	February 96	44.97	35.09	53.46	73.31
	Mean	70.85	33.51	26.83	54.87
	SE	9.08	3.02	6.91	9.93
	SD (among months)	20.16	2.88	13.85	12.64
	CV (among months)	28.46%	8.59%	51.63%	23.04%

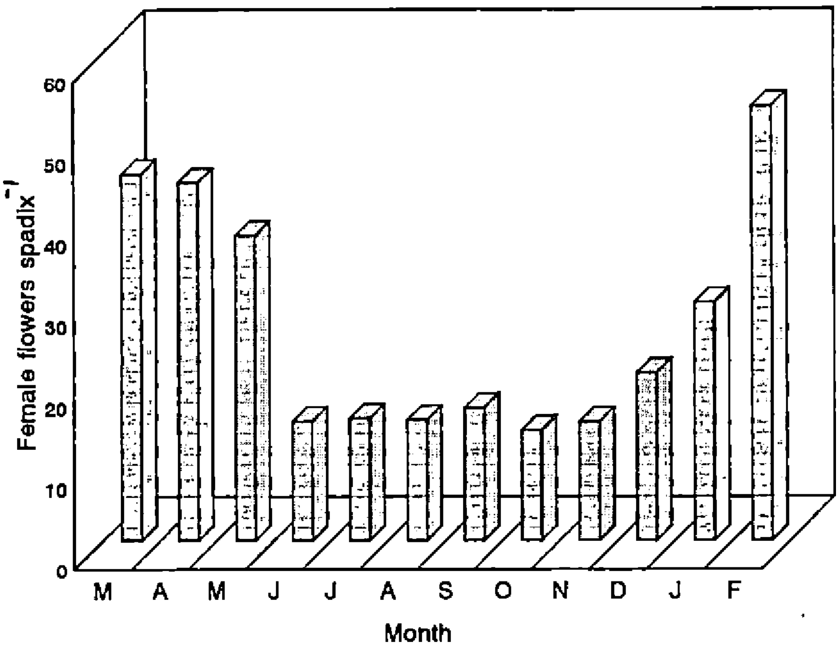


(a) Spadix length

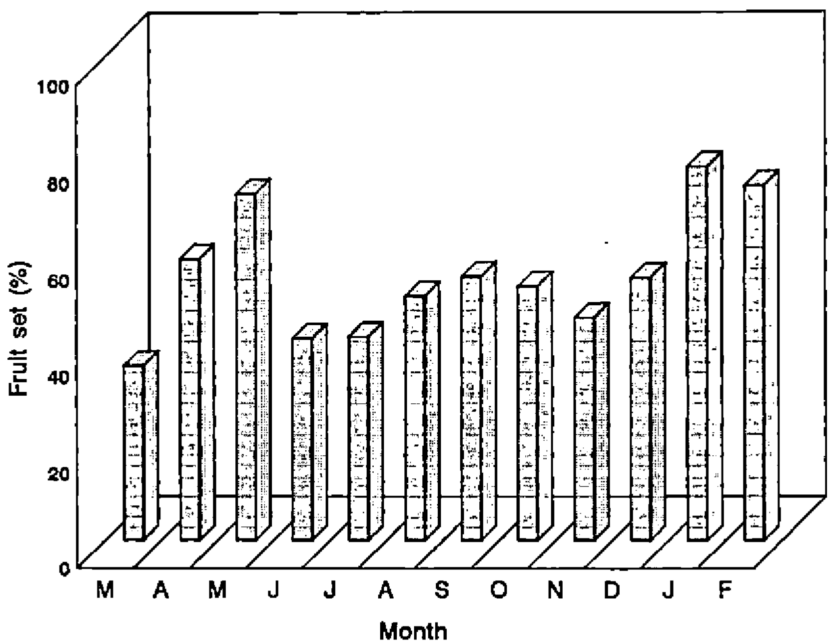


(b) Branches $spadix^{-1}$

Fig.1. Seasonal variability for the reproductive characters



(c) Female flowers spadix^{-1}



(d) Fruit set (%)

4.2 Correlation and regression analyses

4.2.1 Simple correlation

Genotypic, environmental and phenotypic correlation coefficients among vegetative, reproductive and economic characters are presented in Table 9.

4.2.1.1 Genotypic correlation

Trunk characters viz., height and girth were positively correlated. Similarly, correlation for the leaf characters ie., between petiole length and leaf length was positive. But the correlation between trunk girth and leaf length was negative. High negative association was shown by trunk characters with all the reproductive characters. Similar negative relationship was seen for leaf length with spadices year^{-1} and fruit set.

Reproductive characters were positively correlated among themselves. Correlation was significant for economic characters with most of the vegetative and reproductive characters. Copra yield was negatively influenced by trunk girth but positively by all the reproductive characters. Per cent oil content was positively associated with trunk characters but negatively with leaf characters and female flowers spadix^{-1}. Leaf characters influenced oil yield negatively whereas all the reproductive characters did positively. Similarly, a negative association with vegetative characters but positive one with reproductive characters were present for nut yield.

Among the economic characters, correlation was present for all pairs except between copra yield and per cent oil content. However, the correlation was

Table 9. Genotypic, environmental and phenotypic correlation coefficients among various characters

		TH	TG	PL	LL	SY	FF	FS	CY	OC	OY
	G	0.64**									
TG	E	0.40*									
	P	0.47*									
	G	0.31	-0.10								
PL	E	0.14	0.07								
	P	0.21	0.01								
	G	0.03	-0.44*	0.38*							
LL	E	0.24	-0.07	-0.10							
	P	0.17	-0.18	0.11							
	G	-1.06**	-0.94**	0.13	-1.27**						
SY	E	0.33	0.17	-0.31	0.47*						
	P	-0.11	-0.14	-0.12	-0.09						
	G	-0.67**	-1.43**	0.04	0.04	0.90**					
FF	E	-0.11	-0.18	0.05	0.15	-0.06					
	P	-0.21	-0.51**	0.05	0.12	0.22					
	G	-1.31**	-1.62**	-0.08	-1.55**	1.01**	1.38**				
FS	E	0.19	0.15	-0.14	0.62	0.76**	-0.01				
	P	-0.19	-0.24	-0.11	0.05	0.81**	0.31				
	G	-0.36	-0.84**	-0.34	-0.13	1.05**	1.45**	1.59**			
CY	E	0.44*	-0.32	-0.04	-0.14	-0.15	0.05	-0.12			
	P	0.24	-0.43*	-0.13	-0.14	0.13	0.36	0.20			
	G	0.72**	1.19**	-0.49**	-0.71**	-0.21	-0.89**	-0.13	-0.31		
OC	E	-0.15	-0.01	0.20	-0.43	-0.37	0.12	-0.39*	-0.11		
	P	0.19	0.40*	-0.14	-0.54**	-0.30	-0.24	-0.30	-0.16		
	G	0.22	0.29	-0.74**	-0.91**	0.86**	0.51**	1.38**	0.57**	0.61**	
OY	E	0.39*	-0.27	0.11	-0.29	-0.26	0.11	-0.24	0.86**	0.41*	
	P	0.34	-0.15	0.16	-0.44*	0.00	0.20	0.05	0.80**	0.45*	
	G	-0.86**	-1.17**	-0.39*	-0.29	0.77**	1.11**	1.21**	0.91**	-0.42*	0.44*
NY	E	0.47*	-0.19	-0.28	0.00	0.24	0.23	0.16	0.61**	0.04	0.60**
	P	-0.05	-0.52**	-0.33	-0.11	0.43**	0.53**	0.46*	0.67**	-0.17	0.53**

G - genotypic correlation coefficient, E - Environmental correlation coefficient
P - phenotypic correlation coefficient
* Significant at 5% level, ** Significant at 1% level

negative between per cent oil content and nut yield whereas it was positive for others.

4.2.1.2 Environmental correlation

Environmental correlation coefficients were significant only for comparatively few pairs. Among vegetative characters, significant association (positive) was seen only between trunk height and trunk girth, whereas leaf length was similarly associated with the reproductive character spadices year^{-1}. Spadices year^{-1} was positively associated with fruit set. Trunk height showed positive correlation with all the economic characters except per cent oil content which was associated negatively with fruit set. All the significant associations among economic characters were positive. Oil yield was influenced by all the other economic characters. Significant association was seen also between copra yield and nut yield.

4.2.1.3 Phenotypic correlation

Significant correlation among vegetative characters was seen only between trunk characters whereas trunk girth was negatively associated with female flowers spadix^{-1}. Among reproductive characters, spadices year^{-1} was positively associated with fruit set. Trunk girth had correlation with all the economic characters except oil yield, whereas leaf length was negatively associated with both the oil characters. Nut yield was positively correlated with all the reproductive characters. Oil characters were positively correlated between themselves. Copra yield and oil yield were associated positively between each other and also with nut yield.

4.2.2 Simple Regression

Simple regression coefficients (b) and coefficients of determination (R^2) of vegetative and reproductive characters on economic characters are presented in Table 10.

All the economic characters except nut yield were dependent only on vegetative characters especially trunk girth and leaf length. An enhancement of trunk girth by 1 m would be associated with a reduction of copra yield by 28.281 kg per palm and an increase in oil content by 80.462 units, with coefficients of determination being 0.181 and 0.155 respectively. Leaf length influenced the oil characters namely oil content (b = -16.093) and oil yield (b = -2.804) and accounted for 20.5 per cent and 14.4 per cent of their variability respectively. Nut yield was influenced negatively by trunk girth (b = -149.731), but positively by all the reproductive characters. The most influencing character on nut yield was trunk girth which explained 26.5 per cent of the variability whereas, among reproductive characters, maximum influence was by fruit set (R^2 = 0.185).

4.2.3 Multiple Regression

Dependence of economic characters on vegetative and reproductive characters was examined using step-down multiple regression and results are presented in Table 11.

i) Copra yield

Variability in the character could be explained upto 66 per cent when all the seven characters were included in the multiple regression model. During the step-down process spadices year^{-1}, fruit set, petiole length and female flowers year^{-1}

Table 10. Simple regression coefficients of vegetative and reproductive characters on economic characters

Sl. No.	Vegetative/ reproductive characters	Economic characters							
		Copra yield		Oil content		Oil yield		Nut yield	
		b	R^2	b	R^2	b	R^2	b	R^2
	<u>Vegetative characters</u>								
1	Trunk height (m)	-0.890	0.042	2.951	0.048	0.949	0.117	-0.763	0.002
2	Trunk girth (m)	-28.281*	0.181	80.462*	0.155	-6.381	0.023	-149.731**	0.265
3	Petiole length (m)	-5.562	0.014	-21.201	0.022	-4.553	0.024	-68.412	0.109
4	Leaf length (m)	-1.601	0.019	-16.093*	0.205	-2.804*	0.144	-5.353	0.011
	<u>Reproductive characters</u>								
5	Spadices $year^{-1}$	0.630	0.019	-4.524	0.104	-0.036	0.000	8.490*	0.177
6	Female flowers $spadix^{-1}$	0.146	0.093	-0.383	0.069	0.033	0.012	0.901*	0.183
7	Fruit set (%)	0.087	0.037	-0.363	0.067	0.022	0.006	0.867*	0.185

b - Simple regression coefficient
R^2 - Co-efficient of determination
* - Significant at 5% level
** - Significant at 1% level

Table 11. Multiple regression models for economic characters based on vegetative and reproductive characters

Economic character	a	TH (m)	TG (m)	PL (m)	LL (m)	SY	FF	FS (%)	R^2
Copra yield (kg palm^{-1}	71.78	3.40	-44.74	-10.67	-5.47	-0.66	0.16	0.09	0.66
	65.75	3.41	-45.82	-10.37	-5.14		0.14	0.05	0.65
	69.17	3.41	-47.22	-10.74	-5.03		0.14		0.64
	57.42	3.18	-46.65		-5.12		0.13		0.59
	70.17	2.91	-52.20		-5.45				0.54
Oil content (%)	243.41	3.70	30.81	-25.33	-21.57	-7.46	-0.04	0.34	0.54
	241.90	3.78	32.44	-25.75	-21.55	-7.61		0.35	0.54
	275.12	4.85		-27.34	-23.13	-7.46		0.30	0.52
	254.48	4.81		-27.75	-21.22	-5.19			0.50
	220.59	4.42			-21.48	-4.99			0.46
	224.69				-18.33	-5.65			0.36
Oil yield (kg palm^{-1})	59.59	2.47	-22.02	-7.88	-5.75	-1.16	0.08	0.11	0.78
	62.84	2.31	-25.52	-6.97	-5.78	-0.84		0.08	0.74
	58.99	2.35	-27.13	-7.15	-5.35	-0.23			0.70
	55.07	2.37	-26.70	-6.97	-5.27				0.70
	46.47	2.24	-25.91		-5.30				0.64
Nut yield (no. palm^{-1})	273.37	10.21	-170.35	-79.89	-15.67	1.29	0.74	0.53	0.73
	285.04	10.19	-168.26	80.48	-16.30		0.77	0.63	0.73

a - intercept constant, R^2 - coefficient of determination had been eliminated successively in that order. Final model that included trunk height, girth and leaf length gave a coefficient of determination of 54 per cent.

ii) Oil content (%)

A multiple regression model that included all the characters explained 54 per cent of variability in oil content. Female flowers spadix^{-1}, trunk girth, fruit set, petiole length and trunk height had been successively eliminated to yield the final model based on leaf length and spadices year^{-1} explaining 36 per cent.

iii) Oil yield

Proportion of variation in oil yield accounted by the model based on all the independent variables was high (78%). Successive elimination in the order of female flowers spadix^{-1}, fruit set, spadices year^{-1} and petiole length occurred during step-down process. Final model included three vegetative characters only viz., trunk height, trunk girth and leaf length and explained 64 per cent of total variation.

iv) Nut yield

Model with all the independent variables produced a coefficient of determination of 73 per cent. Only one variable namely spadices year^{-1} was eliminated during step down process for the final model.

4.2.4 Direct and indirect effects

i) Copra yield

Direct and indirect effects of the vegetative and reproductive characters on copra yield are furnished in Table 12.

Table 12. Direct and indirect effects of vegetative and reproductive characters on copra yield

	TH	TG	PL	LL	SY	FF	FS	Total correlation coefficient
TH	**0.780**	-0.279	-0.040	-0.138	0.027	-0.131	-0.017	0.204
TG	0.323	**-0.673**	0.000	0.084	0.019	-0.130	-0.050	-0.426
PL	0.135	0.001	**-0.229**	-0.043	0.015	0.017	-0.015	-0.120
LL	0.227	0.112	-0.021	**-0.473**	0.023	-0.040	0.026	-0.139
SY	-0.144	0.088	0.024	0.074	**-0.146**	0.095	0.147	0.138
FF	-0.311	0.265	-0.012	0.057	-0.043	**0.328**	0.020	0.304
FS	-0.063	0.163	0.016	-0.059	-0.104	0.032	**0.206**	0.191

Residual = 0.343
Elements on the principal diagonal are direct effects

Table 13. Direct and indirect effects of vegetative and reproductive characters on oil content (%)

	TH	TG	PL	LL	SY	FF	FS	Total correlation coefficient
TH	**0.276**	0.062	-0.031	-0.177	0.098	0.010	-0.020	0.219
TG	0.114	**0.151**	0.001	0.108	0.070	0.010	-0.060	0.394
PL	0.048	-0.001	**-0.177**	-0.056	0.055	-0.001	-0.017	-0.148
LL	0.080	-0.027	-0.016	**-0.607**	0.083	0.003	0.031	-0.453
SY	-0.051	-0.020	0.018	0.095	**-0.533**	-0.007	0.174	-0.323
FF	-0.110	-0.059	-0.009	0.073	-0.155	**-0.025**	0.024	-0.262
FS	-0.022	-0.037	0.012	-0.076	-0.379	-0.003	**0.245**	-0.260

Residual = 0.464
Elements on the principal diagonal are direct effects

The highest direct effect on the character was by trunk height (0.780), but the total correlation was greatly reduced (r = 0.204). It was due to indirect negative effects through most characters among which trunk girth was most important (-0.279). Other vegetative characters had negative direct effects on copra yield with the highest by trunk girth (-0.673). Among the reproductive characters, only spadices year^{-1} showed negative direct effect. Direct effect of female flowers spadix^{-1} was modified by the trunk characters in opposite directions so that its total correlation with nut yield was comparatively unaffected.

ii) Oil content (%)

Direct and indirect effects of the vegetative and reproductive characters on oil content (%) are presented in Table 13.

The highest direct effect on oil content was by leaf length (-0.607) among the vegetative characters and by spadices year^{-1} (-0.533) among the reproductive characters. The highest indirect effect of spadices year^{-1} was through fruit set (0.174). The highest positive direct effects were shown by trunk height (0.276) and fruit set (0.245). However, correlation of fruit set with oil content was highly modified due to negative indirect effects among which the most pronounced was through spadices year^{-1} (-0.379). Similarly, the direct effects of trunk girth (0.151) was modified to a large extent by positive indirect effects through other vegetative characters viz., trunk height and leaf length.

iii) Oil yield

Direct and indirect effects of the selected characters on oil yield palm^{-1} are furnished in Table 14.

Table 14. Direct and indirect effects of vegetative and reproductive characters on oil yield

	TH	TG	PL	LL	SY	FF	FS	Total correlation coefficient
TH	**0.892**	-0.216	-0.046	-0.228	0.074	-0.104	-0.029	0.343
TG	0.369	**-0.521**	0.001	0.139	0.053	-0.103	-0.088	-0.151
PL	0.154	0.002	**-0.266**	-0.072	0.042	0.014	-0.026	-0.154
LL	0.259	0.093	-0.024	**-0.783**	0.063	-0.031	0.046	-0.379
SY	-0.164	0.068	0.028	0.123	**-0.401**	0.076	0.258	-0.012
FF	-0.355	0.205	-0.014	0.094	-0.117	**0.262**	0.036	0.111
FS	-0.072	0.126	0.019	-0.098	-0.286	0.026	**0.363**	0.077

Residual = 0.216
Elements on the principal diagonal are direct effects

Table 15. Direct and indirect effects of vegetative and reproductive characters on nut yield

	TH	TG	PL	LL	SY	FF	FS	Total correlation coefficient
TH	**0.528**	-0.239	-0.067	-0.089	-0.012	-0.139	-0.021	-0.040
TG	0.219	**-0.578**	0.002	0.055	-0.008	-0.138	-0.064	-0.515
PL	0.091	0.003	**-0.387**	-0.028	-0.007	0.019	-0.019	-0.331
LL	0.154	0.103	-0.035	**-0.306**	-0.010	-0.042	0.033	-0.104
SY	-0.097	0.076	0.040	0.048	**0.064**	0.102	0.188	0.421
FF	-0.210	0.228	-0.021	0.037	0.019	**0.350**	0.026	0.428
FS	-0.043	0.140	0.024	-0.038	0.045	0.035	**0.265**	0.431

Residual = 0.273
Elements on the principal diagonal are direct effects

Trunk height and leaf length had the highest direct effects on the character (0.892 and -0.783 respectively). However, their effects were highly modified due to indirect effects through other components in opposite directions. Reproductive characters had comparatively low direct effects. Here also, indirect effects determined the total correlation, though to a moderate extent. In general, the characters produced the highest indirect effect through trunk height.

iv) Nut yield

Direct and indirect effects of the selected characters on nut yield palm^{-1} are presented in Table 15.

Vegetative characters had higher direct effects on nut yield than the reproductive characters had. The direct effect of trunk height was, however, highly modified due to the indirect effects through all the other characters and the highest indirect effects were through trunk girth and female flowers spadix^{-1}. Among the reproductive characters, female flowers spadix^{-1} had the highest (0.350) and spadices year^{-1}, the lowest (0.064) direct effects. However, the correlation of spadices year^{-1} with nut yield was enhanced to a large extent by the positive indirect effects through the other reproductive characters.

DISCUSSION

The important results obtained in the present study are discussed hereunder:

5.1 Variability

Absence of varietal variance for most of the vegetative characters viz., trunk height, trunk girth, total leaves and leaves $year^{-1}$ is at variance with the general trend of previous observations. For example, Louis and Chopra (1989) reported variation for trunk height among 31 cultivars. Balakrishnan and Namboodiri (1987) reported variation for trunk girth and leaf number among 24 cultivars whereas similar variation was noticed for trunk girth, functional leaves and annual leaf production by Sreelatha (1987). However, Ramanathan *et al.* (1992) reported absence of variability for functional leaves. Significant differences were observed for petiole length and leaf length in the present study which are in agreement with the findings of Pillai *et al.* (1991) and Sreelatha (1987). The three hybrids showed moderate size for petioles whereas the cultivars showed extreme variation.

Reproductive characters though were characterised by the lack of variability among varieties, spadices $year^{-1}$ and female flowers $spadix^{-1}$ showed variability significant at 10% level of probability. Nonsignificant variation was observed also by Vanaja (1993) for the reproductive characters viz., female flowers and fruit set. But the above results are contradictory to the previous results in general [for example, Ratnam and Satyabalan, 1964, Potty *et al.*, 1980, Rajamony *et al.*, 1983]. Despite the nonsignifcant variation, certain trends were observed. For instance, Laccadive Ordinary, a recommended variety for the state, produced the highest values for spadices $year^{-1}$, spadix length and branches $spadix^{-1}$, besides being endowed with comparatively high female flower production and fruit set (%). Likewise, variety Jawa was characterised by the lowest values for all the reproductive characters.

Varieties showed differences with respect to nut yield and oil content (%). But it was not realised in terms of the total yield in copra or oil. This was due to the inverse relationship of these characters with nut yield. For example, the hybrid West Coast Tall x Choughat Yellow Dwarf had the highest nut yield but only moderate oil content (%). Similarly, Laccadive Ordinary x Gangabondam was characterised by high nut yield but the lowest oil content. Significant variation was found in several works for nut yield (for example, Satyabalan and Pillai, 1977, Potty *et al.*, 1980, Ramanathan and Nallathambi, 1988, Balakrishnan and Kannan, 1991) and oil content (for example, Reddy *et al.*, 1980, Louis and Ramachandran, 1981, Balakrishnan and Namboodiri, 1987). Hybrids of Laccadive Ordinary and West Coast Tall with Gangabondam had less nut yield and oil content (%) than their respective female parents.

All characters except female flowers $spadix^{-1}$ and economic characters showed low coefficients of genotypic and phenotypic variation. A high coefficient of variation for female flowers and a low coefficient of variation for spadices $year^{-1}$ and fruit set (%) highlight the importance of the former for nut yield, which showed high coefficient of variation in the present study as well as in previous works (Reddy *et al.*, 1980 and Vanaja, 1993).

Heritability (broad sense) was nil in the case of total leaves, leaves $year^{-1}$, spadix length and branches $spadix^{-1}$ owing to the absence of genetic variance. It ranged from 17.6 per cent to 51.5 per cent for other characters. Nut yield $palm^{-1}$ showed a high heritability (44.8%) second only to petiole length (51.5%). This is in agreement with the findings of Lakshmanachar (1959) and Bavappa *et al.* (1973). Similarly, high heritability for oil content in the present study (45%) is supported by the reports of Bavappa and Sukumaran (1983) and Meunier (1984). Contradictory to the present findings, Liyanage and Sakai (1960) obtained heritability higher for copra yield than for nut yield.

5.2 Seasonal effects

Of the reproductive characters studied for the seasonal effect, female flower production fluctuated the most over months. Female flowers $year^{-1}$ along with fruit set (%), the two most important characters for nut yield, were generally low during the rainy season (June to November). This is in agreement with the results of Muhammed *et al.* (1970) and Sreelatha and Kumaran (1991). Low fruit set during rainy season is possibly due to the hindrance to the pollination. The trend in female flower production with the maximum during summer months was observed by Marechal (1928), Patel (1938) etc.

Female flower production closely follows the changes in the soluble and insoluble fractions of carbohydrates in the stem and leaves during initiation stages which occur about twelve months before the spathe opening (Bai and Ramadasan, 1982). They observed low sugar content in stem and leaves during summer when female flower production was at the peak. Enhanced flow of sugars from stem to inflorescence during summer because of comparatively more sunshine hours was suggested. In the present study summer months showed an average sunshine hours of 262.3 hrs and rainfall 123 mm compared to 154.92 hrs and 385.85 mm respectively during rainy months (June to November).

5.3 Correlation

Correlation observed between two characters in a genetically variable population is of phenotypic nature since variability is contributed both by genotype and environment. Phenotypic correlation is the net result of genotypic and environmental correlations and hence its magnitude is intermediate. In the present study, phenotypic correlation coefficients were generally less than genotypic because environmental correlation coefficients were either less or in opposite direction in relation to the genetic.

Negative genotypic association was observed only in cases where vegetative characters were involved. Correlation between vegetative and reproductive characters was negative wherever it was significant contradicting the results in Tall x Choughat Dwarf Orange population (Sreelatha, 1987). Similarly, correlation between vegetative and economic characters was in general negative, though oil content showed positive correlation with trunk characters.

In contrast to the above trends, reproductive characters showed high positive correlation with economic characters except oil content which had either a nonsignificant or a negative correlation. Negative association for female flowers with nut yield was reported previously (Nampoothiri *et al.*, 1975). Reproductive characters showed correlation that was positive and high. Sreelatha (1987) reported similar results in WCT x CDO hybrid. Correlation among economic characters was in general positive though nut yield and oil yield were negatively associated. Positive association was reported by Liyanage and Sakai (1960) for copra and nut yield.

5.4 Multiple regression

Determination of a complex character by a set of interrelated component characters by use of multiple regression is of importance in crop improvement. Step-down regression is one method for eliminating less important characters in a multiple regression model. This is achieved by successive elimination of the least contributing character at each step until such elimination results in a drastic reduction in the coefficient of determination.

Only a limited number of works was done in coconut in this area viz., Abeywardena and Mathes (1980) and Darwis (1991). Inclusion of all the component characters in the multiple regression models explained the variability in oil yield to the maximum extent and percent oil content, to the minimum. In the final model for nut yield, only spadices year^{-1} could be excluded without significant reduction in the coefficient of determination, whereas for other economic characters, upto four or five characters could be excluded. Only leaf length was retained in the final models of all economic characters and trunk characters (trunk height and trunk girth) except for oil content. No reproductive character was included in the final models of copra or oil yield. Spadices year^{-1} appeared in the final model for oil content whereas female flowers spadix^{-1} and fruit set for nut yield.

5.5 Direct and indirect effects

Correlation coefficients observed between complex and component characters are the ultimate reflection of direct and indirect effects of the latter on the former. Path analysis is a technique to partition the total correlation in terms of direct and indirect effects so that direct influence of component characters unconfounded by other characters can be understood. In coconut only a limited number of works of this nature had been done - Kumar *et al.* (1993) on copra yield, Pamin and Asmono (1993) on oil yield and Vanaja (1993) on copra content.

The present study examined the effects of four vegetative characters and three reproductive characters on copra yield, oil content, oil yield and nut yield. In most cases, the direct effects of component characters on economic characters were affected by the influence of other component characters as evidenced by lower correlation coefficients. However, both direct effects and correlation coefficients were generally in the same direction. Moreover, the direct effects by a component character were of same direction on all economic characters. For example, trunk height exerted positive and leaf length, negative effects on all the four economic characters. Compared to the reproductive characters, high direct effects were exerted by vegetative characters of which trunk height was the most prominent.

Results from correlation, regression and path analyses that reproductive characters exerted less influence, than vegetative, on economic characters are at variance with the logical expectation and also the previous findings (Sukumaran *et al.*, 1981, Louis, 1981, Ohler, 1984 etc.). Female flowers and fruit set are expected to have a high influence on the economic characters. These characters, in the present study, showed high variability and therefore cannot be attributed as the reason for the lack of correlation and regression.

The study had been carried out and the data on all characters had been recorded during March 1995 to February 1996. The economic characters recorded during the study would be directly influenced by the reproductive characters during the previous year (Menon and Pandalai, 1960). Correlation was estimated in this study between the reproductive and economic characters both recorded during current year. It would, therefore, be the product of the correlation of reproductive characters during previous year with economic characters during current year as well as that of the former with reproductive characters during current year. Since yield characters are expected to be strongly influenced by female flower production and percent fruit set of previous year, the low correlation observed in this study might be attributed to a lack of correlation for these characters between years, suggesting the presence of genotype x environment (year) interaction.

Summary

SUMMARY

The nine coconut varieties studied belonged to diverse origin. They included the most widely cultivated local cultivar West Coast Tall, Laccadive Ordinary, four exotic varieties and three hybrids. However varietal variation was absent for most characters at the chosen levels of probability. Consequently, genotypic variation was generally low. Certain characters viz., petiole length, leaf length, oil content (%) and nut yield showed high variability. Female flowers spadix^{-1} and economic characters showed comparatively high genotypic and phenotypic variation. Heritability ranged from zero to 51.5 per cent for various characters with petiole length, oil content and nut yield in that order showing the highest values.

Seasonal variability for reproductive characters was pronounced in female flower production compared to branches spadix^{-1}, spadices year^{-1} and fruit set. Production of female flowers was low during the rainy season but picked up during winter months and attained the maximum during summer months.

Phenotypic correlation was generally less than genotypic since environmental correlation was either less or in opposite direction in relation to the genetic. Genetic correlation was in general positive, not only among economic characters, but also for them with reproductive characters. However, vegetative characters were in general negatively associated with reproductive and economic characters.

Inclusion of all the component characters in the multiple regression models explained the variability in oil yield to the maximum extent and oil content (%) to the minimum. In the final model for nut yield, only spadices year^{-1} could be

excluded without significant reduction in the coefficient of determination. No reproductive character was included in the final models of copra yield or oil yield.

Path analysis showed that the direct effects of component characters on economic characters were affected by the influence of other component characters as evidenced by lower correlation coefficients. However, both direct effects and correlation coefficients were in the same direction. Moreover, the direct effects by a component character were of the same direction on all economic characters. Compared to vegetative characters, low direct effects were exerted by reproductive characters.

Results from correlation, regression and path analyses that reproductive characters exerted less influence than vegetative characters on economic characters deviated from the logical expectation and previous literature. This may be attributed to a lack of correlation for reproductive characters between current and previous year suggesting the presence of genotype x environment (year) interaction.

References

REFERENCES

Abeywardena, V. 1971. Yield variations in coconut. *Ceylon Cocon. Q.* **22**:97-103

Abeywardena, V. 1976. Relationship between leaf length and yield in coconut. *Ceylon Cocon. Q.* **27**:47

Abeywardena, V. and Mathes, D.T. 1980. A Biometrical approach to evolving a selection index for seed parents in coconut (*Cocos nucifera* L.). *Ceylon Cocon. Q.* **31**:112-118

Aiyadurai, S.G. 1962. Report of a Botanist. *Cocon. Bull.* **16**(8):311-314

Babu, K.S., Asan, R.B., Bhaskaran, C., Mohanakumaran, N. and Kunju, U.M. 1993. Coconut yield response to monthly rainfall. *Indian Cocon. J.* **23**(10):8-10

Bai, K.V.K. and Ramadasan, A. 1982. Changes in the carbohydrate fractions in relation to female flower production in coconut. *J. Plant. Crops* **10**(2):124-128

Balakrishnan, P.C. and Kannan, K. 1991. Evaluation of certain coconut (*Cocos nucifera* L.) hybrids under rainfed conditions. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.109-111

Balakrishnan, P.C. and Namboodiri, K.M.N. 1987. Genetic divergence in coconut. *Indian Cocon. J.* **18**(7):13-17

Balakrishnan, P.C. and Vijayakumar, N.K. 1988. Performance of Indigenous and exotic cultivars of coconut in the Northern region of Kerala. *Indian Cocon. J.* **19**(1):3-7

Balakrishnan, P.C., Nambiar, S.S. and Rajan, K.M. 1991. Selection indices in coconut. *Coconut Research and Development*. Nayar, M.M. (ed.). Wiley Eastern Ltd., New Delhi, p.137-139

Balingasa, E.N. and Carpio, C.B. 1983. Genetic potential of some coconut population of the Philippines. *Coconut Research and Development*. Nayar, N.M. (ed.). Wiley Eastern Ltd., New Delhi, p.71-81

Bavappa, K.V.A. and Sukumaran, C.K. 1983. Coconut improvement by selection and breeding - A review in the light of recent findings. *Coconut Research and Development*. Nayar, N.M. (ed.). Wiley Eastern Ltd., New Delhi, p.44-55

Bavappa, K.V.A., Sukumaran, C.K. and Mathew, J. 1973. A study of F_1 hybrids of Tall x Dwarf coconuts and its bearing on the genetics of dwarfness. *J. Plant. Crops*. I (Suppl.):1-6

Bhaskaran, U.P. and Leela, K. 1964. Hybrid coconut - Tall x Dwarf - a comparative study with parental types. *Agric. Res. J. Kerala* **1**(2):67-84

Bhaskaran, U.P. and Leela, K. 1983. Seasonal influence on yield of Tall x Dwarf and West Coast Tall coconuts in Kerala, India. *Coconut Research and Development*. Nayar, N.M. (ed.). Wiley Eastern Ltd., New Delhi, p. 136-143

* Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassld. Cong.* **1**:277-283

Chan, E. 1979. Growth and early yield performance of Malayan Dwarf x Tall coconut hybrids on the coastal clays of Peninsular Malaysia. *Oleagineux* **34**(2):65-69

Darwis, S.N. 1991. Indonesian coconut research highlights. *Indian Cocon. J.* **22**(6&7):22-24

George, M.V. 1997. Status of Plantation Crops in India. *J. Plant. Crops* **25**(1):1-14

Gopimony, R. 1982. Preliminary observations on a local coconut type 'Komadan'. *Proc. PLACROSYM V*, CPCRI, Kasaragod, December 15-18, 1982, p.177-179

* Harland, S.C. 1957. The improvement of the coconut palm by breeding and selection. Circular paper No.7/57. Coconut Research Institute Bulletin, Ceylon (15):1-14

Islam, M.S., Paul, T.K., Rashid, M.A. and Ahmad, A. 1994. Variation in Bengladeshi coconut as compared with exotic coconut cultivars. *Indian Cocon. J.* **25**(6):10-12

* Johns, R. 1938. A study of coconut palm yields and seed selection in Zanzibar. *E. Afr. agric. J.*, **3**:186-194

Joseph, P.A., Balakrishnan, P.C. and Nayar, N.K. 1992. Comparative performance of West Coast Tall and Lakshadweep Ordinary cultivars of coconut. *Indian Cocon. J.* **23**(7):10-12

Kalathiya, K.V. and Sen, N.L. 1991. Correlation among floral and yield characteristics in coconut, variety Dwarf Green. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.116-117

Kannan, K. and Nambiar, P.K.N. 1974. A comparative study of six tall types (var. *Typica*) of coconut crossed with semi tall Gangabondam (var. *Javanica*). *Agric. Res. J. Kerala* **12**(2):124-130

Kartha, A.R.S. and Sethi, A.S. 1957. A cold percolation method for rapid gravimetric estimation of oil in small quantities of oil seeds. *Indian J. agric. Sci.* **27**:211-217

Krishnan, P. and Nambiar, K.P.P. 1972. Effect of different dwarfs on the performance of Tall x Dwarf hybrids. *Cocon. Bull.* **11**(10):2-5

Kumar, A.L.R., Rangaswamy, S.R.S. and Sreedharan, C.S. 1993. Genetic improvement of copra out turn in coconut palms. *South Indian Hort.* **41**(1):33-39

Kutty, M.C.N. and Gopalakrishnan, P.K. 1991. Yield components in coconut palms. *Coconut Breeding and Management.* Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.94-98

Lakshmanachar, M.S. 1959. A preliminary note on the heritability of yield in the coconut. *Indian Cocon.J.* **12**(2):65-68

Liyanage, D.V. 1962. The use of isolated seed gardens for coconut seed production. *Indian Cocon. J.* **15**(3/4):105-110

Liyanage, D.V. and Sakai, K.I. 1960. Heritabilities of certain yield characters of the coconut palm. *J. Genet.* **57**(2&3):245-252

Louis, I.H. 1981. Genetic variability in coconut palm (*Cocos nucifera* L.). *Madras agric. J.* **68**(9):588-593

Louis, I.H. and Annappan, R.S. 1980. Environmental effects on yield of coconut palms. *Indian Cocon. J.* **10**(12): 1-3

* Louis, I.H. and Chopra, V.L. 1989. Genetic divergence in coconut (*Cocos nucifera* L.). Biological Approaches and Evolutionary trends in plants. International Symposium of Plant Biosystematics, p.11-20

Louis, I.H. and Chopra, V.L. 1991. Exploiting heterosis in coconut palms. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.69-74

Louis, I.H. and Ramachandran, T.K. 1981. Note on the oil content of some varieties of coconut palm. *Indian Cocon. J.* **12**(5):4-5

Manju, P. 1992. Fruit component and seedling progeny analysis of Komadan coconut types. Ph.D.(Ag.) thesis, Kerala Agricultural University, Vellanikkara, Thrissur, India

Manju, P., Gopimony, R. and Saraswathy, P. 1992. Yield components in Komadan coconut type as compared to West Coast Tall and Natural Cross Dwarf. *Abstracts of papers presented in Gregor Johan Mendel Birthday Lecture Series and Symposium International - 1992, July 22, 23*. Department of Botany, University of Calicut, p.40-41

Marechal, H. 1928. Observations and preliminary experiments on coconut with a view to developing improved seednuts for Fiji. *Agric. J. Fiji* **1**:1-4

Mathew, T. and Gopimony, R. 1991. Heritability and correlations in West Coast Tall Coconut palms. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.103-105

Mathew, T., Gopimony, R. and Gangadharan, P. 1984. Evaluation of super mother palms of coconut by progeny analysis. *Agric. Res. J. Kerala* **22**(2):186-190

Menon, K.P.V. and Pandalai, K.M. 1960. *The Coconut Palm - A Monograph*. Indian Central Coconut Committee, Ernakulam, Kerala, India, p.384

Meunier, J., Rognon, F. and Lamothe, M. de Nuce de. 1982. Analysis of Nut components in the coconut. Study of sampling. *Oleagineux* **32**(1):13-14

Meunier, J., Sangare, A., Saint, J.P., Le and Bonnot, F. 1984. Genetic analysis of yield characters in some hybrids of coconut (*Cocos nucifera* L.). *Oleagineux* **39**(12):585-586

Muhammed, S.V., Venkateswaran, A.N. and Rajagopalan, R. 1970. Seasonal variations in yield and the yield components in coconut under east coast conditions. *Madras agric. J.* **57**(9, suppl.):7

Nambiar, M.C. and Ravindran, P.S. 1974. Pattern of genetic variation in the reproductive characters of coconut. *Indian J. Genet.* **34A**:75-82

Nambiar, M.C., Mathew, J., Kutty, S.S. 1970. Inheritance of nut production in coconut. *Indian J. Genet. and Plant Breeding* **30**(3):599-603

Nambiar, M.C., Sreedharan, A. and Sankar, N. 1969. Preliminary observations on growth pattern of, and the likely effect of seasons on, nut development in coconut. *Indian J. agric. Sci.* **39**(5):455-461

Nambiar, P.K.N. and Govindan, M. 1989. Coconut Research Institutes in India. Regional Agricultural Research Station, Pilicode. *Indian Cocon. J.*, **20**(6):13-20

Nambiar, P.K.N. and Rao, G.S.L.H.V.P. 1991. Varietal and seasonal variations in oil content of coconut. *Coconut Breeding and Management.* Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.283-286

* Nampoothiri, K.U.K., Satyabalan, K. and Mathew, J. 1975. Phenotypic and genotypic correlations of certain characters with yield in coconut. *4th FAO Tech. Working Party Cocon. Prod. Prot. and Processing.* Kingston, Jamaica

Narayana, G.V. 1940. Annual Report of the Agric. Res. Stn. Nileshwar III for 1938-39. Govt. Press, Madras, p.483

Narayana, G.V. and John, C.M. 1942. Annual Report of the Agricultural Research Station, Kasaragod for the year 1940-41, Report on the work of the Agricultural stations in the Madras Presidency for 1940-41. p.415-416

Ohler, J.G. 1984. *Coconut, tree of life*. FAO plant production and protection paper 57. Food and Agricultural Organisation, United Nations, Rome, p.446

*Pamin, K. and Asmono, D. 1993. Path analysis of oil production and its components in coconut. *Buletin Pusat Penelitian Kelapa Sawit* **1**(2):189-197

Panda, K.C., Sasmal, S. and Swain, J.N. 1985. A note on the performance of exotic varieties of coconut in Orissa. *Indian Cocon. J.* **16**(7):12-18

Patel, J.S. 1937. Annual Report of the Agricultural Research Station, Nileshwar II for the year 1934-35, Report on the work of the Agricultural Research Stations in the Madras Presidency for 1934-35. p.277

Patel, J.S. 1938. *The Coconut - A Monograph*. Govt. Press, Madras, p. 313

*Pieris, W.V.D. 1934. Studies on the coconut palm-1. Morphological characters and standards of selection. *Trop. Agriculturist.* **82**:75-97

Pillai, R.V. and Satyabalan, K. 1960. A note on the seasonal variation in yield, nut characters and copra content in a few cultivars of coconuts. *Indian Cocon.J.* **13**(2):45-55

Pillai, R.V., Rao, E.V.V.B. and Kumaran, P.M. 1991. Characterisation of coconut cultivars. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.75-82

Potty, N.N., Naik, B.J., Rajamony, L. and Nambiar, P.K.R. 1980. Comparative performance of eight coconut varieties in red loam soil. *Indian Cocon. J.* **11**(5):1-2

Rajamony, L., Kannan, K. and Balakrishnan, P.C. 1983. Comparative performance of coconut hybrids in the laterite soil under rainfed conditions - A preliminary study. *Indian Cocon. J.* **14**(8):7-11

Ramachandran, T.K., Raveendran, T.S., Ramanathan, T. and Louis, I.H. 1990. VHC 2 A new T x D hybrid coconut for Tamil Nadu. *Madras agric. J.* **77**(5&6):211-216

Ramanathan, T. 1984. Character association in coconut. *Madras agric. J.* **71**(3):191-192

Ramanathan, T. 1984. Path coefficient analysis for yield in East Coast Tall coconut. *Proc. PLACROSYM-VI*, RRII, Kottayam. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, p.23-29

* Ramanathan, T. and Louis, I.H. 1983. Heterosis in coconut (Abstract). In Pre-Congress Scientific meeting on Genetics and Improvement of Heterotic Systems. School of Genetics, TNAU, Coimbatore, India, p.16

Ramanathan, T. and Nallathambi, G. 1988. Performance of unirrigated East Cost Tall x Dwarf Green and East Coast Tall x Choughat Dwarf Orange Coconut Hybrids. *Indian Cocon. J.* **18**(12):3-4

Ramanathan, T., Thangavelu, S., Sridharan, C.S. and Alarmelu, S. 1992. Performance of coconut cultivars and hybrids under semidry condition. *Indian Cocon. J.* **23**(6):9-11

Rao, E.V.V.B., Pillai, R.V. and Mathew, J. 1991. Relative drought tolerance and productivity of released coconut hybrids. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.144-149

Rao, G.S.L.H.V.P. 1991. Performance of T x D coconut hybrids in drought years under irrigated conditions in red sandy loam. *Coconut Breeding Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.150-155

Rao, G.S.L.H.V.P. and Nair, R.R. 1989. Influence of weather on nut development in coconut. *J. Plant. Crops* **16**(Suppl.):469-473

Ratnam, T.C. and Satyabalan, K. 1964. A note on the study of a few cultivars of coconut. *Indian Cocon. J.* **17**(1):69-76

Raveendran, T.S., Vijayaraghavan, H. and Ramachandran, T.K. 1989. Some physiological aspects and production trends of certain coconut hybrids and their parents. *Cocos* **7**:36-41

Reddy, N.K., Azeemoddin, G., Ramayya, D.A. and Rao, S.D.T. 1980. Post harvest technology of coconuts. Part II. Component parts of Indian Coconuts. *Indian Cocon. J.* **11**(8):8-9

Santos, C.A., Cano, S.B. and Ilagan, M.C. 1981. Variability of Nut components and copra recovery in various coconut populations. *The Philippine J. Cocon. Studies* **6**(1):34-39

Satyabalan, K. 1982. Yield capacity and transmitting power of mother palms in coconut. *Indian Cocon. J.* **13**(4):5-9

Satyabalan, K. 1994. Effect of weather factors on coconut and copra production in Kerala. 1. Effect of seasonal factors on coconut yield and yield attributes. *Indian Cocon. J.* **24**(12):6-13

Satyabalan, K. and Mathew, J. 1984. Correlation studies on the nut and copra characters of West Coast Tall coconuts harvested during different months of the year. *J. Plant. Crops* **12**(1):17-22

Satyabalan, K. and Pillai, R.V. 1977. Yield performance and nut and copra characters of eight germplasm introductions coconut. *Indian J. agric. Sci.* **47**(9):430-434

Satyabalan, K. and Rajagopal, K. 1983. The Malayan Dwarf Coconut. *Indian Cocon. J.* **13**(12):11-21

Satyabalan, K., Mathew, J. and Radhakrishnan, V. 1972. Yield variation and its relationship with age and growth of underplanted coconut palms. *Oleagineux* **27**(5):257-259

Satyabalan, K., Ratnam, T.C. and Menon, R.M. 1968. Need for selection among dwarf pollen parents in the production of Tall x Dwarf coconut hybrids. *Indian J. agric. Sci.* **38**(1):155-160

Satyabalan, K., Sankar, N. and Ratnam, T.C. 1969. Studies on the Bearing Tendency of the coconut palm (*Cocos nucifera* L.) II - Factors affecting variation in Annual yield of palms. *Trop. Agric. Trin.* **46**(4):353-357

Shylaraj, K.S., Bindu, M., Gopakumar, K. and Gopimony, R. 1991. Comparing Komadan coconut type with West Coast Tall. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.106-108

Singh, R.K. and Choudhary, B.D. 1985. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi, p.318

*Siqueira, L.A., Siqueira, E.R.DE. and Ribeiro, F.E. 1995. Performance of hybrid coconut palms in the North East of Brazil. *Plantations, Recherche, Developpement* **2**(1):48-53

Sreelatha, P.C. 1987. Variability studies on certain T x CDO F_1 hybrids of coconut (*Cocos nucifera* L.). M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, India

Sreelatha, P.C. and Kumaran, K. 1991. Seasonal variation in floral characters of T x CDO coconut hybrids. *Coconut Breeding and Management*. Silas, E.G., Aravindakshan, M., Jose, A.I. (eds.). Kerala Agrl. University, Vellanikkara, Thrissur, India, p.90-93

* Sukumaran, C.K., Narasimhayya, C. and Vijayakumar, G. 1981. Path Coefficient Analysis in Coconut. Genetics, Plant Breeding and Horticulture. Vishveshwara, S. (ed.), p.191-199

Taffin, G.de., Zakra, N. and Bonny, C.P. 1991. Dwarf x Tall coconut hybrid performance under commercial conditions in Côte-d' Ivoire. *Oleagineux* **46**(5):194-195

Thampan, P.K. 1975. *Handbook on Coconut Palm*. Oxford and IBH Publishing Co., New Delhi, p.311

Vanaja, T. 1993. Effect of harvesting time on seednut characters in coconut. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, India

Vijayalakshmi, K., Pillai, M.D. and Marar, M.M.K. 1962. Studies on the development of coconuts during the different months of the year. *Indian Cocon. J.* **15**(2):66-69

Vijayaraghavan, H., Raveendran, T.S. and Ramachandran, T.K. 1993. Seasonal variation in the production of spathes in certain coconut hybrids and their parents. *Indian Cocon. J.* **23**(12):9-11

Vijayaraghavan, H., Raveendran, T.S. and Ramanathan, T. 1988. Influence of weather factors on the yield of rainfed coconut (*Cocos nucifera* L.). *Indian Cocon. J.* **18**(9):7-9

*Originals not seen

Appendix 1. ANOVA for seasonal effects on reproductive characters

Source	df	Mean square			
		Spadix length (cm)	Branches spadix^{-1}	Female flowers spadix^{-1}	Fruitset (%)
Variety (V)	8	1896.330**	365.590**	3111.694**	4942.196**
Month (M)	11	35933.725**	732.961**	16952.710**	14118.256**
V x M	88	738.529	84.112	319.015	1012.344
Error	864	742.327	81.907	441.142	874.190

** Significant at 1% level

GENETIC VARIABILITY AND CORRELATIONS IN NINE DIVERGENT VARIETIES OF COCONUT
(*Cocos nucifera* L.)

By
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ABSTRACT OF A THESIS
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ABSTRACT

An experiment was conducted at Instructional Farm, College of Horticulture, Vellanikkara during 1995-96 on nine coconut varieties viz., West Coast Tall x Choughat Yellow Dwarf, West Coast Tall x Gangabondam, Laccadive Ordinary x Gangabondam,. West Coast Tall, Philippines, Jawa, Cochin China, New Guinea and Laccadive Ordinary. Significant varietal variance was absent among several characters. Economic characters showed the highest genotypic coefficient of variation (16 to 22%). Among the vegetative and reproductive characters, heritability was maximum for petiole length (52%) followed by the economic characters percent oil content and nut yield (45% each).

Among the four reproductive characters studied for seasonal variability viz., spadix length (SL), branches spadix^{-1} (BS), female flowers spadix^{-1} (FF) and fruit set (FS), FF showed the maximum variation. FF andFS had been low during the rainy months. SL was markedly reduced during the winter months.

Phenotypic correlation coefficients were generally lower than genetic since environmental correlation was either less in magnitude or in opposite direction in relation to the genetic. Genotypic correlations were mostly negative where vegetative characters were involved and positive for other pairs. Only nut yield among the four economic characters was correlated with both vegetative and reproductive characters. Other economic characters were dependent only on vegetative characters. Similarly step-down regression revealed that only vegetative characters were retained in the final model for all the economic characters except nut yield.

Vegetative characters also showed higher direct effects than reproductive characters on the variability of economic characters. Trunk height generally produced highest direct effects on the economic characters, but was modified by the indirect effects to large extent except in the case of oil content (%).

Correlation, regression and path analyses suggested that reproductive characters had less effect on economic characters when all the characters were recorded during the same year. This may possibly be due to genotype x season (year) interaction for the reproductive characters.