MORPHOLOGICAL AND BIOCHEMICAL CHARACTERIZATION OF COCONUT (*Cocos nucifera* L.) GERMPLASM

by

P.V. Sreejith

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

DEPARTMENT OF PLANTATION CROPS AND SPICES
COLLEGE OF HORTICULTURE
KAU P.O., THRISSUR - 680 656
KERALA

2006

DECLARATION

I hereby declare that the thesis entitled **"Morphological and biochemical characterization of coconut (*Cocos nucifera* L.) germplasm"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara P.V. Sreejith

CERTIFICATE

Certified that the thesis entitled **"Morphological and biochemical characterization of coconut (*Cocos nucifera* L.) germplasm"** is a record of research work done independently by **Mr. P. V. Sreejith** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

Vellanikkara

Dr. P.V. Nalini
Chairperson, Advisory Committee
Associate Professor
Department of Plantation Crops and Spices
College of Horticulture
Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. P.V. Sreejith,** a candidate for the degree of **Master of Science in Horticulture**, with major field in Plantation Crops and Spices, agree that the thesis entitled **"Morphological and biochemical characterization of coconut (*Cocos nucifera* L.) germplasm"** may be submitted by Mr. P.V. Sreejith, in partial fulfilment of the requirements for the degree.

Dr. P. V. Nalini
(Chairperson, Advisory Committee)
Associate Professor
Department of Plantation Crops and Spices
College of Horticulture
Vellanikkara.

Dr. E. V. Nybe
Member, Advisory Committee
Associate Professor and Head
Department of Plantation Crops and Spices
College of Horticulture
Vellanikkara

Dr. A. Augustin
Member, Advisory Committee
Associate Professor
CPBMB
College of Horticulture
Vellanikkara

Dr. V. S. Sujatha
Member, Advisory Committee
Assistant Professor (Sr. Scale)
Department of Plantation Crops and Spices
College of Horticulture
Vellanikkara

EXTERNAL EXAMINER

In the fond memory of my beloved grand mother

ACKNOWLEDGEMENT

I express my unreserved gratitude to ***Dr. P.V. Nalini****, Associate Professor, Department of Plantation Crops and Spices and Chairman of my advisory committee for her valuable suggestions, constructive criticism, expert guidance, constant encouragement and unfailing help throughout the period of this study and preparation of the manuscript.*

With deep reverence, I express my sincere thanks to ***Dr. E. V. Nybe****, Associate Professor and Head, Department of Plantation Crops and Spices and member of advisory committee for his treasured technical guidance and ever-willing help rendered for the successful completion of the research work.*

I extent my sincere thanks to ***Dr. A. Augustin,*** *Associate professor, CPBMB, College of Horticulture, and member of my advisory committee for his ardent interest, valuable suggestions, critical scrutiny of the manuscript and ever willing help which has helped a lot for the improvement and preparation of the thesis.*

My profound thanks are due to ***Dr. V. S. Sujatha****, Assistant Professor (Sr. Scale) Department of Plantation Crops and Spices, College of Horticulture for offering all possible help and guidance, during the thesis work as a member of the advisory committee.*

I specially thank ***Mr. S. Krishnan****, Associate Professor, Department of Agricultural Statistics, College of Horticulture for his never ending support and guidance for statistical analysis of the data. I also thank* ***Dr. S. Mini****, Assistant Professor, AINP on MAP for their unbounded support offered during biochemical analysis.*

I express my wholehearted gratitude and sincere thanks to ***Mrs. Suma, Assistant Professor, Mrs. Lissamma Joseph, Assistant Professor, , Dr. Alice Kurian, Associate Professor, Dr. Shailaja, Associate Professor, Dr. Asha Sankar, Assistant Professor*** *and* ***Dr. N. Mini Raj, Assistant Professor*** *Department of Plantation Crops and Spices, College of Horticulture, for their valuable suggestions during my course of study.*

I also avail this opportunity to pay my sincere obligations and heartfelt thanks to Mrs. Sincy (SRF) and Miss. Vijini (RA) Department of Plantation Crops and Spices for their kind

help and co-operation at the crucial times of the study for the successful completion of research work.

I wish to place on record my deep sense of gratitude to my senior Sanal Kumar and my friend Johnkutty George in helping me to prepare the manuscript.

I would always like to remember the help offered by my seniors Sunil kumar, Sajeeshjan, Arun G, Anup Balakrishnan, Resmi Paul, Manjusha, Anuja Gopal, and Ambili.

I am deeply indebted to my friends especially Shanker, Anoop N.C. and Jaisal Babu for their splendid support and encouragement during the course of study.

I would always like to remember the help offered by my dear friends Eldho, Srikrishna, Mohan, Ambili, Safeera, Habeeba, Malini, Anupama, Femina, and Basanth.

I gracefully thank the assistance extended by my juniors Rijo, Ayoob, Arun Paul, Arun Babu, Liffey, Fayas, Shareesh and Sreerekha.

I also extend my thanks to all those who helped me directly or indirectly in completion of the research work.

I am forever indebted to my parents, brothers and grand father for their moral support constant prayers, personal sacrifices and unceasing encouragement during the research work.

Thanks are due to Mr. Santhosh Kumar, Students Computer Centre, College of Horticulture for prompt help in the preparation of the manuscript.

The award of KAU Junior Fellowship is thankfully acknowledged.

Above all, I bow my head before god almighty for blessing me to successfully complete the research work.

P. V. Sreejith

CONTENTS

LIST OF TABLES

LIST OF FIGURES

(Continued…)

LIST OF FIGURES (Continued…)

LIST OF PLATES

APPENDIX

Appendix No.	Title
Appendix I	Field serial number of selected palms
Appendix II	Weather parameters during the study period

Introduction

1 INTRODUCTION

The coconut palm (*Cocos nucifera* L.) which is popularly known as "*Kalpavriksha"* is one of the most useful palm crops of the world with recorded history of more than 2000 years. It is an important crop of economic importance to many countries in the Asia and Pacific region. The crop provides livelihood security and employment opportunities to major segments of the rural mass in these countries.

Coconut is being grown in 93 countries in the world with a total production of 10.9 million tonnes of copra equivalent in an area of 12.8 million ha. India is the third largest coconut producing country in the world with an annual production of 11,986 million nuts (productivity 6422 nuts ha^{-1}) from an area of 1.87 million ha (Government of India, 2004). It is an important cash crop for more than ten million farm families and a fiber-yielding crop for more than 15,000 coir based industries. Coconut provides employment to nearly six lakh workers of which 80 per cent are women folk (Mathew, 2005). The coconut based industry also helps to earn foreign exchange to the tune of Rs.4000 million and contributes significantly to the countries GDP.

In India, about 50 per cent of the area and 42 per cent of the production coconut are confined in Kerala with a total area of 906 thousand ha, production of 5484 million nuts and productivity of 6052 nuts ha^{-1} (Government of Kerala, 2004). Coconut occupies around 47 per cent of net cropped area in Kerala. In Kerala for the last three decades the productivity of coconut shows a declining trend. One of the major factor contributing to this is incidence of root (wilt) disease. This disease was more prevailed in eight southern districts of Kerala. Second major factor is drought, unlike other plantation crops in coconut every month a leaf and inflorescence produced so the production is greatly affected by the incidence of drought.

Coconut is mainly cultivated as a rainfed crop and the palm is exposed to drought of different intensities and durations in Kerala. The impact of drought on

coconut persists for two to three years due to the indeterminate flowering habit and perennial nature of crop. As coconut yields are closely linked to favourable weather conditions, occurrence of drought leads to significant reduction in yield there by resulting in considerable economic loss to the growers. So it necessitates identification of drought tolerant lines for cultivation. The physiological and biochemical mechanisms underlying drought have been determined and traits for drought tolerance worked out (Rajagopal *et al.,* 1991).

Crop improvement programmes in coconut have limitations such as the perennial nature of the crop, tall stature, long pre-bearing period, prolonged development period of nuts, heterozygous nature and requirement of large area for experimentation (Iyer and Damodaran, 1994). Thus, assessment of variability and selection of superior palms will be useful in improving the productivity.

In any crop improvement programme, an assessment of the nature and extent of variability will be of immense value in identifying superior genotypes and in formulating breeding procedure. Coconut is a monotypic genus with no known wild or domesticated relatives. The present day population of this palm presents a unique array of variability due to the long history of cross pollination.

Significant progress was made in the country in the selection of superior varieties and development of high yielding hybrids for commercial cultivation. The early efforts were focused at the evaluation of genetically superior planting materials. A large number of the indigenous and exotic cultivars were evaluated in different research stations of the country and promising cultivars were identified.

India is in a formidable position as far as the achievements in germplasm collection and crop improvement are concerned. The country holds the largest germplasm collection of 342 accessions in the world including 132 exotic and 210 indigenous accessions (CPCRI, 2004).

One of the selection programmes contemplated for yield improvement was identification of high yielding mother palms based on growth characters. The

prepotency in coconut was suggested by Harland (1957) which presumed that in these palms the gene combination responsible for high yield potential tends to be transmitted *enbloc* to progenies even under random mating.

Several researchers have attempted to characterize and classify coconut cultivars. Systematic classification of coconut varieties and forms were attempted by Narayana and John (1949) and Gangolly *et al.*(1957). The criteria used in the above classification were based on plant habit and geographical source. Later, coconut cultivars were classified based on fruit component analysis (Harries, 1978 and Rao and Pillai, 1983). Jay *et al.*(1991) and Chempakam and Ratnambal (1991) attempted to describe the genetic variability in coconut using leaf polyphenol as a population parameter.

Identification of some of the individual high yielding palms capable of yielding 471 nuts year $^{-1}$(Iyer *et al.,* 1979) indicates that tremendous variability remains under utilized.

In this context, the present study was taken up with the following objectives

1) To characterize the coconut germplasm available in the Horticulture college farm morphologically and biochemically.

2) To assess the variability among the palms.

3) To identify superior palms having high yield and drought tolerance.

Review of Literature

2. REVIEW OF LITERATURE

Coconut belongs to monotypic genus which limits the possibilities of tapping gene pools from related sources. Genetic diversity has been recognized as an important factor to improve yield, quality and resistance to biotic and abiotic stresses in coconut (Harland,1957 and Whitehead, 1968). The palm shows wide variation in yield potential due to its highly cross pollinated nature. Assessment of variability is one of the important aspects in crop improvement programme to identify superior palms. Several elite disease free palms show unusually high yield (Iyer *et al.,* 1979). This indicates that tremendous variability remains under utilized.

Genetic improvement has been achieved by crossing two genetically distinct ecotypes (Meunier *et al.,* 1984 and Bourdeix *et al.,* 1990). Selection of phenotypically superior palms will result in higher mean yield in the progenies. Collection, conservation and cataloguing of coconut germplasm were accorded the top priority in coconut research.

Earlier attempts on characterisation of coconut were based on phenotypic characters, geographical source and floral biology. Narayana and John (1949) classified coconut based on stature of palms. Gangolly *et al.* (1957) and Menon and Pandalai (1958) recognized two forms in coconut, the tall ones and the dwarf ones. Harries (1978) characterized the cultivars based on fruit component analysis. Rao and Mathew (1981) attempted to characterize coconut accessions based on seedling characters. Later several research workers have attempted to characterise and classify coconut cultivars based on different parametres including polyphenol analysis (Jay *et al.,* 1991; Chempakam and Ratnambal, 1991), by isozyme analysis (Meunier, 1992) and by DNA markers such as Random Amplified Polymorphic DNA (RAPD) (Ashburner *et al.,* 1997).

In this chapter reviews on various parametres taken for study are presented under following headings:

1) Morphological characters
2) Biochemical characters

2.1 MORPHOLOGICAL CHARACTERS

Considerable morphological variations exist among coconut cultivars. This morphological diversity between populations is easily recognised, but the adaptive traits in coconut that relate to the local environment, are rarely morphologically recognisable (Foale, 1991). The vigour and over all growth of the palms can be assessed from the morphological characters (Narayanankutty and Gopalakrishnan, 1991).

Morphological characters are further divided into five other major headings including stem characters, leaf characters, inflorescence characters, bunch characters and nut characters.

2.1.1 Stem characters

Stem characters include presence or absence of surface bole, stem girth and number of leaf scars on the stem.

2.1.1.1 *Presence or absence of bole*

Roots are localised generally at the lower most region of the stem, which has been termed as the bole (Menon and Pandalai, 1958). Presence or absence of bole is a distinct character that can be utilized in identifying a dwarf variety from a tall population (Pillai *et al.,* 1991). Absence of bole formation in Sri Lankan Brown Dwarf was reported by Perera *et al.* (2002).

2.1.1.2 ***Girth of stem at one metre height***

The stem of coconut maintains a uniform girth throughout its life excepting in very old ages when it tapers off. Apart from the heritability variation in the thickness of the stem, it is affected by the soil conditions and rainfall. Malayan varieties have the largest girth at the base than dwarf cultivars (Patel, 1938). Stem girth does not change with the age. Exotic cultivars including Philippines, Andaman Giant, *etc*. posses larger stem girth (Menon and Pandalai, 1958).

Bhaskaran and Leela (1964) reported the mean girth of stem as 65 cm for T x D hybrids, 67.3 cm for talls and 52.3cm for dwarfs. The girth and internode distance varied in Tall x Chowghat Dwarf Orange hybrids (Bavappa *et al.,* 1973).

Thampan (1975) observed mean trunk girth of 65.9 cm for T x D hybrids, 64.6 cm for talls and 55 cm for dwarfs.

Ramanathan (1984) reported that the stem height, girth at base and crown were positively correlated with yield.

Stem girth varied between the talls and dwarfs. Most of the talls have values above 75 cm and typical dwarfs had lower values and Malayan Green Dwarf had intermediate value (74cm) (Pillai *et al.,* 1991). The trunk diametre and rate of elongation of stem varied with growing conditions and genotypes (Folae, 1991).

Narayanankutty and Gopalakrishnan (1991) studied the morphological components of yield and reported that stem girth at collar region had positive correlation with yield. Superiority of Komadan over West Coast Tall for trunk girth was reported by Joseph *et al.* (1992).

Ratnambal *et al.* (2002) studied the vegetative characters of New Caledonian cultivars and reported that trunk height and girth were maximum in cultivar Nugili (7.56 m and 86.6 cm respectively) than cultivar Nufella, Nuqeawen and Nuwehung.

2.1.1.3 *Number of leaves in one metre stem (Leaf scars)*

When the old leaf falls off, it leaves a rough scar on the trunk of the coconut palm and by counting these scars, the approximate age of the palm can be determined. The number of leaf scars varied among the cultivars (Patel, 1938). Roughly, 12 to 14 such successive scars left on the palm correspond to a year of growth. It is possible to gauge the vigour of the palm from these scars (Menon and Pandalai, 1958). There is some genetic variation with in the tall and dwarf in the rate of elongation of the trunk, but this trait interacts strongly with the time of commencement and the level of nut production (Foale, 1991).

Pillai *et al.* (1991) reported that in dwarf, the number of leaf scars produced in one metre stem was very high compared with the tall. This character could be useful in the characterization. However, Jacob (1993) observed that Lakshadweep Micro produced 72 to 108 leaf scars in one metre length of stem.

The number of leaf scars between one and two metre height from the ground level varied significantly among the genotypes. The tall varieties had wide range of variation than the dwarfs but hybrids do not exhibit any general trend in variation (Jayalekshkmy and Sreerangasamy, 2003 b).

2.1.2 Leaf characters

Leaf characters that were reviewed in this study include number of leaves in the crown, petiole length, number of leaflets, length of leaflet bearing area and breadth of leaflets.

2.1.2.1 ***Number of leaves in the crown***

In adult coconut palm, the crown comprises about 30 to 40 opened leaves. The rate of production of leaves is influenced by the size and vigour of the palm, fertility of the soil, cultural and manurial practices and seasonal conditions. Palms showing greater rate of leaf production, in general, gives better yield than others (Menon and Pandalai, 1958).

Bhaskaran and Leela (1964) observed the mean number of functional leaves on the crown as 27.15 for T x D, 20.02 for tall and 24 for dwarf coconut palm. They also reported the mean annual leaf production of 12.91 for T x D, 10 for tall and 14.5 for dwarf. Among the four Tall x Dwarf hybrids, Tall x Laccadive Dwarf exhibited the maximum number of leaves (Krishnan and Nambiar, 1972).

Louis (1981) studied genetic variability among 25 varieties and two hybrids and reported that varieties Fiji, Federated Malayan States and San Ramon possess large number of leaves. Ramanathan (1984) reported that number of leaves produced palm^{-1} was positively and significantly correlated with yield. Ramachandran *et al.* (1990) noticed VHC-2 as superior in production of leaves to its parents *viz*. East Coast Tall and Malayan Yellow Dwarf. Performance of Tall x Dwarf hybrids was better than Dwarf x Tall in leaf production (Balakrishnan and Kannan, 1991). Jacob (1993) reported that the cultivar Lakshadweep Micro produced 35 to 40 leaves, which is generally associated with the high yielders.

Benaulim, Nadora and Calangute are the cultivars from Goa of which Benaulim produced more number of leaves (32) compared to Nadora and Calangute (30 and 28 respectively) (Ratnambal *et al.,* 2000). Cultivar Nufella produced less number of leaves on the crown (32.2) compared to Nuwehung (41.0) (Ratnambal *et al.,* 2002).

According to Nagwekar *et al.* (2003), among the five Banawali types of coconut cultivars, Benawali Green Round (BGR) recorded maximum number of leaves on the crown (33).

2.1.2.2 ***Length of petiole***

The petiole length was about quarter of the total leaf length. Palms with shorter leaf stalks have bunches with short stalk that helped the bunches to be closer to the stem giving less strain on the leaf bracket. The shape of the leaf stalk is of importance have natural variation for the character (Menon and Pandalai, 1958).

Sreelatha (1987) reported that the half sib families from various West Coast Tall mother palms pollinated by a common Chowghat Dwarf Orange pollen parent showed considerable variation in number of functional leaves, leaf length and petiole length.

Pillai *et al.* (1991) observed marked difference between tall and dwarf varieties for leaf number and petiole length. In tall, it varies from 117 to 148 cm while in dwarfs from 96 to 110 cm.

According to Folae (1991), length of the petiole (free of leaf lets) and the main axis (bearing leaf lets), thickness and strength of the petiole and axis varied in different varieties. He also reported that the New Lekha dwarf type has a short petiole and the Rennel Tall type has quite long one.

Sindhumole (1998) observed significant difference in petiole length among different coconut varieties. The longest petiole (1.49m) was in the variety New Guinea, and West Coast Tall had the shortest petiole (1.19m), which was at par with the varieties Philippines and Jawa.

Ratnambal *et al.* (2002) reported that Calidonian cultivar Nuwehung had more petiole length (143.3 cm) as compared to Nufella, Nugili and Nuqeawen (126.8, 130.6 and 125.8 cm respectively).

2.1.2.3 ***Number of leaflets on a leaf***

The number of leaflets on a leaf in tall palms varies from 200 to 250 (Menon and Pandalai, 1958).

Krishnan and Nambiar (1972) reported that among the four T x D hybrids, Tall x Laccadive Dwarf had the maximum number of leaflets. Among the nine Tall x Choughat Dwarf Orange hybrids, number of leaflets varied widely (Bavappa *et al.*, 1973).

According to Ramanathan (1984), number of leaflets in a leaf was found positively correlated with yield. Pillai *et al.* (1991) reported that the number of leaflets on a leaf showed marked difference between talls and dwarfs. Nadora Tall exhibited highest number of leaflets (244) while Malayan Yellow Dwarf (MYD) the lowest (180). Benawali Green Round (BGR) recorded the maximum number of leaflets (238) as compared to other Benawali types (Nagwekar *et al.,* 2003).

2.1.2. 4 ***Length of leaflet bearing area***

The leaflet bearing portion of leaves elongates first and is followed by the development of the leaf base (Patel, 1938).

The length of the leaf ranges from 4.5 to 6 metre and varies with the fertility of the soil and vigour of palms. In old palms, the length will be very much reduced and may not be more than 3.5 metre of the total length; a little less than a quarter represents the length of the leaf stalk (Menon and Pandalai, 1958).

Pillai *et al.,* (1991) reported that the length of leaflet bearing area of leaf varied considerably in dwarfs and talls. According to him tall cultivar Andaman Ranguchan had more leaflet bearing area (464 cm) than other tall cultivars including Nicobar Tall (462cm), Zanzibar Tall (454cm), Borneo (442cm), *etc*. In dwarfs, Malayan Green Dwarf has more leaflet bearing area (374cm) than other dwarfs including Chowghat Orange Dwarf, Malayan Yellow Dwarf and Chowghat Green Dwarf (346 cm, 326cm and 306 cm respectively).

2.1.2.5 *Breadth of leaflet*

The number of leaflets on a leaf varies; when the number is small the leaflets are usually narrow and are widely spaced. The leaflets near the base of the leaf as well as those near the apex are much shorter and narrower than those situated in the middle. The leaflets near the base are about 2.5 cm in width and those near the apex are less than 1.3 cm in width. The longest leaflets are in the lower one third of the leaflet bearing region. They measure about a metre in length and may vary in individual trees. It is clear that there is great variation in the area of the leaf surface in different palms (Menon and Pandalai, 1958).

Pillai *et al.* (1991) reported marked difference among tall and dwarf with respect to leaflet breadth. The leaflet breadth is low in dwarfs while most of the talls have greater values. Tall cultivars including Andaman, Ranguchan, Benaulim, Borneo, Ceylon Tall, *etc*. showed six centimetres in breadth. Dwarf cultivars like Chowghat Green Dwarf, Chowghat Orange Dwarf and Malayan Yellow Dwarf registered five centimetres in breadth.

2.1.3 Inflorescence characters

Inflorescence characters include number of inflorescence produced in a year, length and girth of spadix, number of female flowers inflorescence^{-1}, number

of spikelets in an inflorescence, number of female flowers spikelet^{-1}, duration of male phase, duration of female phase and setting percentage.

2.1.3.1 ***Number of inflorescence in a year***

The number of spadices or inflorescences produced in a palm largely depends on the number of leaves produced. Every leaf axil produces a spadix. The annual production of spadices under normal conditions ranges from 12 to 15 (Menon and Pandalai, 1958).

The average number of inflorescences produced palm^{-1}annum^{-1} of West Coast Tall was 11.3 as reported by Satyabalan and Pillai (1977). Laccadive small and Spicata produced more number of spadices year^{-1} (Louis, 1981). Vijayakumar and Satyabalan (1982) reported that the number of inflorescences annum^{-1} for T x COD hybrids ranged from 7.3 to 12.3 with a mean of 9.2.

According to Balingasa and Carpio (1983), number of inflorescence produced annually varied between tall and dwarf varieties in Philippines. Shylaraj *et al.* (1991) reported that Komadan produced more spadices than WCT. Vijayaraghavan *et al.* (1993) reported that direct and reciprocal hybrids of Malayan Yellow Dwarf and East Coast Tall produced highest number of spadices among various hybrids and their parents. Vanaja and Amma (1997) also reported that the Komadan produced higher number of spadices than WCT. According to Nair *et al.* (2000) Chowghat Green Dwarf produced eight to nine inflorescences year^{-1}.

Ratnambal *et al.* (2002) reported that Caledonian coconut cultivars including Nufella, Nugili, Nuqewen and Nuwehung produced 11 to 12 inflorescences year^{-1}.

Among the different cultivars and hybrids, D x T and West Coast Tall produced highest number of spadices palm^{-1} (9.2) followed by Straight Settlement Green (8.5) (Manna *et al.,* 2003).

2.1.3.2 ***Length and girth of spadix***

The inflorescence develops with in a strong, tough, pointed double sheath called spathe, would be about 1 to 1.2 m in length and 14 to 16 cm in diameter at the broadest point (Thampan, 1975).

According to Pillai *et al.* (1991), in dwarfs the inflorescence is smaller when compared with talls. However, variations do exit in the length of inflorescence in talls. Nicobar Tall exhibited a shorter spadix and Jamaican Tall a longer spadix of 132 cm.

Ratnambal *et al,* (2002) reported that the length of inflorescence was more in cultivar Nuqeawen (101.3 cm) than Nuwehung, Nugili and Nufella (99.5, 98.7 and 96.0 cm respectively). Inflorescence length varied significantly among the genotypes (Jayalekshmy and Sreerangasamy, 2002a).

2.1.3.3 ***Mean number of female flowers inflorescence^{-1}***

The number of female flowers in an inflorescence is variable. There is a difference in the production of female flowers among the palms as well as among the inflorescences of the same palm (Patel, 1938). It varies from zero to three hundred in each spadix depending on the conditions prevailing, *viz.* nature of the palm, cultivars, manuring, season, age of bearing, *etc*. Dwarf palms generally bear female flowers in larger numbers than the tall palms (Menon and Pandalai, 1958).

The varieties Philippines and Straight Settlement Green produced more number of female flowers among various exotic varieties and West Coast Tall

(Ratnam and Satyabalan, 1964). Satyabalan and Pillai (1977) compared eight exotic varieties and West Coast Tall and observed that variation existed in female flower production. Generally exotic varieties produced more female flowers than WCT.

Chan (1979) reported that Malayan Dwarf x West Coast Tall hybrids produced more female flowers than hybrids of Malayan Yellow Dwarf with Malayan Tall and Rennel Tall. 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 the hybrids, Ayiramkachi had the largest number of female flower production, whereas variety Spikeless produced maximum female flowers $year^{-1}$ among the fifteen exotic varieties of coconut evaluated along with local cultivars in Orissa (Panda *et al.,* 1985).

Shylaraj *et al.* (1991) reported that Komadan produced more female flowers $spadix^{-1}$ than WCT. However, Joseph *et al.* (1992) found that Laccadive Ordinary was superior to West Coast Tall for female flower production. Vanaja (1993) reported that Komadan and WCT did not vary for female flower production $spadix^{-1}$. Sri Lankan Brown Dwarf coconut produced 80 female flowers $inflorescence^{-1}$ (Perera *et al.,* 2002).

Bai *et al.* (2003) reported that, among the 12 tall cultivars, Laccadive Micro and among the four dwarf cultivars Malayan Green Dwarf produced more number of female flowers (356 and 255 respectively).

Among the different cultivars and hybrids, D x T and Local Tall produced highest number of female flowers $spadix^{-1}$ (102.0 and 79 respectively) and MYD x WCT and Philippines Ordinary produced less number of female flowers $spadix^{-1}$ (28.3 and 31.7 respectively) (Manna *et al.,* 2003).

Nagwekar *et al.* (2004) reported that highest number of female flowers produced was in Benawali Green Round (33) compared to other Benawali types including Benawali Yellow Round, Benawali Green Long and Benawali Yellow Long (30, 29 and 29 respectively).

2.1.3.4 ***Number of spikelets in an inflorescence***

The inflorescence consists of many flower bearing ramification or spikelets situated on a central axis or a peduncle. Its size varies from 0.75 m to 2 m in length depending up on the individual palm (Menon and Pandalai, 1958).

Pillai *et al.* (1991) reported that the dwarfs have shorter spikelets compared to talls. They also reported that tall cultivar Andaman Raguchan, Benaulim, Borneo, Ceylon Tall, *etc*. have more number of spikelets in an inflorescence (43) and dwarf cultivars like Malayan Yellow Dwarf have comparatively less number of spikelets in an inflorescence (40, 35 and 31 respectively).

Jayalekshmy and Sreerangasamy (2002a) reported that inflorescence characters like spikelet length, number of spikelets inflorescence^{-1}, *etc*. vary significantly among the different coconut genotypes.

Ratnambal *et al.* (2003) reported that among the different tall cultivars, Borneo Tall, Benaulim Tall and Litu Tall have more spikelets inflorescence^{-1} (45.6, 44.6 and 44.3 respectively), cultivars like Rangoon Kobbari Tall, Zanzibar Tall, Kong Thein Yong Tall have less number of spikelets in inflorescence (26.0, 28.3 and 30.7 respectively). Dwarf cultivars include Neu Leka Dwarf, Nigerian Dwarf and Malayan Green Dwarf have more spikelets inflorescence^{-1} (42.6, 40.1 and 30.4 respectively), cultivars like Kulasekaram Orange Dwarf and Chowghat Green Dwarf and Chowghat Orange Dwarf have less number of spikelets inflorescence^{-1} (25.1, 28.5 and 29.8 respectively).

Manna *et al.* (2003) reported that hybrid MYD x WCT produced more spikelets inflorescence^{-1} (46.3) than hybrid D x T and T x D (40.3 and 37.3 respectively).

2.1.3.5 *Number of female flowers spikelet^{-1}*

The coconut palm is monoecious, producing both male and female flowers on the same inflorescence. Several hundred male flowers are produced by an inflorescence with only a few female flowers. The inflorescence bears 30 to 35 flower bearing spikelets, densely set with male flowers. The female flowers are found at the base of the spikelets and each spikelet may carry one or a few female flowers, having already attained the shape of small coconuts (Thampan, 1975).

Perera *et al.* (2002) reported that Sri Lankan Brown Dwarf Coconut produced 80 female flowers inflorescence^{-1} and on an average, four female flowers spikelet^{1}.

2.1.3.6 *Male phase*

The interval between the opening of the first male flower and the shedding of the last male flower is termed as the male phase. In coconut, duration of male phase varies from 18 to 20 days (Patel, 1938). In dwarfs, duration of male phase varied from 15 to 24 days with an average of 21 days (Gangolly *et al.*, 1957).

Pillai *et al.* (1991) reported that Malayan Yellow Dwarf, Chowghat Green Dwarf and Malayan Orange Dwarf have short duration of male phase (18, 16 and 14 days respectively). In talls, Borneo and Philippines Lono have longest duration of male phase (21 and 20 days respectively).

According to Nair *et al.* (2000), duration of male phase in Chowghat Green Dwarf is 16 days from the date of opening of spathe.

Duration of male phase in cultivar Nufella is minimum (18.4 days) as compared to Nugili (18.9 days), Nuqeawen (18.9 days) and Nuwehung cultivar (19.4days) (Ratnambal *et al.,* 2002). Male phase in talls varied from 13.3 days in Standard Kudat to 21.6 days in Surinam Tall with an average of 19.2 days. In dwarfs largest male phase was reported in Niu Leka Dwarf (20.6 days) and shortest period in Gangabondam Green Dwarf (16.3 days) (Ratnambal *et al.,* 2003).

2.1.3.7 ***Female phase***

The female phase which is the interval between the receptive stage of the first female flower and the last receptive stage of the last female flower was also observed to vary according to the condition of the palm. But generally it is shorter than the male phase and extends for four days to a week, depending on the nature of the palm (Menon and Pandalai, 1958).

Pillai *et al.* (1991) observed that the female phase in Chowghat Orange Dwarf and Chowghat Green Dwarf extend upto five days, while tall cultivars like Benaulim and Borneo have only four days.

The nut yield is significantly and positively correlated with number of spadix produced and duration of female phase (Kalathiya and Sen, 1992). Nair *et al.* (2000) reported that the female phase remains for an average of five days in Chowghat Green Dwarf. But the average duration of female phase in cultivar Nuwehung is 4.9 days (Ratnambal *et al.,* 2002).

Ratnambal *et al.* (2003) reported that the average duration of the female phase in talls was 4.2 days and in dwarfs, the duration was little longer (6.7 days). Tall cultivar Jamaica Tall showed 6.1 days duration in female phase than other tall

cultivars. Among the tall types, West African Tall and Kenya Tall have lowest period of female phase, 3.2 days. Among the different dwarf cultivars, Kenthali Dwarf showed ten days duration in female phase and Nigerian Dwarf showed 3.9 days, which is the shortest duration among the dwarf cultivars.

2.1.3.8 *Setting percentage*

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

Ramachandran *et al.* (1977) found the variety Ayiramkachi as intermediate between tall and dwarf types for nut setting percentage. The important character of this variety is high female flower production but the low setting percentage.

According to Chan (1979), Malayan Dwarf x West African Tall hybrids had early flowering and higher nut set than hybrids of Malayan Dwarf with Malayan Tall and Rennal Tall.

Potty *et al.* (1980) reported that West Coast Tall showed high female flower production and setting percentage in red loam. Highest fruit set in Straight Settlement was reported by Panda *et al.* (1985) among fifteen exotic varieties of coconut.

Joseph *et al.* (1992) found that Laccadive Ordinary was superior to West Coast Tall for female flower production and setting percentage. Vanaja (1993) reported that Komadan and WCT did not vary in nut set. 38 per cent fruit set in Chowghat Green Dwarf was reported by Nair *et al.* (2000).

Ratnambal *et al.* (2002) reported that among the different Calidonian coconut cultivars, Nugili set 28.7 per cent female flowers to nut than Nufella (26.7 %) and Nuqeawen (25.6 %).

Among the 12 tall cultivars, higher nut set was observed in Laccadive micro (46%) followed by Malayan Yellow Dwarf (38%) among the four dwarf cultivars (Bai *et al.,* 2003).

Nagwekar *et al.* (2003) reported that among the five Banawali types of coconut, high percentage of fruit set was observed in Banawali Green Round (Pratap) (29.65 %) and Banawali Green Long (29.6%) and low fruit set in Banawali Red Round (28.57%).

2.1.4 Bunch characters

Bunch characters that are reviewed in this study include number of bunches produced year^{-1}, length of bunch stalk and number of nuts bunch^{-1}

2.1.4.1 *Number of bunches palm $^{-1}$ year^{-1}*

In a coconut palm, at the bearing stage, every leaf axil produces a spadix or inflorescence. The annual production of spadices, therefore, coincides with the number of leaves produced by the palm, which under normal conditions ranges from 12 to 15 numbers. After fertilization, it takes about 11 to 12 months for developing into a nut. When the nut is about 160 days old, it attains full size (Thampan, 1975). Number of bunches palm^{-1}, length of bunches, *etc.* varied among the coconut cultivars (Folae, 1991).

Shylaraj *et al.* (1991) observed that Komadan produced more bunches (17) than WCT (13.6). Among the five Banawali types, Banawali Green Round (Pratap)

produced the highest number of bunches palm^{-1} year^{-1} (14.5) followed by Banawali Yellow Round (14.0) and Banawali Green Long (13.8) (Ratnambal *et al.*, 2003).

According to Mali *et al.*(2004) hybrid T x D and D x T produced more bunches palm^{-1}(11.43) than other cultivars Pratap(11.10), Philippines Ordinary (10.78) and WCT (8.22).

2.1.4.2 ***Length of bunch stalk***

Short and stout bunch stalks are better supporters of nuts in the bunch and do not require propping. On the other hand, bunches with long stalks are prone to buckle leading to premature nut fall (Thampan, 1975). The bunch stalk length varied among different cultivars (Foale, 1991).

Ratnambal *et al.* (2002) reported that Calidonian cultivar Nuwehung produced long panicles (60.8 cm) as compared to other cultivars Nugili (57.7 cm), Nuqeawen (56.3cm) and Nufella (52.4 cm).

According to Nagwekar *et al.* (2003) length of bunch stalk varied among different Banawali cultivars. Banawali Green Round (50.4 cm) had highest value than Banawali Green Long, Banawali Yellow Round, Banawali Yellow Long and Banawali Red Round (47.6, 48.8, 47.2 and 46.5 cm respectively).

2.1.4.3 ***Number of nuts bunch^{-1}***

Even though an inflorescence may produce a large number of female flowers, only very few develop and mature into nuts. A minimum of 12 nuts are required to classify a bunch as heavy bunch, and a maximum of six nuts for a light bunch (Patel, 1938).

Balakrishnan and Namboodiri (1987) reported variation among 24 exotic and indigenous cultivars for nuts bunch^{-1}. Higher number of nuts bunch^{-1} for VHC - 1 than East Coast Tall, Malayan Dwarf Yellow and VHC-2 were reported by Ramachandran *et al.* (1990). Foale (1991) reported that number of nuts developed in a bunch varied between the cultivars.

Vanaja (1993) reported the superiority of Komadan over West Cost Tall for nut characters like total nuts bunch^{-1} and annual nut yield. Jayalekshmi *et al.* (2002a) inferred that the hybrids produced maximum number of nuts bunch^{-1}.

Perera *et al.* (2002) reported that Sri Lankan Brown Dwarf produced large number of small nuts bunch^{-1} (50- 80).

The production of nuts bunch $^{-1}$ was maximum in D x T hybrid and Pratap (12 nuts bunch^{-1}) which was followed by Philippines Ordinary, T x D (G) and T x D (O) (11.50, 11.17 and 11.0 nuts bunch^{-1} respectively). However, the minimum number of nuts bunch^{-1} was recorded in San Raman (6.43) (Mali *et al.,* 2004).

2.1.4.4 *Total number of nuts palm^{-1}year^{-1}*

The yield depends on different factors including number of spadices opened, the number of female flowers produced and the number of female flowers set. The factors that affect these characters are inherent nature of the palm, manuring, cultivation practices, season and age of the palm (Patel, 1938).

Harland (1957) reported prepotency in coconut. Prepotent palms transmit high yield capability to their progenies probably through the possession of a favourable combination of dominant genes even when they are subjected to random open mating.

Heritability estimates for yield of nuts in a coconut varied from 0.48 to 0.63 (Lakshmanachar, 1959).

Iyer *et al.* (1979) reported that there are several elite disease free palms showing unusually high yield of over 470 nuts palm^{-1} year^{-1}.Yield in coconut being a complex character controlled by a number of components and their interaction. Path coefficient and regression analysis were attempted on coconut to identify the characters with direct inflorescence on cumulative and average yield (Sukumaran *et al.,* 1981).

Ramanathan *et al.* (1984) noticed VHC -1, a cross between East Coast Tall x Dwarf Green, as most promising with a mean nut yield of 115 nuts palm^{-1} year $^{-1}$ and 21,648 nuts ha^{-1}.

Hybrid VHC-2 (West Coast Tall x Malayan Yellow Dwarf) produced a mean nut yield of 147 nuts palm^{-1} which was significantly higher than that of ECT (Ramachandran *et al.,* 1990).

The mean annual nut yield of Komadan palm (126.0 nuts palm^{-1} year^{-1}) was found to be more than that of WCT (83.1 nuts palm^{-1} year^{-1}) (Shylaraj *et al.,* 1991). Philippines Ordinary gave 37.5 per cent higher yield than West Coast Tall (110 nuts palm^{-1} year^{-1}) (Ratnambal *et al.,* 1996). Vanaja and Amma (1997) also reported that Komadan (116 nuts palm^{-1} year^{-1}) had greater nut production potential than WCT (89 nuts palm^{-1} year^{-1}).

Hore (1999) compared the performance of different indigenous and exotic cultivars of coconut in West Bengal and reported that the average nut yield was maximum in Jamaica Tall (8.2 palm^{-1}) followed by Zanzibar (64.8 palm^{-1}) and Hazari (64.5 palm^{-1}).

Malayan Green Dwarf cultivar produced medium sized nuts with the average yield of 120 nuts palm^{-1} year^{-1} (Ratnambal, 1999), while cultivar Benaulim produces about 80 to 190 nuts^{-1} year^{-1} with a mean of 151 nuts^{-1} year^{-1}. The highest yield potential of the cultivar Benaulim was reported as 316 nuts year^{-1} (Ratnambal *et al.*, 2000).

Natarajan *et al.* (2001) reported that VHC-3 hybrid coconut produced an annual nut yield of 156 nuts palm^{-1}. Among the four economic characters, only nut yield was correlated with both vegetative and reproductive characters of the palm (Sindhumole and Ibrahim, 2001).

Ganesamurthy *et al.* (2003) compared twenty eight coconut genotypes at Coconut Research Station, Veppankulam and reported that West Coast Tall has the highest cumulative mean nut yield (139.9 nuts palm^{-1} year^{-1}) followed by Spicata (130.8 nuts palm^{-1} year^{-1}) and Laccadive Micro (123.7 nuts palm^{-1} year^{-1}). Tenga Tall, Palu Tall and Bali Tall are the high yielding tall cultivars of Indonesia (Gopalakrishnan, 2003).

Gopalakrishnan (2004) reported that the MATAG and MAWA hybrids can yield up to 30,000 nuts ha $^{-1}$ or 180 to 190 nuts palm^{-1} year $^{-1}$.

Among the indigenous tall cultivars, higher yield in terms of more number of nuts was observed in Kuttiyadi Tall, Komadan and Elite Tall (Gopalakrishnan and Teresa, 2004).

2.1.5 Nut characters

2.1.5.1 *Weight of unhusked nut*

Liyanage and Sakai (1960) reported that yield attributing character such as weight of husked nut showed comparatively high heritability value of 0.97. In

addition to the high variability for yield and its components the population of East Coast Tall showed high degree of variability in the quality of whole nut and husked nut (Peter and Jayaraman, 1977). Panda and Maharana (1989) observed a gradual increase in fruit weight, water content and husk weight of the coconut upto the eighth month.

Balakrishnan and Kannan (1991) compared the performance of fifteen hybrids along with West Coast Tall as check variety. According to them weight of husked nut was more in hybrid Cochin China x COD (851 g) than Fiji x COD (812.9 g) and WCT x MYD recorded the minimum value of 520.2 g.

Weight of husked nut showed significant positive correlation with weight of unhusked nut, meat and germination of nut (Mathew and Gopimony, 1991), while weight of copra obtained was significantly correlated with fruit size and volume, weight of the husked nut (Kalathiya and Sen, 1992).

Sharma *et al.,* (2000) reported that whole nut weight was maximum in natural cross dwarf (1.27 kg) and lowest in Dwarf Orange (0.83 kg).

Fruit component analysis of eight DxT hybrids along with WCT in the hybrid evaluation trial–VI revealed significant difference in weight of husked nut (Kumaran *et al.,* 2004), while Antony *et al.* (2004) reported that weight of unhusked nut contributed the maximum towards the observed genetic diversity followed by weight of husked nut and weight of copra.

2.1.5.2 *Kernel thickness*

Kernel development in nut begins from eighth month of the nut development and increases to a maximum weight of 168 g in eleventh month (Panda and Maharana, 1989).

According to Balakrishnan and Kannan (1991) wide variation showed in nut characters of different hybrids among which kernel thickness varied significantly at one per cent level. They reported that hybrid WCT x COD showed highest thickness of meat 1.36 cm and hybrid CDO x LO showed lowest value 1.13 cm. Kumarn *et al.* (2004) reported that significant difference in kernel thickness among different D x T hybrids.

Borneo recorded 0.56 cm kernel thickness at seven month maturity and San Ramon recorded 1.05 cm kernel thickness in eight month old nut (Mali *et al.,* 2004).

2.1.5.3 ***Copra content***

Liyanage and Sakai (1960) reported that copra palm^{-1} year^{-1} showed high heritability value of 0.67.

Population of East Coast Tall showed high degree of variability in the quality of whole nut and copra (Peter and Jayaraman, 1977).

Kalathiya and Sen (1992) reported that the weight of the copra obtained was significantly and positively correlated with fruit size and volume, weight of the husked nut, shell weight and kernel weight. Philippines Ordinary showed more copra yield than West Coast Tall (Ratnambal and Nair, 1996), while cultivar FMS Big gave the highest copra weight nut^{-1} than Fiji (225 g) (Indiresh *et al.,* 1997).

Compared to WCT, Komadan had higher copra content nut^{-1} (Vanaja and Amma, 1997). In dwarf copra content was less compared to tall. Copra content of Malayan Yellow Dwarf was 71g nut $^{-1}$ (Ratnambal, 1999).

Ratnambal *et al.* (2000) compared the popular cultivars of Goa including Benaulim, Nadora and Calangute, cultivar Nadora had the highest copra content

(174g nut^{-1}) than other two cultivars Calanute and Benaulim (148.5 g and 143.0g respectively).

Comparing Dwarf cultivars and natural cross hybrids, copra out turn and copra content were highest in natural cross hybrids (125 g nut $^{-1}$) than Dwarf Green (117 nut $^{-1}$).

Ganesamurthy *et al.* (2002) studied genetic variability and correlation of yield and nut characters in coconut. They revealed that variability was observed in copra yield. Copra yield was strongly and positively correlated with nut yield, copra weight and kernel weight.

2.1.5.4 ***Oil content***

Sudha (1984) reported that oil content in copra increased with nut age to a maximum of 73 per cent at the twelfth month. Oil content was significantly correlated with number of nuts produced by palm (Kalathiya and Sen, 1992).

Oil content in Malayan Green Dwarf was 67 per cent (Ratnambal, 1999) and in cultivar Calangute it was 68 per cent and 65 per cent in Benawali (Ratnambal *et al.,* 2000).

Chowdhary *et al.* (2001) reported that Kamarupa had less oil content (64.50 per cent). Vegetative characters of palm are correlated with copra yield and oil content as reported by Sindhumole and Ibrahim (2001).

The copra and oil yield palm^{-1} and copra and oil yield ha^{-1} were highest in Andaman Giant followed by Andaman Ordinaray, Kappadam and WCT (Ganesamurthy *et al.,* 2003).

2.2 BIOCHEMICAL CHARACTERS

Earlier attempts on characterisation of coconut varieties were based on phenotypic characters, geographical source and floral biology. Later, biochemical characterization of coconut germplasm has also been attempted. Chempakam and Ratnambal (1991) considered leaf polyphenols as a population parameter. The polyphenol level varied among varieties and the higher phenolic level correlated to better tolerance to root (wilt) disease. Rajagopal *et al.* (1991) characterised the coconut cultivars as drought tolerant and susceptible types using physiological and biochemical aspects. Biochemical aspects included certain stress sensitive enzymes like acid phosphatase and L-asparate 2-oxoglutarate amino-transferase.

Shivashankar *et al.* (1991) reported that activities of these enzymes greatly enhanced by the onset of drought and increased exponentially with further increase in the degree of stress during rainless months. These enzymes also showed statistically significant difference between tolerant and susceptible types under conditions of soil water deficits.

2.2.1 Leaf polyphenol

Analysis of polyphenols by high performance liquid chromatography is an effective technique to describe the genetic variability in coconut (Jay *et al.,* 1991). This analysis helps to know genetic variability for polyphenols composition between ecotypes and with in ecotypes. The polyphenol levels varied significantly among the varieties. Chowghat Green Dwarf and Kappadam had higher phenol levels (10.82 and 10.74 mg g^{-1} respectively). Cultivars from India have maximum variability which ranged from 4.72 mg g^{-1} for Laccadive Ordinary to 10.82 mg g^{-1} for Chowghat Green Dwarf. The higher phenolic levels associated with Chowghat Green Dwarf was correlated to its relatively better tolerance to root (wilt) disease (Chempakam and Ratnambal, 1991). Significant difference in phenol content in

different geographical origins was also reported and dwarf cultivars had higher phenolic levels as compared to tall cultivars. Gopalakrishnan and Teresa (2004) also reported higher total phenol content in Chowghat Green Dwarf followed by Jappanan.

2.2.2 Drought tolerance

The ability of coconut genotypes to withstand drought condition depends up on various physiological and biochemical factors, which impart drought tolerance. Soil and plant water deficit limits the yield of crops in many regions of the world. For the good growth of coconut palm with optimum nut yield, a well distributed rainfall throughout the year with an annual precipitation between 1300 and 2500 mm is the most essential requirement (Murry, 1977). Depending on the intensity of drought, coconut palms show the symptoms like drooping and drying of leaves, poor spathe development, shedding of buttons and poor nut yield (Pomier and de Taffin, 1982; Rao, 1985; Rao, 1986; Ramadasan *et al.,* 1991).

The coconut genotypes differed not only in the extractability of soil moisture by roots but also in conserving the water in leaf tissues, *i.e*., low transpiration rate through the effective control of stomata. The tolerant genotypes could conserve water in the tissues for various physiological and metabolic processes, whereas the susceptible genotypes tend to lose more water.

Leaf characters and nut yield were used to screen five coconut hybrids and a West African Tall for drought tolerance (Pomier and de Taffin, 1982). The percentage of dry leaves compared to the number of living one x 100 was used as the drought tolerance index, according to which the hybrid PB 121 (Malayan Yellow Dwarf x West African Tall) was found to be most drought tolerant, while the Rennel Tall x West African Tall the most sensitive to drought. The hybrid PB 121 had less reduction in the production of nuts due to moisture stress as compared to other hybrids. Rajagopal (1990a) developed a rapid screening method involving

the determination of leaf water potential and the activity of acid phosphatase enzyme. The released hybrids LO x GB proved to be drought tolerant, while the other popular hybrid COD x WCT is observed to be more susceptible to drought. The tolerant types maintained higher leaf water potential and less enzyme activity when subjected to stimulated stress conditions. Accessions that display drought tolerant traits can be used as a source for breeding to bring desirable characters into a single ideotype with a good expectation of increasing drought tolerance.

2.2.2.1 *Acid phosphatase (APH) and Glutamate Oxalacetate Transaminase (GOT) enzymes*

Isozymes are different variants of the same enzyme having identical or similar functions and present in the same individual (Market and Moller, 1959). It has played an essential role in many branches of biology like taxonomy, host pathogen interaction analysis and evolutionary studies. Isozymes were also used as genetic indication in date palms.

Analysis of seven gene-enzyme systems in parents and progenies of *Phoenix dactylifera* were carried out by starch gel electrophoresis in mature leaflets. Alcohol dehydrogenase, two esterases, two glutamate oxalacetate transaminases, phospoglucose isomerase and phosphoglucose mutase were each controlled by a single gene with two alleles. Isozyme variations were related to the allelic state of genes. Genotypes of 45 female and 20 male cultivars and 9 hybrids were tabulated showing single gene markers (Tisseral and Torres, 1979).

Isozyme analysis was used to identify the oil palm species. Six enzyme systems were analysed by gel electrophoresis, esterases and acid phosphatases were found to be useful genetic markers for identifying the different fruit types. Certain bands were species specific, while others were found only in the hybrids (Rahman *et al.,* 1981).

The biochemical basis for drought tolerance in coconut has been reported by Shivashankar (1988). Rajagopal *et al*. (1990a) found that activities of stress sensitive enzymes like super oxide dismutase, catalase and peroxidase are the biochemical characters that help in maintenance of cell membrane integrity. These enzymes showed statistically significant difference between tolerant and susceptible types under drought condition (Shivashankar, 1990).

Rajagopal *et al.* (1990b) studied the morphological, physiological and biochemical responses of coconut genotypes. The result revealed that the activities of enzymes like acid phosphatase and glutamate oxalacetate transaminase were enhanced during stress conditions. Under pre-stress condition the activity of acid phosphatase did not differ much between tolerant and susceptible genotypes (195 and 210 n mole $h^{-1}g^{-1}$ fresh weight respectively), whereas with the onset of stress, the activities increased to 78.6 per cent in COD x WCT (susceptible type) as against 43 per cent in WCT (tolerant type). The activity of glutamate oxalacetate transaminase enhanced three fold among the four genotypes (Rajagopal *et al.,* 1991).

The activity of acid phosphatase and L-aspartate 2-oxoglutarate amino-transferse enzymes were greatly enhanced with the onset of stress in the field and increased exponentially with further increase in the degree of stress during rainless months (Shivashankar *et al.,* 1991).

Asmono *et al.* (1993) studied genetic diversity in coconut, using starch gel electrophoresis-5 and reported the variation in isoenzyme banding pattern of acid phosphatase and glutamate oxalacetate transaminase.

The activities of acid phosphatase, polyphenol oxidase and L-aspartate, 2-oxoglutarate amino transferase were higher in the susceptible cultivar (Shivashankar and Nagaraja, 1996).

Materials and Methods

3. MATERIALS AND METHODS

The study on 'Morphological and biochemical characterization of coconut (*Cocos nucifera* L.) germplasm was undertaken at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 2004-2005.

Coconut palms of 20 years old available at the Department farm were used for the study (Plate 1). The germplasm material consists of progenies collected from selected palms throughout the state as a part of KADP project (Kerala Agricultural Development Project). Forty palms were selected randomly (APPENDIX-I) representing the available variability in yield from the germplasm based on previous years yield data. The populations comprised of 367 palms and were maintained under rainfed condition. The monthly weather parameters during the study period were collected from the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara (APPENDIX-II).

Observations on 25 morphological and three biochemical characters were recorded from forty selected palms during a period of one year (2004-2005). The details of observations recorded were as follows:

3.1 MORPHOLOGICAL CHARACTERS

3.1.1. Stem characters

3.1.1.1 *Presence or absence of bole*

The basal portion of the trunk was usually observed and the presence or absence of bole was recorded.

Plate 1. Experimental plot

3.1.1.2 *Girth of stem at one metre height (GS)*

The girth of each palm selected was measured in centimetres at one meter above the ground level using a measuring tape.

3.1.1.3 *Number of leaves in one metre stem (LS)*

One meter stem was marked from one meter above the ground level. And number of leaf scars present was counted for each selected palm.

3.1.2 Leaf characters

3.1.2.1. *Number of leaves in the crown (L)*

The total number of fully opened leaves present on the crown was counted discarding dried and unopened ones.

3.1.2.2. *Length of petiole (LP)*

Length of petiole was measured in centimetres from the base of the point of emergence of leaflets using a measuring tape.

3.1.2.3. *Number of leaflets in a leaf (NLT)*

All leaflets in the fourteenth leaf of every selected palm were counted.

3.1.2.4. *Length of leaflet bearing area (LLB)*

Length of leaflet bearing area was measured in centimetres from the point of emergence of leaflet in base to tip of the leaf using a measuring tape.

3.1.2.5. *Breadth of leaflets (BL)*

Breadth of three selected leaflets was recorded in centimetres and their arithmetic mean was taken as the breadth of leaflets.

3.1.3 Inflorescence characters

3.1.3.1. *Number of inflorescence in a year (NIY)*

The inflorescence produced during the period of one year from 2004 – 2005 were counted.

3.1.3.2 *Length* *and girth of spadix (LSX and GSX)*

Length and girth of unopened spadix at middle region were measured in centimetres using a measuring tape.

3.1.3.3 *Mean number of female flowers inflorescence $^{-1}$(FFIP)*

Total number of female flowers in three inflorescences was recorded, and mean number of female flowers per inflorescence was calculated.

3.1.3.4 *Number of spikelets in an inflorescence (NSI)*

Total number of spikelets in three inflorescences was recorded and mean number of spikelets in an inflorescence was calculated.

3.1.3.4 *Number of female flowers spikelet^{-1}(NFFPS)*

Number of female flowers per spikelet was calculated by dividing the total number of female flowers produced in an inflorescence with total number of spikelets.

3.1.3.5 *Male phase (MP)*

The date of opening of each inflorescence and that of the first male flower in it was recorded for each selected palm. Similarly, the date of falling of the last male flower in every inflorescence was recorded. The number of days between the opening of the first male flower and falling of the last male fewer in an inflorescence (inclusive of both days) was taken as the duration of male phase for that inflorescence. The duration of male phases of three inflorescences produced in a palm was recorded and the average worked out and expressed as average duration of male phase.

3.1.3.6 *Female phase (FP)*

The number of days from the day of attaining receptivity of the first female flower to the fading up of the last female flower in an inflorescence was recorded as the female phase for that inflorescence. The stage of receptivity was identified by the presence of honey secretion in the swollen trifid stigma. Arithmetic mean of female phase of three inflorescence of selected palm was calculated and expressed as duration of female phase of that palm.

3.1.3.7 *Setting percentage (SP)*

Setting percentage was calculated by dividing number of nuts per bunch with the total number of female flowers produced in the same inflorescence. It is

expressed in percentage. The mean of three inflorescences were calculated and taken as setting percentage of selected palm.

3.1.4 Bunch characters

3.1.4.1 *Number of bunches palm^{-1}year $^{-1}$(NBPPY)*

The total number of bunches in the crown at different stages of maturity was counted.

3.1.4.2 *Length of bunch stalk (LBS)*

Length of stalk of matured bunch was measured in centimeters from the base to point of emergence of spikelet.

3.1.4.3 *Number* ***of nuts bunch^{-1}(NNPB)***

Number of nuts in three matured bunches in the crown was counted and mean was then calculated.

3.1.4.4 *Total* ***number of nuts palm^{-1}year^{-1}(YIELD)***

This was recorded by taking the total number of nuts harvested from each of the selected palm during the study period.

3.1.5 Nut characters

3.1.5.1 *Weight of unhusked nut (g) (WN)*

Three nuts collected from each of the selected palms were weighed in a balance and the mean calculated.

3.1.5.2 ***Kernel thickness (cm) (KT)***

Thickness of kernel or meat was measured from each of three opened nut by using a measuring scale and its mean value was calculated.

3.1.5.3. ***Copra content (g) (CC)***

Oven dried copra cup to constant weight extracted the three nuts per palm was weighed and weight recorded in gram. The mean value was then calculated.

3.1.5.4 ***Oil content (%) (OC)***

The percentage of oil in the copra of each nut was estimated by cold percolation method (Bhandari, 1974).

3.2 BIOCHEMICAL CHARACTERS

Biochemical analysis was carried out with the fresh leaf sample collected from each palm. Samples were collected selecting the fourteenth leaf from the top excluding the unopened leaf, which was suggested by Ziller and Prevot (1962).

Three to four leaflets from middle portion of the leaf were collected and midrib was removed. The middle 10 to 15 cm portion was used for analysis.

3.2.1. Leaf polyphenols (PP)

The total phenols were estimated as per the method given by Sadasivam and Manikam (1996) using Folin- ciocalteau phenol reagent. 0.5g of fresh leaf samples was used for analysis. Sample was extracted with five milliliter of 80 per cent methanol. Phenolic content of leaf was expressed in mg g^{-1} of sample.

3.2.2. Estimation of Acid Phosphatase enzyme activity (APH)

Activity of acid phosphatase enzyme was estimated by method given by Malik and Singh (1980). 0.5 g of fresh leaf sample was used. Samples were extracted with 100 ml acetate buffer (pH 4.8) and 0.5 ml extract used for the analysis. Simultaneously, protein content of the sample was also estimated using Lowry's method suggested by Sadasivam and Manikam (1996). And activity of acid phosphatase was expressed in mol ml^{-1} 30 minutes of one gram of protein at 35ºC.

3.2.3 Estimation of Glutamate Oxalacetic Transaminase activity (GOT)

Glutamate oxalacetic transaminase (GOT) activity was assayed by the method suggested by Bergmeyer (1963). 0.5 g of fresh leaf sample was used for analysis. Samples were extracted with 90 ml phosphate buffer in which 0.1 ml was used for analysis. From the same extract, 0.1 ml was used for analysis of protein by Lowry's method suggested by Sadasivam and Manikam (1996). And GOT activity was expressed in mol ml^{-1} mg^{-1} protein 37ºC at 30 minutes.

3.3 STATISTICAL ANALYSIS OF DATA

To reduce the dimentiality of the problem Principal Component Analysis (PCA) was carried out. Based on PCA the forty palms were grouped in to eleven clusters (Chatfield and Collins, 1980). To know the inter relationship between the characters under study inter correlation were also worked out (Snedecor and Cochran, 1967). And Path coefficient analysis was also carried out to know the direct and indirect effects of different characters with yield (Narain, 1990).

Results

4. RESULTS

The results obtained on various morphological and biochemical characters are summarized based on the statistical analysis and presented in this chapter. Marked differences were noticed with respect to most of the morphological and biochemical characters. Cluster analysis was performed based on principal components using 24 morphological and three biochemical characters.

The cluster analysis of the forty palms resulted in eleven clusters. Cluster no. I, IV, VI, X and XI had only single member. Cluster number V and IX include eight members each and III and VII contain five and six members respectively (Table 1).

Table1.Grouping of palms based on cluster analysis

Cluster number	Palm number
C1	T_{33}
C2	T_1 ,T_{26}, T_{29} ,T_{38}
C3	T_9, T_{10} ,T_{20} , T_{21},T_{32}
C4	T_{22}
C5	T_8 ,T_{11} , T_{18}, T_{27}, T_{28},T_{30},T_{37},T_{40}
C6	T_{24}
C7	T_5 ,T_{23} ,T_{25},T_{26},T_{36}, T_{39}
C8	T_2 , T_3,T_{19}, T_{31}
C9	T_4, T_{12},T_{13},T_{14}, T_{15}, T_{16} ,T_{17}, T_{34}
C10	T_{35}
C11	T_7

Table 2. Average distance between clusters

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
C2	170.58									
C3	224.85	69.45								
C4	251.81	97.77	49.33							
C5	180.27	20.15	61.20	93.22						
C6	113.85	76.01	138.88	162.75	87.93					
C7	205.86	39.67	58.32	80.08	34.51	107.58				
C8	151.66	40.22	106.60	130.48	51.63	46.90	67.16			
C9	178.98	42.48	99.68	120.57	50.03	73.59	51.80	31.77		
C10	216.54	76.30	104.84	113.58	79.72	116.49	54.28	82.98	60.78	
C11	161.51	94.18	152.31	160.53	108.08	67.66	108.77	67.38	75.68	95.51

4.1. MORPHOLOGICAL CHARACTERS

Remarkable differences were noticed with respect to most of the morphological characters among different clusters.

4.1.1. Stem characters

4.1.1.1. *Presence or absence of bole*

The enlarged portion at the base of the coconut trunk is called bole. Presence of bole is a distinct character which can be utilized for identifying a tall variety from a dwarf population. In the present study, most of the palms showed presence of bole in the surface of the trunk. Palms like T_{11}, T_{12}, T_{24}, T_{25} and T_{38} showed the absence of bole (Table 3). This character was not included for clustering of selected palms.

Table 3. Lists of palms showing the presence or absence of bole

Palm No.	Surface bole	Palm No.	Surface bole	Palm No.	Surface bole	Palm No.	Surface bole
T_1	Present	T_{11}	**Absent**	T_{21}	Present	T_{31}	Present
T_2	Present	T_{12}	**Absent**	T_{22}	Present	T_{32}	Present
T_3	Present	T_{13}	Present	T_{23}	Present	T_{33}	Present
T_4	Present	T_{14}	Present	T_{24}	**Absent**	T_{34}	Present
T_5	Present	T_{15}	Present	T_{25}	**Absent**	T_{35}	Present
T_6	Present	T_{16}	Present	T_{26}	Present	T_{36}	Present
T_7	Present	T_{17}	Present	T_{27}	Present	T_{37}	Present
T_8	Present	T_{18}	Present	T_{28}	Present	T_{38}	**Absent**
T_9	Present	T_{19}	Present	T_{29}	Present	T_{39}	Present
T_{10}	Present	T_{20}	Present	T_{30}	Present	T_{40}	Present

4.1.1.2. *Girth of stem at one metre height*

Stem girth was maximum in cluster number 4 (87cm) followed by C2 (73.25 cm) with SD 10.24 and C3 (73.20cm) with SD 5.81. Minimum stem girth was observed in C1 (62 cm) followed by C6 and C10 (64 cm each) (Table 4).

4.1.1.3. *Number of leaves in one metre stem (Leaf scars)*

Leaf scars present in one metre stem highly varied among different clusters.C6 showed highest mean value 41, followed by C11 (40) and C8 (35). The lowest number of leaf scars was recorded in C4 (20), followed by C5 (27.38) and Cl.no.1 (28) (Table 4).

Table 4. Mean and standard deviations of stem characters for eleven clusters

Cluster number	**Stem girth (cm)**		**Leaf scars (Nos)**	
	Mean	SD	Mean	SD
1	62.00	*	28.00	*
2	73.25	10.24	32.00	7.30
3	73.20	5.81	31.20	3.63
4	87.00	*	20.00	*
5	69.38	4.03	27.38	5.37
6	64.00	*	41.00	*
7	69.50	4.32	30.00	4.73
8	70.75	2.87	35.00	1.41
9	69.13	3.04	30.12	5.91
10	64.00	*	30.00	*
11	67.00	*	40.00	*

SD-Standard deviation, * Single value so there is no SD computed

4.1.2. Leaf characters

4.1.2.1. *Number of leaves in the crown*

Number of fully opened leaves in the crown varied from 23 to 37.67 in different clusters. Maximum number of leaves in the crown was observed in C10 (37.67) with a standard deviation of 1.53, followed by C4 (37) with a standard deviation of two and C6 (36.33) with a standard deviation of 1.53. And lowest number was observed in C1 (23) with a standard deviation of three, followed by C2 (30.5) and C11 (31) (Table 5).

4.1.2.2. *Length of petiole*

The highest petiole length was observed in C4 (121cm) followed by C3 (119cm) with a SD 9.92, and C9 (103.38 cm) with a SD 9.93. Petiole length varied from 69cm to 121 cm. The shortest petiole was noticed in C1 (69cm) followed by C11 and C6 (83 cm and 88 cm respectively) (Table5).

4.1.2.3. *Number of leaflets in a leaf*

The value of mean leaflets in a leaf ranged from 190 to 233.20. The lowest number of leaflets was observed in C1 (190) followed by C11 and C8 (200 and 211.50 respectively). And the highest number was observed in C3 (233.20) with a SD 11.89, followed by C4 and C10 (226 and 224 respectively) (Table 5).

Table 5. Mean and standard deviation of leaf characters for eleven clusters

Cluster number	**Number of leaves**		**Length of petiole (cm)**		**Number of leaflets in a leaf**		**Length of leaflet bearing area (cm)**		**Breadth of leaflet (cm)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	23.00	3.00	69.00	*	190.00	*	240.00	*	4.17	0.29
2	30.50	1.98	102.00	6.63	217.50	1.91	353.00	15.25	4.88	0.64
3	35.68	2.92	119.00	9.92	233.20	11.89	393.80	18.12	4.50	0.63
4	37.00	2.00	121.00	*	226.00	*	388.00	*	6.00	0
5	34.71	4.28	98.25	10.43	218.50	8.05	369.00	15.02	4.75	0.63
6	36.33	1.53	88.00	*	214.00	*	294.00	*	4.17	0.29
7	33.22	4.28	98.83	6.40	220.00	15.85	376.00	16.16	5.22	0.71
8	31.83	6.68	98.00	6.68	211.50	8.39	330.00	18.22	5.00	0.85
9	31.88	2.50	103.38	9.93	217.75	12.07	347.00	14.22	4.93	0.90
10	37.67	1.53	92.00	*	224.00	*	355.00	*	5.50	0.50
11	31.00	1.00	83.00	*	200.00	*	280.00	*	5.16	2.89

SD- Standard deviation, * Single value so there is no SD computed

Table 6. Mean and standard deviation of inflorescence characters for eleven clusters

Cluster number	Number of inflorescence in a year		Length of spadix (cm)		Girth of spadix (cm)		Female flowers inflorescence^{-1}		Number of spikelets inflorescence^{-1}		Number of female flowers spikelet^{-1}		Male phase (days)		Female phase (days)		Setting Percentage	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	7.00	*	42.33	2.08	15.67	1.53	18.00	9.17	15.67	1.53	1.26	0.61	16.67	0.58	3.00	0	38.45	21.09
2	11.5	0.58	87.16	8.21	24.92	4.67	33.83	6.16	31.67	5.43	1.15	0.45	18.33	1.07	4.03	0.90	37.97	9.46
3	12.00	0	99.73	11.11	29.33	5.51	40.40	4.14	28.33	5.05	1.43	0.21	19.73	1.83	3.80	0.68	40.76	6.82
4	12.00	*	117.00	1.73	31.67	1.53	39.00	5.00	32.67	3.05	1.32	0.22	19.00	0	5.00	0	26.70	5.49
5	11.00	1.31	90.08	15.21	28.17	4.58	32.54	4.76	32.42	5.44	1.01	0.20	19.46	1.56	4.29	0.81	38.15	9.43
6	10.00	*	84.00	4.58	30.00	1.00	24.67	2.52	22.67	3.05	1.10	0.26	18.67	2.08	5.33	0.58	28.68	5.59
7	10.83	1.47	89.16	11.59	27.39	5.90	34.89	7.65	31.16	4.41	1.13	0.41	20.22	1.31	4.28	0.96	42.00	9.71
8	10.00	1.63	90.33	8.48	24.08	2.68	29.83	3.81	30.33	4.46	1.00	0.18	19.00	0.74	3.67	0.49	33.89	6.50
9	9.75	1.16	86.46	13.39	25.92	5.14	33.25	6.63	32.00	4.50	1.04	0.23	19.13	1.23	4.00	1.06	27.86	8.03
10	12.00	*	67.00	7.00	26.33	3.79	33.33	2.31	31.33	1.15	1.16	0.15	19.00	1.00	5.00	0	40.04	9.43
11	12.00	*	97.00	1.00	27.67	1.53	36.67	2.52	37.00	1.00	0.99	0.04	19.67	2.08	4.33	0.58	28.46	6.24

SD- Standard deviation * Single value so there is no SD computed

4.1.2.4. *Length of leaflet bearing area*

The highest leaflet bearing area in leaf was observed in C3 (393.8cm) with a SD of 18.12, followed by C4 (388cm) and C7 (376cm). The lowest area was observed in C1 (240 cm) followed by C11 and C6 (280cm and 294 cm respectively) (Table 5).

4.1.2.5. *Breadth of leaflet*

It was observed that breadth of leaflets ranged from 4.17 cm to 6 cm. Cluster number 4 had highest leaflet breadth (6cm) followed by C10 (5.5cm) with a SD of 0.5 followed by C7 (5.22cm) with SD 0.71.The lowest value was noticed in C1 and C6 (4.17 cm) with a SD of 0.29 (Table 5).

4.1.3. Inflorescence characters

4.1.3.1. *Number of inflorescence in a year*

The number of inflorescence produced varied among different clusters. The mean value ranged from 7 to 12. C 3, C4, C10 and C11 produced 12 inflorescences, followed by C2 (11.50) and lowest observed in C1 (7) followed by C9 (9.75) and C8 (10) (Table 6).

4.1.3.2. *Length and girth of spadix*

Longest spadix observed was in C4 (117cm) with SD of 1.73 followed by C3 (99.73 cm, with SD 11.11) and C11 (97 cm, with SD of 1). Shortest spadix was recorded in C1 (43.33 cm) with SD of 2.08, followed by C10 (67cm, SD of 7) and C6 (84cm with SD of 4.58) (Table 6).

Maximum girth also observed in C4 (31.67 cm) with SD of 1.53, followed by C6 (30 cm) with SD 1 and C3 (29.33cm) with SD of 5.51. The lowest was observed in C1 (15.67 cm) with 1.53. Followed by C 8 (24.08 cm) with SD 2.68 and C2 (24.92cm) with SD of 4.67 (Table 6).

4.1.3.3. *Mean number of female flowers inflorescence^{-1}*

The mean number of female flowers inflorescence^{-1} was high in C3 (40.40) with SD of 4.14.This was followed by C4 (39) with SD of 5 and C11 (36.67) with a SD of 2.52.The lowest was observed in C1 (18) with SD of 9.17 followed by C6 (24.67) with SD of 2.52 and C8 (29.83) with SD of 3.81 (Table 6).

4.1.3.4. *Number of spikelets in an inflorescence*

The maximum number of spikelets in an inflorescence was found in C11 (37) with a SD of 1, followed by C4 (32.67) with a SD of 3.05 and C5 (32.42) with a SD of 5.44. The lowest was recorded in C1 (15.67) with a SD of 1.53, followed by C6 (22.67) with a SD of 3.05 and C3 (28.33) with a SD of 5.05 (Table 6).

4.1.3.5. *Number of female flowers spikelet^{-1}*

The number of female flowers spikelet^{-1} ranged from 0.99 to 1.43. Highest value was recorded in C3 (1.43) with a SD of 0.21 followed by C4 (1.32) with a SD of 0.22 and C1 (1.26) with a SD of 0.61.The lowest value was recorded in C11 (0.99) with a SD of 0.04 followed by C8 (1) with a SD of 0.18 and C5 (1.01) with a SD of 0.2 (Table 6).

4.1.3.6. *Male phase*

Duration of male phase ranged from 16.67 days to 20.22 days among different clusters. It was observed that C7 took more days for completion of male phase (20.22 days) with a SD of 1.31, followed by C3 (19.73) with a SD of 1.83 and C11 (19.67) with a SD of 2.08 .C1 showed shortest duration of male phase among different clusters (16.67 days) with a SD of 0.58, followed by C2 (18.33 days) with a SD of 1.07 and C6 (18.67 days) with a SD of 2.08 (Table 6).

4.1.3.7. *Female phase*

Among different clusters, female phase duration in days ranged from 3.00 to 5.33. Longest duration of female phase was observed in C6 (5.33 days) with a SD of 0.58 followed by C4 and C10 (5.00 days). Whereas the shortest duration was observed in C1 (3.00) followed by C8 (3.67 days) with a SD of 0.49 and C3 (3.80) with a SD of 0.68 (Table 6).

4.1.3.8. *Setting percentage*

Nut set in different clusters ranged from 26.7% to 42%. C7 recorded the highest setting percentage with a SD of 0.58, followed by C3 (40.76%) with SD of 6.82 and C10 (40.04%) with SD of 9.43. C4 showed comparatively low nut set (26.7%) with a SD of 5.49, followed by C9 (27.86%) with a SD of 8.03 and C11 (28.46%) with a SD of 6.24 (Table 6).

4.1.4. Bunch characters

4.1.4.1. *Number of bunch palm^{-1} year^{-1}*

Total number of bunches palm^{-1} year^{-1}varied among the clusters. It ranged from 6 to 12 bunches palm^{-1} year^{-1}. C3, C4 and C11 recorded the highest number of bunches (12) followed by C2 and C10 (11). The lowest value was recorded in C1 (6) followed by C8 (9) with SD of 1.41 and C9 (9.25) with SD of 1.28 (Table 7).

4.1.4.2. *Length of bunch stalk*

Mean length of bunch stalk ranged from 31.67 to 47.33cm. The highest mean bunch stalk length was observed in C4 (47.33 cm) with a SD of 1.15, followed by C10 (47cm) with a SD of 3.61 and C7 (42.28cm) with a SD of 6.83. Shortest bunch stalk was recorded in C1 (31.67 cm) with a SD of 1.53 followed by C2 (33.25cm) with a SD of 9.69and C9 (36.54cm) with a SD of 2.38 (Table 7).

4.1.4.3. *Number of nuts bunch^{-1}*

Mean number of nuts bunch^{-1} varied among the clusters. It ranged from 5.67 to 19 nuts bunch^{-1}. The highest mean value was recorded in C4 (19 nuts) with a SD of 3 followed by C3 (16 nuts) with a SD of 2.65 and C7 (14.50 nuts) with a SD of 4.25. The lowest value was recorded in C1 (5.67 nuts) with a SD of 0.58 followed by C6 (7 nuts) with a SD of 1 and C9 (8.92 nuts) with a SD of 2.04 (Table 7).

4.1.4.4. *Total number of nuts palm^{-1}year^{-1}*

It was noted that nut yield varied highly among different clusters. The mean nut yield of different clusters ranged from 30 to 158 nuts palm^{-1} year^{-1}. The highest nut yield was recorded in C4 (158 nuts) followed by C3 (129.2 nuts) with a SD of 23.7 and C7 (93.67 nuts). And the lowest yield was recorded in C1 (30 nuts), followed by C6 (46 nuts) with a SD of 20.38 and C8 (52.5 nuts) with a SD of 6.45 (Table 7).

Table 7. Mean and standard deviations of bunch characters for eleven clusters

Cluster No.	Number of bunches palm^{-1}year^{-1}		Length of bunch stalk (cm)		Number of nuts bunch^{-1}		Total number of nuts palm^{-1} year^{-1}	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	6.00	*	31.67	1.53	5.67	0.58	30.00	*
2	11.00	1.15	33.25	9.69	13.25	5.15	82.00	26.18
3	12.00	0	42.00	4.11	16.00	2.65	129.2	23.70
4	12.00	*	47.33	1.15	19.00	3.00	158.00	*
5	10.75	1.28	39.63	6.58	12.50	3.24	82.00	17.86
6	10.00	*	37.67	1.53	7.00	1.00	46.00	20.38
7	10.67	1.75	42.28	6.83	14.50	4.25	93.67	*
8	9.00	1.41	40.16	8.90	9.75	1.71	52.50	6.45
9	9.25	1.28	36.54	2.38	8.92	2.04	54.63	18.17
10	11.00	*	47.00	3.61	13.33	3.05	87.00	*
11	12.00	*	39.67	2.52	10.33	1.53	58.00	*

SD-Standard deviation, * Single value so there is no SD computed

4.1.5. Nut characters

4.1.5.1. *Weight of unhusked nut*

The nut weight was high in C10 (1.46kg) with a SD of 0.07 followed by the C7 (1.39 kg) with a SD of 0.2 and C5 (1.37 kg) with a SD of 0.18. The lowest nut weight was recorded in C4 (1.10kg) with a SD of 0.17 followed by C8 (1.11 kg) with a SD of 0.12 and C6 (1.13kg) with a SD of 0.14 (Table 8).

4.1.5.2. *Kernel thickness*

The thickness of kernel varied among the clusters. The value ranged from10 mm to 12.67mm. The highest value was recorded in C4 (12.67 mm) with a SD of 0.58, followed by C10 (12 mm) and C5 (11.54 mm) with a SD of 1.26. The lowest value was recorded in C6 (10mm) with a SD of 1, followed by C1 (10.33mm) with SD of 1.53 and C8 (10.42 mm) with SD of 0.9 (Table 8).

4.1.5.3. *Copra content*

The value of copra content ranged from 56 g to 220 g. The highest mean value recorded was in C10 (220g) with a SD of 10.58, followed by C11 (193.67g) with a SD of 7.23 and C9 (179.13g) with SD of 11.95. C1 showed the lowest value (56g) with a SD of 4 followed by C6 (135.33g) with a SD of 7.02g and C3 (145.2 g) with a SD of 9.04 (Table 8).

4.1.5.4. *Oil content*

Highest oil content was recorded in C1 (69.6%) with a SD of 0.45, followed by C6 (68.09%) with a SD of 0.4 and C3 (68.09%) with a SD of 1.29. The lowest value was recorded in C10 (62.84%) with a SD of 1.14, followed by C2 (64.27%) with a SD of 2.65 and C7 (64.32%) with a SD of 3.32 (Table 8).

Table 8. Mean and standard deviations of nut characters for eleven clusters

Cluster No.	**Weight of unhusked nut (kg)**		**Kernel thickness (mm)**		**Copra content (g)**		**Oil content (%)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	1.13	0.04	10.33	1.53	56.00	4.00	69.60	0.45
2	1.22	0.15	10.58	1.38	150.00	38.16	64.27	2.65
3	1.16	0.18	10.53	1.25	145.20	9.04	68.09	1.29
4	1.10	0.17	12.67	0.58	170.00	29.46	65.86	0.47
5	1.37	0.18	11.54	1.26	146.42	12.83	64.40	6.57
6	1.13	0.14	10.00	1.00	135.33	7.02	68.67	0.40
7	1.39	0.20	11.22	1.35	177.39	10.71	64.32	3.32
8	1.11	0.12	10.42	0.90	156.00	7.29	65.03	1.72
9	1.15	0.22	10.88	1.22	179.13	11.95	66.57	2.20
10	1.46	0.07	12.00	0	220.00	10.58	62.84	1.14
11	1.33	0.15	11.33	1.15	193.67	7.23	65.23	0.11

SD-Standard deviation

4.2 BIOCHEMICAL CHARACTERS

Leaf polyphenol content and activity of Acid Phosphatase (APH) and Glutamate Oxalacetate Transaminase (GOT) were analysed and the results are furnished hereunder:

4.2.1. Leaf polyphenol content

Polyphenol content in different clusters ranged from 3.74 $mg^{-1}g$ to 9.5 mg g^{-1}. The highest value recorded was in C6 (9.5 mg g^{-1}) with a SD of 0.96, followed by C5 (9.14 mg g^{-1}) with a SD of 2.14 and C7 (8.69 mg g^{-1}) with a SD of 1.03.The lowest value was recorded in C4 (3.74 mg^{-1} g) followed by C3 (6.09mg g^{-1}) with a SD of 3.6 and C11 (6.35 mg g^{-1}) (Table 9).

4.2.2. Acid Phosphatase (APH)

The mean activity of acid phosphatase enzyme among the different clusters ranged from 5.45 to 7.59 micro mol ml^{-1} protein at 30°C for 30 min. The highest activity was observed in C6 (7.59 micro mol ml^{-1} protein at 30°C for 30 min.) followed by C3 and C10 (7.17 and 7.13 micro mol ml^{-1} protein at 30°C for 30 min. respectively).However the lowest value was recorded in C4 (5.45 micro mol ml^{-1} protein at 30°C for 30 min.) followed by C1 and C11 (5.66 and 6.12 micro mol ml^{-1} protein at 30°C for 30 min. respectively) (Table 9).

4.2.3. Glutamate Oxalacetate Transaminase (GOT)

The activity of GOT enzyme ranged from 0.021 to 0.089 mol ml^{-1} mg^{-1} protein at 37 °C for 30 min. C4 showed the highest mean GOT activity (0.089 mol ml^{-1} mg^{-1} protein at 37 °C for 30 min.) followed by C2 and C7 (0.073 and 0.054 mol ml^{-1} mg^{-1} protein at 37 °C for 30 min. respectively). It was recorded that the C6 showed lowest activity among different clusters (0.021 mol ml^{-1} mg^{-1} protein at 37 °C for 30 min.) followed by C11 and C8 (0.025 and 0.028 mol ml^{-1} mg^{-1} protein at 37 °C for 30 min. respectively) (Table 9).

Table 9.Mean and standard deviations of biochemical characters for eleven clusters

Cluster No.	**Leaf polyphenol (mg g^{-1})**		**APH (micro mol ml^{-1} of protein at 30°C for 30 min.)**		**GOT (mol ml^{-1} mg^{-1} protein at 37°C for 30 min.)**	
	Mean	SD	Mean	SD	Mean	SD
1	8.44	*	5.66	*	0.044	*
2	7.74	1.19	6.25	0.81	0.073	0.07
3	6.09	3.60	7.17	0.91	0.044	0.01
4	3.74	*	5.45	*	0.089	*
5	9.14	2.41	7.12	1.20	0.045	0.02
6	9.50	0.96	7.59	*	0.021	*
7	8.69	1.03	6.37	1.11	0.054	0.06
8	7.13	*	6.50	0.60	0.028	0.02
9	8.18	2.28	6.78	1.31	0.041	0.03
10	6.97	*	7.13	*	0.045	*
11	6.35	*	6.12	*	0.025	*

SD- Standard deviation,* Single value so there is no SD computed

4.3 CORRELATION STUDIES

Karl Pearson's coefficient of correlation was worked out between the 24 morphological and three biochemical characters and are presented in Table 10.

4.3.1 Correlation between nut yield and stem characters

Girth of stem had significant positive correlation with nut yield (0.427), number of nuts $bunch^{-1}$ (0.417), length and girth of spadix (0.387, 0.399), number

of leaflets leaf^{-1} (0.393), length of leaflet bearing area (0.468) and number of leaf scars on one metre stem (-0.423).

Number of leaf scars in one meter stem was significantly and negatively correlated with length of leaf let bearing area (-0.377) and kernel thickness (-0.374).

4.3.2 Correlation between nut yield and leaf characters

Number of leaves on the crown showed highly significant positive correlation with the nut yield (0.343), number of nuts bunch^{-1} (0.482), number of bunches palm^{-1} year^{-1} (0.446), number of inflorescence year^{-1} (0.412), length of leaflet bearing area (0.414), duration of female phase (0.363), and number of leaflets (0.324).

Petiole length had significant positive correlation with yield (0.448), number of female flowers spikelet^{-1} (0.466), length of spadix (0.454), length of leaflet bearing area (0.541), number of leaflets (0.547), female flowers inflorescence^{-1} (0.348), number of bunches palm^{-1} year^{-1} (0.315) and activity of GOT enzyme(0.334).

Number of leaflets in a leaf recorded significantly positive correlation with nut yield (0.394), number of bunches per palm^{-1} year^{-1} (0.485), number of female flower spikelet^{-1}, length and girth of spadix (0.461, 0.441), number of inflorescence produced (0.492) and leaflet bearing area (0.565).

Highest significant positive correlation between nut yield and length of leaf let bearing area was recorded (0.593) nut yield had significant correlation with weight of nut (0.424), number of nuts bunch^{-1} (0.600), number of bunches palm^{-1} year^{-1} (0.516), number of female flowers inflorescence^{-1} (0.481), length and girth of

spadix (0.400, 0.451) number of inflorescence produced (0.466) and duration of male phase (0.342).

Leaf let breadth was significantly positively correlated with setting percentage (0.313) and significantly negatively correlated with length of spadix (-0.310).

4.3.3 Correlation between nut yield and inflorescence characters

Number of inflorescence produced palm^{-1} year^{-1} had high significant positive correlation with nut yield (0.645), number of nuts bunch^{-1} (0.661), number of bunches palm^{-1} (0.928), setting percentage (0.406), female flowers inflorescence^{-1} (0.494), kernel thickness (0.320), nut weight (0.370), number of spikelet inflorescence^{-1} (0.324) and significant negative correlation with leaf poly phenol content (-0.335).

Length of spadix also had highly significant positive correlation with nut yield (0.400) and girth of spadix (0.685), number of bunches palm^{-1} year^{-1} (0.337) and female flowers inflorescence^{-1} (0.347). Girth of spadix was positively correlated with nut yield (0.329), number of bunches palm^{-1}, female flowers spikelet^{-1} (0.454).

Female flowers inflorescence^{-1} showed highly significant positive correlation with nut yield (0.692), number of nuts bunch^{-1} (0.645), weight of nut (0.466), number of bunches palm^{-1} year^{-1} (0.548), number of female flowers spikelet^{-1} (0.605), male phase (0.348) and number of spikelet inflorescence^{-1} (0.316).

Number of spikelet inflorescence^{-1} recorded highly significant negative correlation with number of female flowers spikelet^{-1} (-0.535).

Number of female flowers spikelet^{-1} was highly significant positively correlated with nut yield (0.548), number of nuts bunch^{-1} (0.484), weight of nut (0.455), number of bunches palm^{-1} (0.356) at highly significant level.

Duration of male phase had highly significant positive correlation with nut weight (0.455), bunch stalk length (0.313). So also, duration of female phase was highly correlated with nut weight (0.417) at highly significant level.

Setting percentage had highly significant positive correlation with nut yield (0.446), number of nuts bunch^{-1} (0.658) and number of bunches palm^{-1} (0.385).

4.3.4 Correlation between nut yield and bunch characters

Number of bunches palm year^{-1} was positively correlated with nut yield (0.720), number of nuts bunch^{-1} (0.693), nut weight (0.370) and kernel thickness (0.317).

Length of bunch stalk and nuts bunch $^{-1}$ also showed significant positive correlated with nut weight (0.329) and nut yield (0.875).

4.3.5 Correlation between nut character and yield

Weight of nut was positively correlated with copra content at highly significant level (0.399), whereas kernel thickness was positively correlated with copra content (0.310).

4.3.6 Correlation between nut yield and biochemical characters

Leaf polyphenol content was negatively correlated with yield (-0.327).

Table 10. Correlation between yield and different biometric and biochemical characters

	GS	LS	L	LP	NLT	LLB	BL	NIY	LSX	GSX	FFPI	NSI	NFFPS
LS	-0.423**												
L	0.330*	-0.004											
LP	0.269	-0.149	0.098										
NLT	0.393**	-0.150	0.342*	0.547**									
LLB	0.468	-0.377**	0.414**	0.541	.565**								
BL	-0.051	0.089	0.129	-0.150	-0.139	0.127							
NIY	0.288	-0.014	0.412**	0.285	0.492**	0.466**	0.147						
LSX	0.445**	-0.180	0.339*	0.454**	0.461**	0.400**	-0.310*	0..302					
GSX	0.387**	-0.208	0.309	0.276	0.441**	0.451**	-0.117	0.271	0.685**				
FFPI	0.399**	-0.124	0.333*	0.348*	0.247	0.481**	0.074	0.494**	0.347*	0.454**			
NSI	0.190	-0.012	0.190	-0.190	-0.174	0.256	0.168	0.324*	0.035	0.018	0.316*		
NFFPS	0.169	-0.100	0.141	0.466**	0.381**	0.226	-0.108	0.225	0.273	0.372*	0.605**	-0.535**	
MP	0.061	-0.009	-0.079	0.229	0.264	0.342*	0.097	0.175	0.109	0.143	0.348*	0.182	0.100
FP	0.075	0.204	0.363*	-0.140	0.182	0.097	0.266	0.094	0.015	0.077	0.236	0.119	0.109
SP	0.017	-0.117	0.256	-0.072	0.146	0.304	0.313*	0.406**	-0.114	-0.139	-0.061	-0.068	0.064
NBPPY	0.294	-0.048	0.446**	0.315*	0.485**	0.516**	0.166	0.928**	0.337*	0.350*	0.548**	0.243	0.356*
LBS	-0.145	0.027	-0.149	0.217	0.180	0.158	-0.164	0.154	0.199	0.112	0.119	0.009	0.096
NNPB	0.417**	-0.268	0.482**	0.263	0.308	0.600**	0.282	0.661**	0.225	0.274	0.645**	0.146	0.484**
YIELD	0.427**	-0.277	0.434**	0.448	0.394**	0.593**	0.136	0.645**	0.400**	0.329*	0.692**	0.064	0.548**
WN	0.089	0.040	0.263	-0.005	0.278	0.424**	0.160	0.370*	0.132	0.196	0.466**	-0.174	0.455**
KT	0.173	-0.374*	0.228	0.001	0.062	0.183	-0.162	0.320*	0.245	0.140	0.278	-0.004	-0.069
CC	0.038	-0.032	0.299	0.088	0.258	0.257	0.019	0.216	0.226	0.242	0.300	0.063	0.177
OC	0.167	-0.016	0.100	-0.008	-0.013	-2.002	0.152	-0.104	0.010	-0.093	-0.230	0.210	-0.076
PP	-0.189	-0.006	-0.166	-0.179	0.002	-0.020	0.054	-0.335*	-0.031	0.238	-0.144	-0.256	-0.090
APH	-0.212	0.053	0.214	0.180	0.151	0.045	0.165	-0.038	0.113	0.130	-0.214	0.230	-0.023
GOT	0.070	-0.133	0.236	0.334*	0.228	0.086	-0.056	0.255	0.094	-0.057	-0.149	0.065	-0.237

(Continued……)

Table 10. Correlation between yield and different biometric and biochemical characters (Continued…..)

	MP	FP	SP	NBPPY	LBS	NNPB	YIELD	WN	KT	CC	OC	PP	APH
FP	0.184												
SP	-0.142	-0.106											
NBPPY	0.254	0.160	0.385**										
LBS	0.313*	0.085	0.023	0.124									
NNPB	0.078	0.153	0.658**	0.693	0.136								
YIELD	0.239	0.128	0.446**	0.720**	0.231	0.875**							
WN	0.455**	0.417**	0.198	0.370*	0.329*	0.249	0.179						
KT	-0.069	0.146	0.014	0.317*	0.073	0.213	0.245	0.259					
CC	0.177	0.243	-0.009	0.257	0.137	0.231	0.174	0.399**	0.310*				
OC	-0.076	0.100	-0.084	-0.067	-0.223	-0.034	0.076	-0.246	0.096	-0.115			
PP	-0.090	-0.084	0.053	-0.227	-0.019	-0.262	-0.327*	0.028	-0.152	-0.061	-0.231		
APH	-0.023	0.272	-0.074	0.037	0.142	0.005	0.090	-0.032	-0.234	0.047	-0.060	0.287	
GOT	-0.237	-0.236	0.188	0.254	-0.150	0.194	0.236	-0.257	0.224	0.023	-0.095	-0.124	-0.118

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

GS-Girth of stem, **LS**- Number of leaves scars, **L**-Number of leaves, **LP**-Length of petiole, **NLT**- Number of leaflets,**LLB**-Length of leaflet bearing area, **BL**- Breadth of leaflet, **NIY**-Number of inflorescence , **LSX**- Length of spadix, **GSX**-Girth of spadix, **FFIP**-Number of female flowers inflorescence^{-1}, **NSI**- Number of spikelets in an inflorescence, **NFFPS**- Number of female flowers spikelet^{-1},**MP**- Male phase, **FP**- Female phase, **SP**- Setting percentage, **NBPPY**- Number of bunches palm^{-1} year^{-1},**LBS** – Length of bunch stalk, **NNPB**- Number of nuts bunch $^{-1}$, **YIELD**- Total number of nuts palm^{-1} year^{-1},**WN**- Weight of unhusked nut ,**KT**- Kernel thickness, **CC**- Copra content .**OC**- Oil content ,**PP**- Leaf polyphenol, **APH**-Acid phosphatase, **GOT**- Glutamate Oxalacetate Transaminase

4.4 PATH ANALYSIS

Path analysis was carried out to study the structure of correlation of the 26 characters namely girth of stem at one meter height, number of leaves in one meter stem length, number of leaves in the crown, length of petiole, number of leaflets in leaf, length of leaf let bearing area, breadth of leaflet, number of inflorescence in year, length of spadix, girth of spadix , mean number of female flowers inflorescence^{-1}, number of spikelets in an inflorescence, number of female flowers spikelet^{-1}, male phase, female phase, setting percentage , number of bunches palm^{-1} year^{-1}, length of bunch stalk, number of nuts bunch^{-1}, weight of unhusked nut, kernel thickness, copra content, oil content, leaf polyphenol content, activity of acid phosphatase enzyme and activity of glutamate oxalacetate tranzamase enzyme with yield.

4.4.1 Direct effects on yield

Mean number of female flowers inflorescence^{-1} registered very high positive direct effect of nut yield (1.39) (Table 10) followed by setting percentage (0.479) and number of bunches Palm^{-1} year^{-1} (0.387).

Characters like duration of female phase (0.184), length of bunch stalk (0.137) and length of petiole (0.138) and GOT enzyme activity (0.120) had low positive direct effect on nut yield.

Girth of stem at one metre height (0.082), length of leaflet bearing area (0.0571), girth of spadix (0.025), duration of male phase (0.058), number of nuts bunch^{-1} (0.0259), kernel thickness (0.0807) and activity of APH enzyme had negligible positive direct effect on yield.

Number of female flowers spikelet^{-1} (-1.196) recorded high negative direct effect on yield followed by number of spikelet in an inflorescence (-0.985), and weight of nut (-0.188).

Characters like number of leaves in one metre stem (-0.117), total number of leaves in the crown (-0.0539), number of leaflets in a leaf (-0.184), breadth of leaflet (-0.144), number of inflorescence year^{-1} (-0.0967), copra content (-0.0128), oil content (-0.0395) and leaf polyphenol content (-0.134) also recorded negative direct effects on yield.

4.4.2 Indirect effect on yield

Number of nuts bunch^{-1} (0.898), number of female flowers spikelet^{-1} (0.843), number of bunches palm^{-1}year^{-1} (0.764), number of inflorescence palm^{-1} year^{-1} (0.688), length of leaflet bearing area (0.670), girth of stem at one meter height (0.555), male phase (0.485), length of petiole (0.485), length of spadix (0.483), copra content (0.467), number of leaves in the crown (0.463), number of spikelets inflorescence^{-1} (0.440), number of leaflet (0.344) and duration of female phase (0.329) exhibited high positive indirect effects on yield through number of female flower inflorescence^{-1}.

Characters like weight of nut (0.278), kernel thickness (0.261) and breadth of leaf let (0.220) exhibited moderate positive indirect effect on yield through number of female flowers inflorescence^{-1}.

Inflorescence character like number of female flowers spikelt^{-1} (0.527) exhibited high positive indirect effect on yield through number of spikelet in an inflorescence, and the characters like oil content (0.2264) and activity of acid phosphatase enzyme (0.211) exhibited moderate positive indirect effect on yield through number of spikelet in an inflorescence.

Table. 11. Direct and indirect effects of 26 characters of 40 coconut palms on nut yield

	GS	LS	L	LP	NLT	LLB	BL	NIY	LSX	GSX	FFPI	NSI	NFFPS	MP
GS	**0.0828**	0.0497	-0.0178	0.0373	-0.0723	0.0267	-0.0319	-0.0279	0.0520	0.0098	0.5559	-0.1873	-0.2019	0.0035
LS	-0.0350	**-0.1176**	0.0002	-0.0206	0.0276	-0.0215	0.0488	0.0014	-0.0211	-0.0052	-0.1729	0.0114	0.1193	-0.0005
L	0.0274	0.0005	**-0.0539**	0.0136	-0.0630	0.0236	0.0063	-0.0399	0.0396	0.0078	0.4638	-0.1875	-0.1684	-0.0046
LP	0.0223	0.0175	-0.0053	**0.1387**	-0.1007	0.0309	0.0196	-0.0276	0.0530	0.0070	0.4845	0.1875	-0.5577	0.0133
NLT	0.0325	0.0176	-0.0185	0.0758	**-0.1840**	0.0323	0.0424	-0.0476	0.0538	0.0111	0.3443	0.1716	-0.4563	0.0154
LLB	0.0388	0.0443	-0.0223	0.0750	-0.1040	**0.0571**	-0.0225	-0.0450	0.0467	0.0114	0.6702	-0.2523	-0.2703	0.0199
BL	0.0183	0.0398	0.0024	-0.0189	0.0542	0.0089	**-0.1441**	0.0025	-0.0030	-0.0008	0.2208	-0.4660	0.3476	0.0081
NIY	0.0239	0.0017	-0.0222	0.0396	-0.0906	0.0266	0.0038	**-0.0967**	0.0352	0.0069	0.6888	-0.3199	-0.3055	0.0102
LSX	0.0369	0.0212	-0.0183	0.0630	-0.0848	0.0228	0.0037	-0.0292	**0.1167**	0.0173	0.4838	-0.0348	-0.3263	0.0063
GSX	0.0320	0.0244	-0.0167	0.0383	-0.0812	0.0258	0.0045	-0.0262	0.0799	**0.0252**	0.6328	-0.0178	-0.4448	0.0083
FFPI	0.0330	0.0146	-0.0179	0.0482	-0.0454	0.0274	-0.0228	-0.0478	0.0405	0.0115	**1.3942**	-0.3111	-0.7240	0.0203
NSI	0.0157	0.0014	-0.0102	-0.0264	0.0320	0.0146	-0.0681	-0.0314	0.0041	0.0005	0.4400	**-0.9859**	0.6402	0.0106
NFFPS	0.0140	0.0117	-0.0076	0.0646	-0.0702	0.0129	0.0419	-0.0247	0.0318	0.0094	0.8438	0.5276	**-1.1964**	0.0058
MP	0.0050	0.0011	0.0043	0.0317	-0.0487	0.0195	-0.0199	-0.0169	0.0127	0.0036	0.4854	-0.1790	-0.1201	**0.0582**
FP	0.0063	-0.0240	-0.0196	-0.0194	-0.0335	0.0056	0.0017	-0.0091	0.0018	0.0020	0.3293	-0.1173	-0.1305	0.0107
SP	0.0014	0.0137	-0.0138	-0.0100	-0.0269	0.0173	0.0127	-0.0392	-0.0133	-0.0035	-0.0856	0.0670	-0.0767	-0.0083
NBPPY	0.0243	0.0057	-0.0240	0.0437	-0.0892	0.0294	0.0032	-0.0897	0.0393	0.0088	0.7646	-0.2393	-0.4263	0.0148
LBS	-0.0120	-0.0032	0.0080	0.0302	-0.0332	0.0090	0.0061	-0.0149	0.0232	0.0028	0.1664	-0.0090	-0.1143	0.0182
NNPB	0.0346	0.0315	-0.0260	0.0364	-0.0566	0.0343	-0.0176	-0.0639	0.0298	0.0069	0.8989	-0.1435	-0.5785	0.0045
WN	0.0074	-0.0047	-0.0142	-0.0007	-0.0511	0.0242	0.0111	-0.0358	0.0154	0.0049	0.2780	-0.4596	0.2079	0.0265
KT	0.0143	0.0439	-0.0123	0.0002	-0.0113	0.0104	-0.0308	-0.0309	0.0286	0.0035	0.2614	-0.2738	0.0050	-0.0040
CC	0.0032	0.0037	-0.0161	0.0122	-0.0474	0.0147	-0.0323	-0.0209	0.0264	0.0061	0.4670	-0.2959	-0.0751	0.0103
OC	0.0139	0.0019	-0.0054	-0.0012	0.0025	-0.0001	0.0283	0.0101	0.0012	-0.0023	0.1000	0.2264	-0.2510	-0.0044
PP	-0.0156	0.0007	0.0090	-0.0248	-0.0003	-0.0011	0.0098	0.0323	-0.0036	0.0060	-0.5411	0.1418	0.3057	-0.0052
APH	-0.0175	-0.0063	-0.0116	0.0249	-0.0278	0.0026	0.0217	0.0037	0.0131	0.0033	0.1519	0.2113	-0.2750	-0.0013
GOT	0.0060	0.0159	-0.0127	0.0460	-0.0424	0.0050	-0.0154	-0.0249	0.0109	-0.0014	-0.1405	0.1486	-0.0801	-0.0137

(Continued……..)

Table. 11. Direct and indirect effects of 26 characters of 40 coconut palms on nut yield (Continued….)

	FP	**SP**	**NBPPY**	**LBS**	**NNPB**	**WN**	**KT**	**CC**	**OC**	**PP**	**APH**	**GOT**	**Correlation coefficient**
GS	0.0139	0.0082	0.1138	-0.0200	0.0108	-0.0168	0.0139	-0.0005	-0.0066	0.0254	-0.0028	0.0087	0.4269
LS	0.0376	-0.0560	-0.0188	0.0037	-0.0069	-0.0075	-0.0302	0.0004	0.0006	0.0008	0.0007	-0.0163	-0.2775
L	0.0669	0.1228	0.1728	-0.0205	0.0125	-0.0495	0.0184	-0.0038	-0.0040	0.0223	0.0028	0.0284	0.4344
LP	-0.0257	-0.0347	0.1221	0.0300	0.0068	0.0009	0.0001	-0.0011	0.0003	0.0240	0.0024	0.0400	0.4481
NLT	0.0336	0.0699	0.1881	0.0249	0.0080	-0.0522	0.0050	-0.0033	0.0005	-0.0002	0.0020	0.0278	0.3945
LLB	0.0179	0.1457	0.2000	0.0218	0.0155	-0.0797	0.0147	-0.0033	0.0001	0.0026	0.0006	0.0105	0.5934
BL	-0.0021	-0.0422	-0.0087	-0.0058	0.0032	0.0144	0.0172	-0.0029	0.0078	0.0091	-0.0020	0.0129	0.0706
NIY	0.0173	0.1945	0.3600	0.0213	0.0171	-0.0696	0.0258	-0.0028	0.0041	0.0449	-0.0005	0.0310	0.6449
LSX	0.0028	-0.0545	0.1306	0.0275	0.0066	-0.0249	0.0198	-0.0029	-0.0004	0.0041	0.0015	0.0113	0.3998
GSX	0.0143	-0.0668	0.1358	0.0154	0.0071	-0.0368	0.0113	-0.0031	0.0037	-0.0320	0.0017	-0.0066	0.3286
FFPI	0.0435	-0.0294	0.2127	0.0165	0.0167	-0.0375	0.0151	-0.0043	-0.0028	0.0521	0.0014	-0.0122	0.6924
NSI	0.0219	-0.0326	0.0941	0.0013	0.0038	-0.0876	0.0224	-0.0038	0.0091	0.0193	-0.0028	-0.0182	0.0639
NFFPS	0.0201	0.0307	0.1382	0.0132	0.0125	0.0327	-0.0003	-0.0008	-0.0083	0.0343	0.0030	0.0081	0.5480
MP	0.0340	-0.0683	0.0987	0.0432	0.0020	-0.0856	-0.0056	-0.0023	0.0030	0.0121	-0.0003	-0.0283	0.2395
FP	**0.1842**	-0.0509	0.0621	0.0118	0.0039	-0.0784	0.0118	-0.0031	-0.0039	0.0112	0.0036	-0.0284	0.1279
SP	-0.0196	**0.4793**	0.1495	0.0032	0.0170	-0.0372	0.0011	0.0001	0.0033	-0.0072	-0.0010	0.0226	0.4463
NBPPY	0.0295	0.1847	**0.3878**	0.0171	0.0179	-0.0696	0.0256	-0.0033	0.0026	0.0304	0.0005	0.0309	0.7195
LBS	0.0157	0.0112	0.0480	**0.1379**	0.0035	-0.0618	0.0059	-0.0018	0.0088	0.0025	0.0019	-0.0181	0.2313
NNPB	0.0281	0.3154	0.2688	0.0187	**0.0259**	-0.0467	0.0172	-0.0029	0.0013	0.0352	0.0001	0.0236	0.8752
WN	0.0768	0.0947	0.1435	0.0454	0.0064	**-0.1880**	0.0209	-0.0051	0.0097	-0.0037	-0.0004	-0.0311	0.1785
KT	0.0268	0.0068	0.1228	0.0101	0.0055	-0.0487	**0.0807**	-0.0040	-0.0038	0.0203	-0.0031	0.0271	0.2449
CC	0.0448	-0.0042	0.0998	0.0189	0.0060	-0.0750	0.0251	**-0.0128**	0.0045	0.0082	0.0006	0.0026	0.1744
OC	0.0184	-0.0400	-0.0258	-0.0307	-0.0009	0.0462	0.0078	0.0015	**-0.0395**	0.0310	-0.0008	-0.0109	0.0758
PP	-0.0154	0.0256	-0.0879	-0.0026	-0.0068	-0.0052	-0.0122	0.0008	0.0091	**-0.1342**	0.0038	-0.0150	-0.3265
APH	0.0500	-0.0357	0.0142	0.0196	0.0001	0.0060	-0.0189	-0.0006	0.0024	-0.0386	**0.0131**	-0.0146	0.0902
GOT	-0.0433	0.0900	0.0994	-0.0207	0.0051	0.0485	0.0181	-0.0003	0.0036	0.0166	-0.0016	**0.1206**	0.2374

GS-Girth of stem, **LS**- Number of leaves scars, **L**-Number of leaves, **LP**-Length of petiole, **NLT**- Number of leaflets,**LLB**-Length of leaflet bearing area, **BL**-Breadth of leaflet, **NIY**-Number of inflorescence , **LSX**- Length of spadix, **GSX**-Girth of spadix, **FFIP**-Number of female flowers inflorescence^{-1}, **NSI**- Number of spikelets in an inflorescence, **NFFPS**- Number of female flowers spikelet^{-1},**MP**- Male phase, **FP**- Female phase, **SP**- Setting percentage, **NBPPY**- Number of bunches palm^{-1} year^{-1},**LBS** – Length of bunch stalk, **NNPB**- Number of nuts bunch $^{-1}$, **YIELD**- Total number of nuts palm^{-1} year^{-1},**WN-** Weight of unhusked nut ,**KT**- Kernel thickness, **CC**- Copra content .**OC**- Oil content ,**PP**- Leaf polyphenol, **APH**-Acid phosphatase, **GOT**- Glutamate Oxalacetate Transaminase

Number of spikelet inflorescence^{-1} (0.640), breadth of leaflet (0.347) and leaf polyphenol content (0.305) exhibited high positive indirect effect on yield through number of female flowers spikelet^{-1}. And weight of nut (0.207) exhibited moderate positive indirect effects on yield through number of female flowers spikelet^{-1}.

Number of inflorescence year^{-1} (0.3600), number of nuts bunch^{-1} (0.268), female flowers inflorescence^{-1} (0.212) and length of leaflet bearing area (0.20) had high and moderate positive indirect effects on yield through number of bunch palm^{-1}year^{-1}.

Number of female flowers inflorescence^{-1}(-0.724), number of nuts bunch^{-1} (-0.578), length of petiole (-0.557), number of leaflet (-0.456), girth of spadix (-0.444), number of bunches palm^{-1}year^{-1} (-0.426), length of spadix (-0.326) and number of inflorescence year^{-1} (0.305) had high negative indirect effect on yield through number of female flowers spikelet^{-1}.

Activity of acid phosphatase enzyme (-0.275), length of leaflet bearing area (-0.270), oil content (-0.251) and girth of stem at one metre height (-0.201) had moderate negative indirect effect on yield through number of female flowers spikelet^{-1} and leaf polyphenol content (-0.541) had high negative indirect effects on yield through number of female flowers inflorescence^{-1}.

Weight of nut (-0.459), breadth of leaflet (-0.319) and number of female flowers inflorescence^{-1} (-0.311) had high negative indirect effect on yield through number of spikelets inflorescence^{-1}.

Copra content (-0.295), kernel thickness (-0.273) and length of leaflet bearing area (-0.252) had moderate negative indirect effects on yield through number of spikelets inflorescence^{-1}.

Discussion

5. DISCUSSION

Coconut (*Cocos nucifera* L.) is a versatile and an important commercial palm in the tropics of the world. Coconut improvement is a difficult and time consuming process mainly because of its long breeding cycle, large experimental area and complex resources required for experimentation and the low seed multiplication ratio. Indian coconut population is comprised of enormous variability occurred over the years of cultivation. Improvement in yield potential so far achieved in coconut has been through conventional breeding methods like selection and hybridization. It is a well established fact that the performance of the cultivar in a locality is a function of its genotype and environment. Therefore, the performance will vary under different agro-climatic situations. Identification of superior palms and utilization of such superior palms in hybridization programme is a part of coconut crop improvement. Thus, the present study was taken up to characterize the available germplasm and identify the superior palms based on yield and other characters.

5.1 CLUSTER ANALYSIS

Based on Principle Component Analysis, cluster analysis was carried out using 24 morphological and three biochemical characters. Eleven clusters were obtained having C1, C4, C6, C10 and C11 with only single member and C5 and C9 with eight members each and C3 and C7 with five and six members respectively (Table 1).

The inter cluster distance between C4 and C1 (251.81) was more, followed by C3 and C1 (224.85). The distance between C2 and C5 (20.05) and C8 and C9 (31.77) were comparatively lesser indicating their closeness (Table 2) (Fig.1).

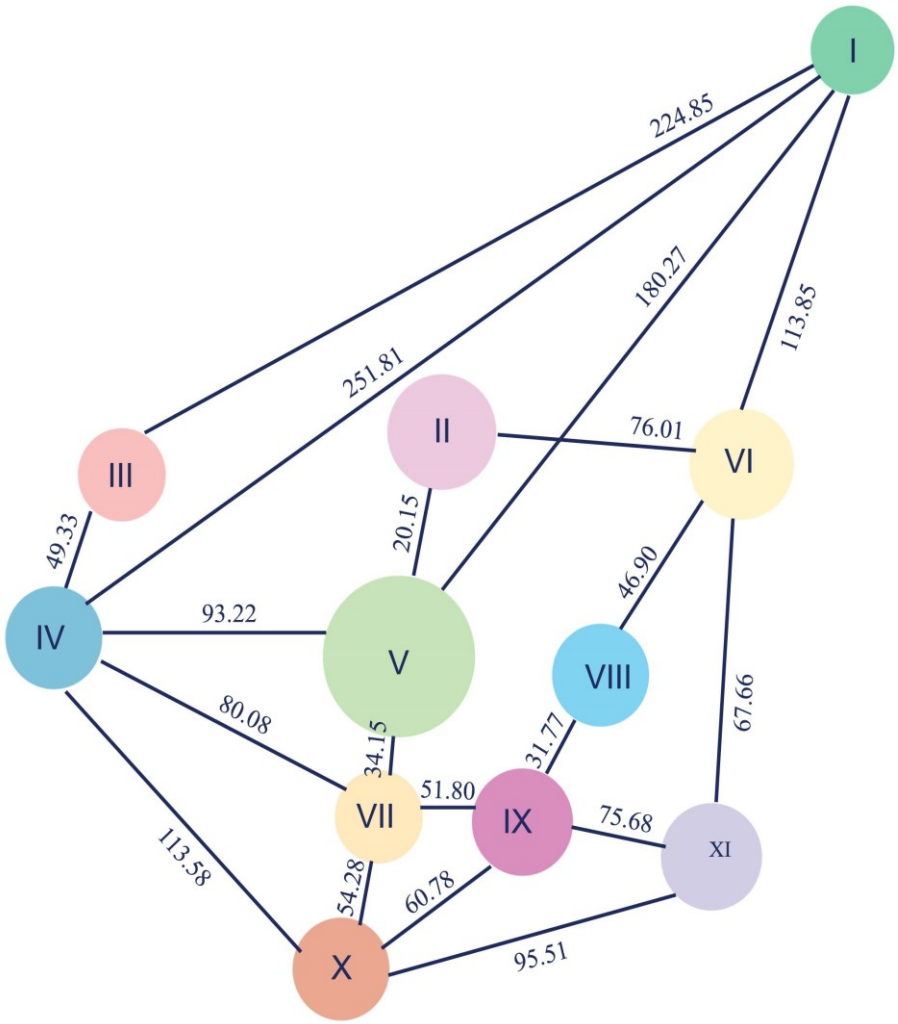

Fig.1. Cluster diagram showing the distribution of clusters

5.1.1 Morphological characters

5.1.1.1 *Stem characters*

Presence of bole is a distinct character which can be utilized for identifying a tall variety from a dwarf population. Among the 40 palms studied, only five palms were devoid of surface bole. Dwarf palms generally show absence of bole (Pillai *et al.,* 1991). In general the palms studied showed less prominent surface bole. It may be due to surface planting. In deep planted palms the bole portion will be 80 cm to 100 cm in height, but in surface planted trees it will be only 30 cm or less (Menon and Pandalai, 1958).

Maximum stem girth was observed in C4 (87 cm) and C2 (73.25cm) and minimum in C1 (62 cm), C6 (64cm) and C10 (64 cm) (Fig.2).In the study conducted by Baskaran and Leela (1964), The stem girth of Tall and Dwarf palms observed to be 67.3cm and 52.3cm respectively while Pillai *et al.* (1991) reported that the stem girth ranged from 58cm to 96cm. It may be due to the growing condition of palm or genotype (Folae, 1991).

Leaf scars present in one metre stem height were highest in C6 (41) and lowest in C4 (20) (Fig. 3). The tall palms showed less number of leaf scars and dwarf plams showed more number of leaf scars (Pillai *et al.,* 1991 and Jacob, 1993).

5.1.1.2 *Leaf characters*

Considerable variations were observed in the leaf characters. C10 had the highest number of leaf production (37.67) with high SD value followed by C4 (37). C1 had the lowest value (23) (Fig.4). The rate of production of leaves is influenced by the size and vigour of the palm (Menon and Pandalai, 1958). Higher rate of leaf production is associated with high yielding character of palms (Jacob, 1993).

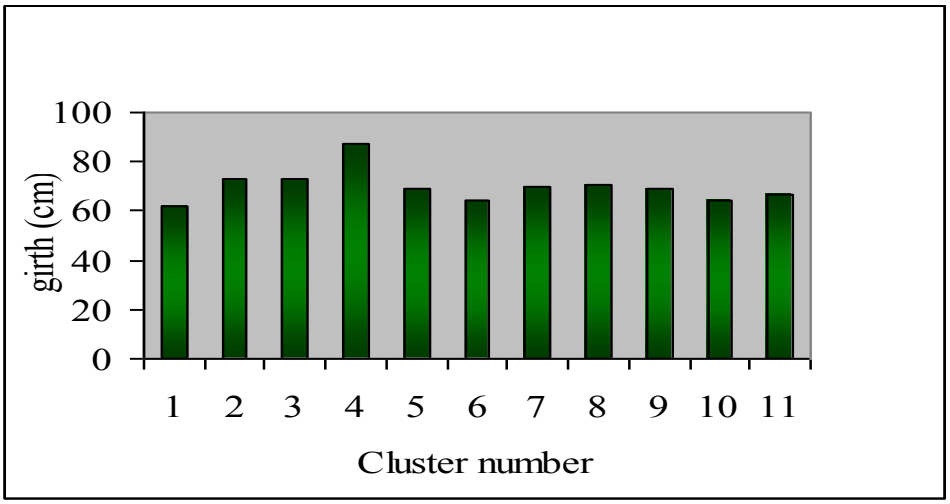

Fig.2 Mean stem girth recorded for coconut palms in different clusters

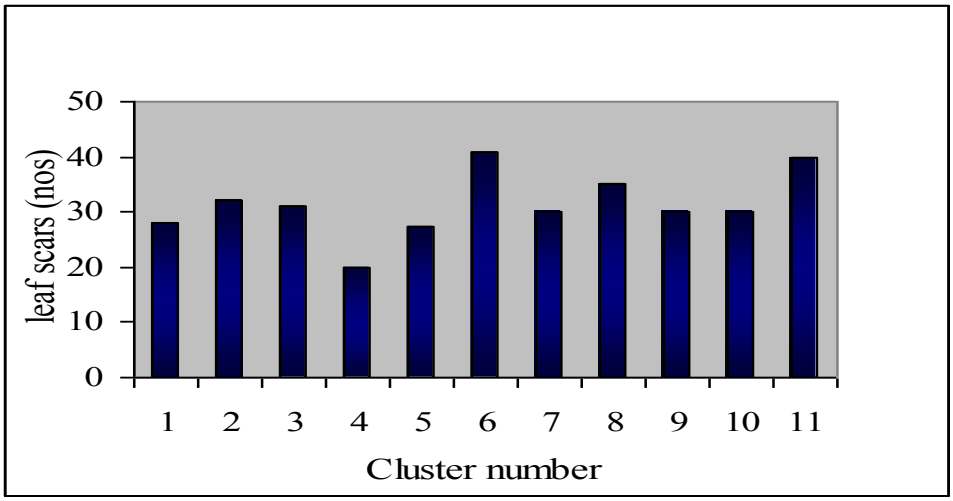

Fig. 3 Mean number of leaves scars for coconut palms in different clusters

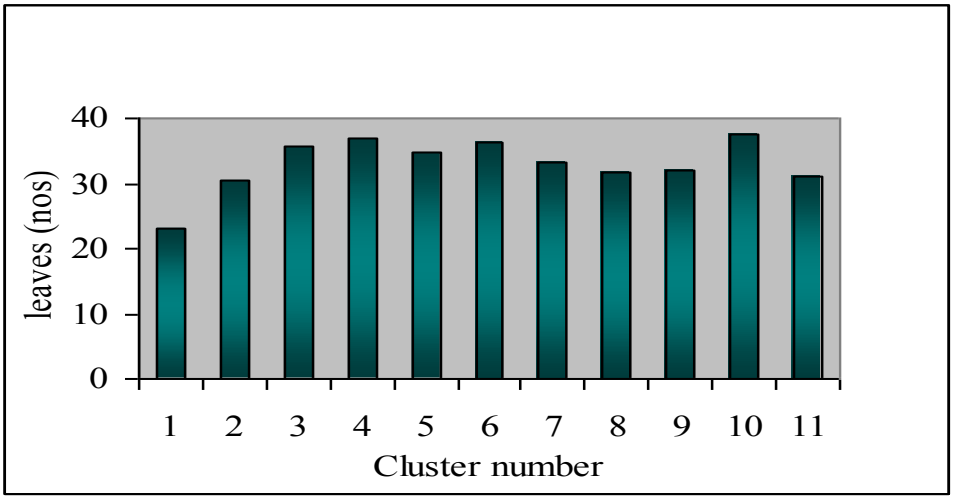

Fig. 4 Mean number of leaves recorded in different clusters

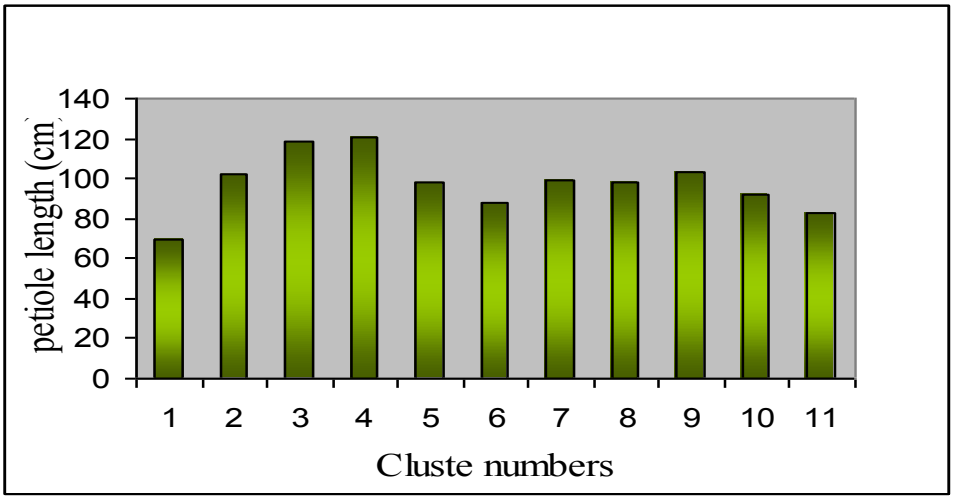

Fig. 5 Mean length of petiole recorded in different clusters

The results showed that the petiole length was more in C4 (121 cm) and the shortest petiole was recorded in C1 (69 cm) (Fig.5). The study conducted by Pillai *et al.* (1991) reported that the talls exhibited length ranging between 117cm to 148cm while dwarf exhibited petiole length ranged between 96cm to 110cm.

C1 recorded lesser number of leaflets (190) than C11 and C8 (200.00 and 211.50 respectively). Highest number was observed in C3 (233.20). The study conducted by Menon and Pandalai (1958) inferred that the number of leaflets in tall palms ranged between 200 to 250 while Pillai *et al.* (1991) reported that the cultivars under study exhibited mean number of leaflets ranging from 180 to 244.

C3 showed highest leaflet bearing area (393.8 cm) while C10 had highest breadth of leaflet (5.50 cm) and C1 recorded shortest leaflet bearing area and leaflet breadth (240 cm and 4.17 cm respectively). In a study conducted by Pillai *et al.* (1991) reported that cultivar Andaman Raguchan exhibited maximum leaflet bearing area (464cm) with breadth of 6cm. While Chowghat Green Dwarf exhibited minimum leaflet bearing area (306cm) with breadth of 5cm.

5.1.1.3 ***Inflorescence characters***

The number of inflorescence produced by the different palms showed variation among them. Coconut palm generally produces 12 leaves in a year, and from every leaf axil one inflorescence emergences. The inflorescence is initiated in the leaf axil of every leaf, but in a few palms during certain seasons these inflorescence get aborted (Menon and Pandalai, 1958). The results of the study showed that C3, C4, C10 and C11 produced 12 inflorescences. This may be due to the higher number of leaf production in the palms. C8 produced lesser number of inflorescence year^{-1}(10) (Fig.6).

Thampan (1975) reported that annual production of spadices in coconut palm coincides with the number of leaves produced by the palm. According to

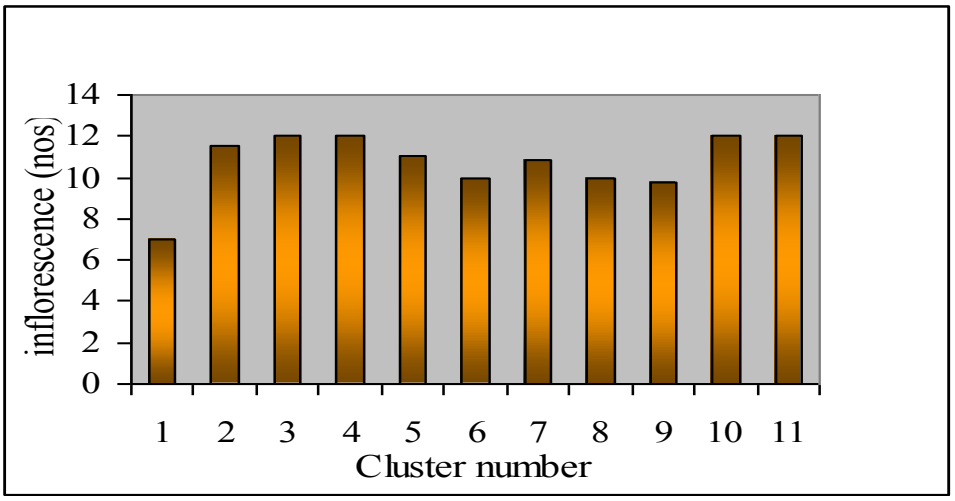

Fig. 6 Mean number of inflorescence produced in a year in different clusters

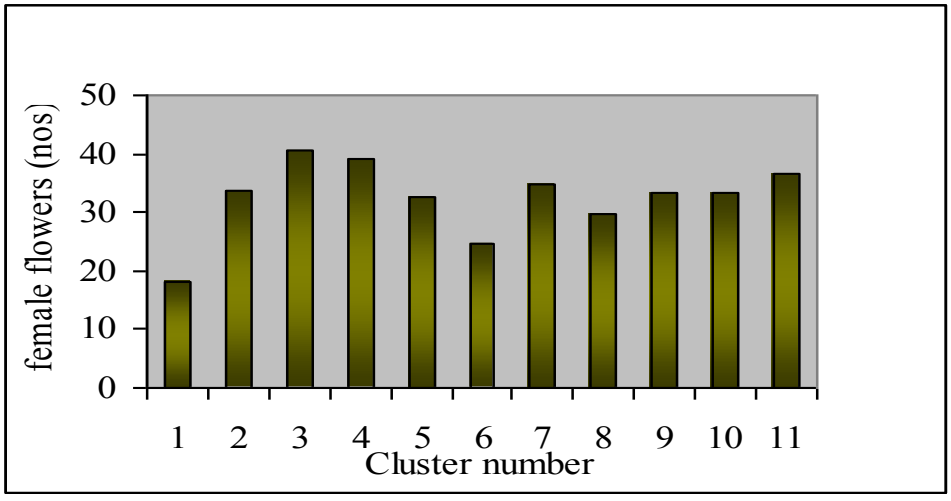

Fig. 7 Mean number of female flowers inflorescence^{-1} in different clusters

Satyabalan and Pillai (1977), West Coast Tall produced 11.3 inflorescences palm^{-1}year^{-1} while Nair *et al.* (2000) reported that Chowghat Green Dwarf produced eight to nine inflorescences year^{-1}. Ratnambal *et al.* (2002) reported that Calidonian coconut cultivars produced 11 to 12 inflorescences year^{-1}.

The length and girth of spadix varied among different clusters. C4 recorded highest values with respect to length and girth (117 cm and 31.67 cm respectively) and the shortest spadix was recorded for C1 (43.33cm length and 15.67 cm width). According to Thampan (1975) the length of spadix in coconut ranged from 1 to 1.2m and diameter ranged from 14 to 16cm. In another study, Ratnambal *et al.* (2002) reported that the length of the inflorescence was more in cultivar Naqeawen (101.30 cm).

Number of female flowers inflorescence^{-1} (40.40) (Fig.7) and number of female flowers spikelet^{-1} (1.47) was observed to be high for C3, while C1 recorded low female flowers inflorescence^{-1} (18) and low number of female flowers spikelet^{-1} (1.26). According to Menon and Pandalai (1958), dwarf palms generally bear large number of female flowers. Patel (1938) reported that female flower production varies in each spadix depending on the conditions prevailing, nature of the palm, cultivars, manuring, season and age of bearing.

Among the different cultivars and hybrids, D x T and local tall produced highest number of female flowers spadix^{-1} (102.0 and 79 respectively) and MYD x WCT and Philippines Ordinary produced less number of female flowers spadix^{-1} (28.30 and 31.7 respectively) (Manna *et al.,*2003).

Maximum number of spikelet was recorded in C11 (37) and minimum spikelet was recorded in C1 (15.67). Dwarf palms have shorter spikelet compared to the tall cultivars (Pillai *et al.,* 1991). Jayalakshmi and Sreerangasamy (2002a) reported that inflorescence characters like spikelet length and number of spikelets inflorescence^{-1} vary significantly among the different cultivars. Similar result was

reported by Ratnambal *et al.* (2003) in different exotic tall cultivars and in hybrids. According to Perera *et al.* (2002), Sri Lankan Brown Dwarf coconut produced on an average four female flowers spikelet^{-1}.

Results showed that the male phase duration ranged from 16.67 days to 20.22 days. Among the different clusters, C7 took more days for completion of male phase (20.22 days). The C1 recorded shortest male phase (16.67 days) (Fig.8). In coconut, male phase duration varies from 18 to 20 days (Patel, 1938). According to Gangolly *et al.* (1957), in dwarf palms the duration of male phase was on an average 21 days. Similar results were also reported in Malayan Yellow Dwarf, Chowghat Orange Dwarf and Malayan Orange Dwarf (18, 16 and 14 days respectively) (Pillai *et al.,* 1991). Ratnambal *et al.*(2002) reported that male phase in talls varied from 13.3 days in Standard Kudat to 21.6 days in Surian Tall.

In the present study the duration of female phase ranged from 3.00 to 5.33 days. Here also the C1 reported the shortest duration of female phase (3 days) and maximum duration was recorded in C6 (5.33 days) (Fig.9). Generally the female phase is shorter than the male phase and it extends four days to a week (Menon and Pandalai, 1958). According to Pillai *et al.* (1991) female phase in Chowghat Orange Dwarf and Chowghat Green Dwarf extend to five days and tall cultivars like Benaulim and Borneo have four days. Similar results were reported in CGD by Nair *et al.* (2000) and in cultivar Nuwehung (Ratnambal *et al.,* 2002).

Nut set was more in C7 (40.76 per cent) and C4 recorded comparatively low nut set (26.70 per cent) (Fig.10). In the present study, it was observed that C7 recorded longest duration of male phase and female phase. Menon and Pandalai (1958) reported that nut setting percentage is directly related with the total number of female flowers produced in an inflorescence. Even though an inflorescence produces large number of female flowers, only a few develop and mature into nuts (Patel, 1938; Folae, 1991; Balakrishnan and Namboodiri, 1987). Cultivars Ayiramkachi has the low setting percentage reported by Ramachandran *et al.*

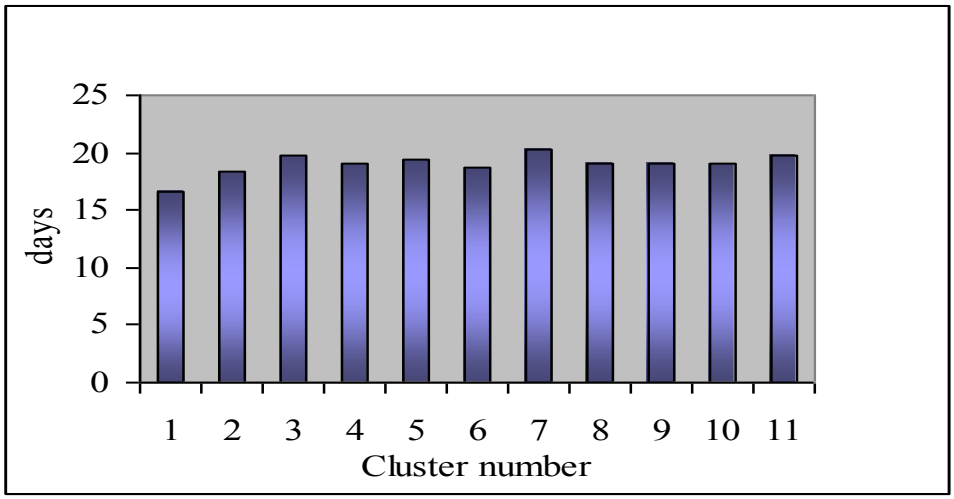

Fig.8 Mean duration of male phase recorded in different clusters

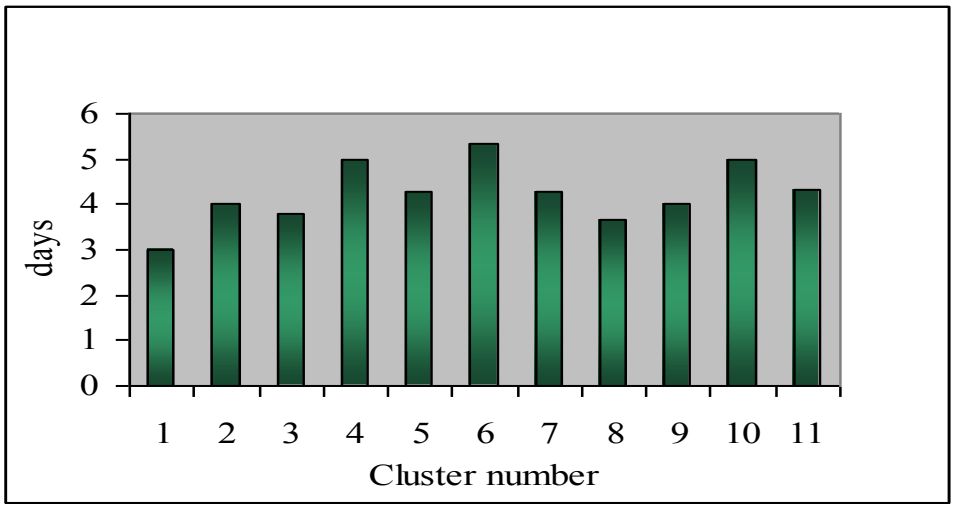

Fig.9 Mean duration of female phase in different clusters

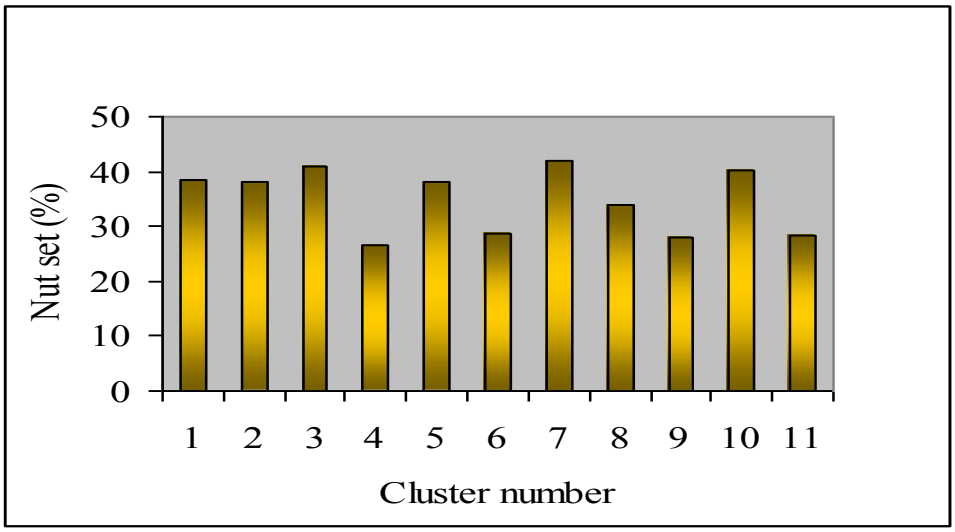

Fig.10 Mean setting percentage recorded in different clusters

(1977). Among the 12 tall cultivars, higher nut set in Laccadive Micro (46 %) reported by Bai *et al.* (2003). Panda *et al.* (1985) also reported similar result in Straight Settlement and Nagwekar *et al.* (2003) in Banawali Green Round (29.65 %).

5.1.1.4 *Bunch characters*

Highest number of bunches palm^{-1}year^{-1} was observed in C3, C4 and C11 (12 each) and lowest in C1 (6) (Fig.11). In the present study, it was observed that an increase in number of leaves increased the number of inflorescence which in turn contributes to the bunch production. Shylaraj *et al.* (1991) reported that Komadan produced more bunches (17) than WCT (13.6). Banawali Green Round produced 14.5 bunches palm^{-1} year^{-1} (Ratnambal *et al.,* 2003). Bunch stalk length (47.33cm) and number of nuts bunch^{-1} (19 nuts) were more in C4 and shortest bunch stalk (31.67 cm) and lowest number of nuts bunch^{-1}(5.67 nuts) were recorded in C1 (Fig.12). Short and stout bunch stalks are supporters of nuts in the bunch (Foale, 1991). Benawali Green Round produced long bunch stalk (50.40 cm) than other Benawali types (Nagwekar *et al.,* 2003). Mali *et al.* (2004) inferred that VHC-1 had the highest number of nuts bunch^{-1} than ECT, MYD and VHC-2.

The yield in terms of nuts depends on different factors which include the number of spadices, number of female flowers produced and the number of female flowers set and develop into nuts (Patel, 1938). In the present study, highest nut yield was recorded in C4 (158 nuts) followed by C3 (129.20 nuts) and may be due to the high values for the characters like number of leaves produced, inflorescence year^{-1}, female flowers inflorescence^{-1}, male and female phase duration, number of bunches and nuts bunch^{-1}, whereas C1 recorded the lowest nut yield (30 nuts) followed by C6 (46 nuts) (Fig.13). Shylaraj *et al.* (1991) reported that mean annual nut yield of Komadan palm (126) was more than that of WCT (83.1). Malayan Green Dwarf cultivars produced on an average 120 nuts palm^{-1} year^{-1}(Ratnambal,

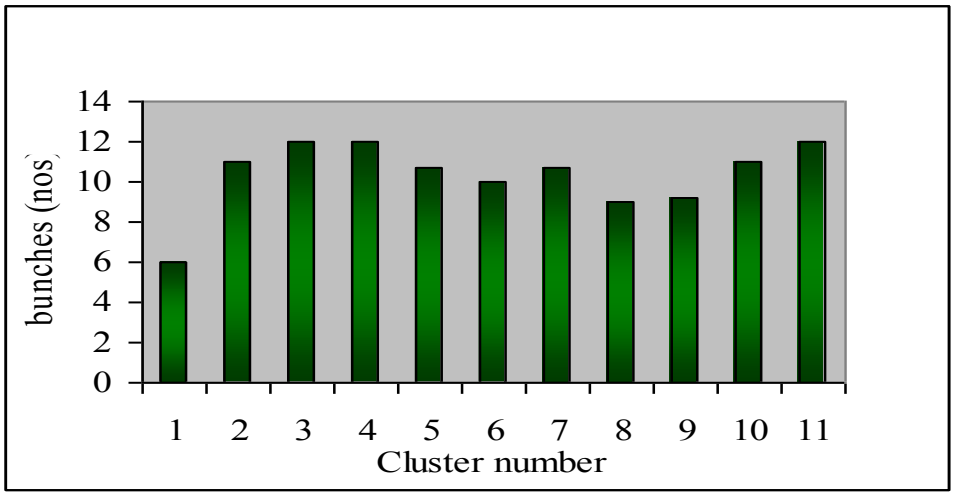

Fig.11 Mean number of bunches palm^{-1} recorded in different clusters

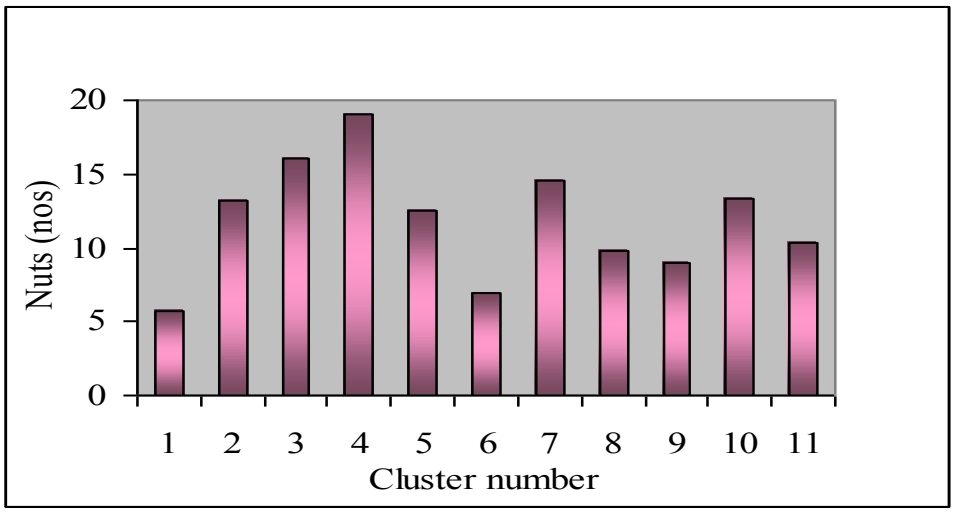

Fig.12 Mean nuts bunch^{-1} recorded in different clusters

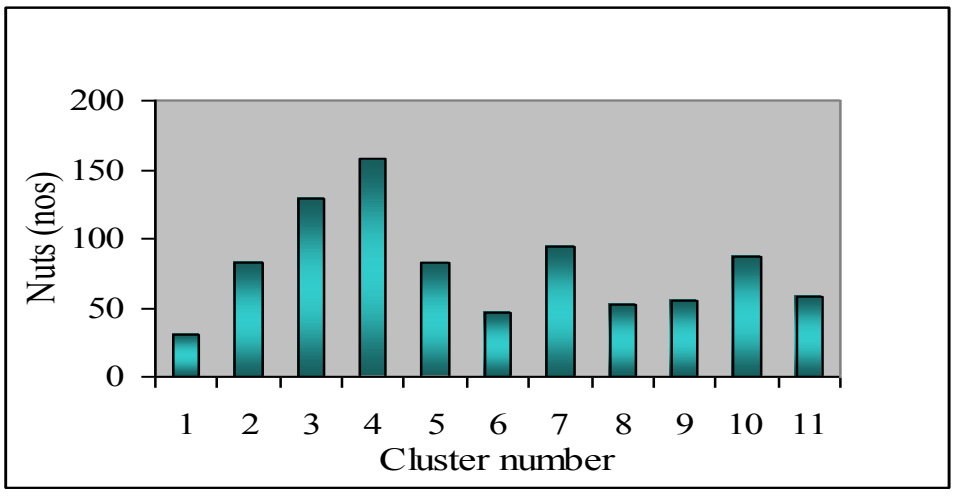

Fig. 13 Mean nut yield recorded in different clusters

1999). According to Natarajan *et al.* (2001), hybrid VHC -3 produced an annual nut yield of 156 nuts palm^{-1}.

5.1.1.5 ***Nut characters***

In the present study, result showed that the nut weight was high in C10 (1.46 kg) and lowest in C4 (1.1 kg) (Fig.14). Liyange and Sakai (1960) reported that weight of husked nut has comparatively high heritability value of 0.97. According to Balakrishnan and Kannan (1991) among the fifteen hybrids, weight of husked nut was more in hybrid Cochin China x COD (0.85 kg), whereas whole nut weight was maximum in natural cross dwarf (1.27 kg) and lowest in Dwarf Orange (0.83 kg) (Sharma *et al.,* 2000).

In the present study, the highest value for kernel thickness was recorded in C4 (12.67 mm) and the lowest in C6 (10mm) (Fig.15). Panda and Maharana (1989) reported that kernel development in nut begins in eight month of the nut development and increases to a maximum weight of 168 g at the eleventh month. The hybrid WCT x COD showed kernel thickness of 13.6 mm and hybrid CDO x LO showed lowest value of 11.3 mm (Balakrishnan and Kannan, 1991).

Copra content per palm showed high heritability value 0.67 (Liyanage and Sakai, 1960). ClusterC10 recorded the highest copra content (220g).The result showed that C10 recorded higher mean copra content than released hybrid Kerasree (216g) and Kerasowbhagya (195g) (Parthasarathy *et al.,* 1998). Cluster C1 recorded the lowest copra content (56g) (Fig.16). Komadan had higher copra content nut^{-1} than WCT as reported by Vanaja and Amma (1997). According to Ratnambal (1999), in dwarf palms, copra content was less compared to tall.

The highest oil content was observed in C1 (69.60 per cent). It was observed that Cluster C1 had higher oil content than released hybrids like Kerasree (66%) and Kerasowbhagya (65%) (Parthasarathy *et al.,* 1998). The lowest was

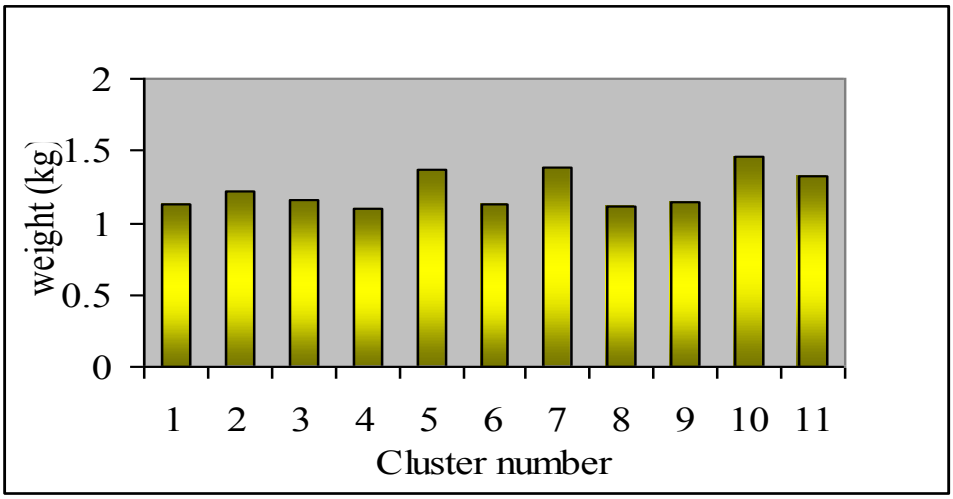

Fig. 14 Mean weight of unhusked nut recorded in different clusters

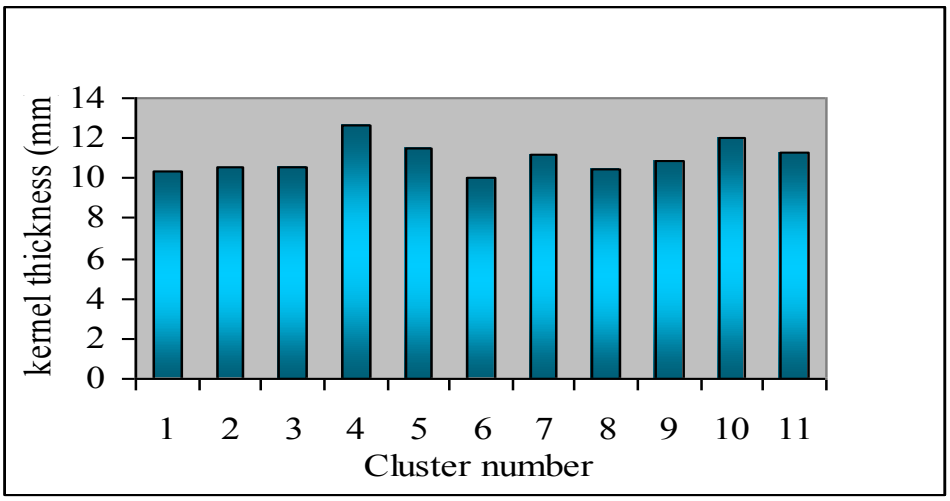

Fig.15 Mean kernel thickness recorded in different clusters

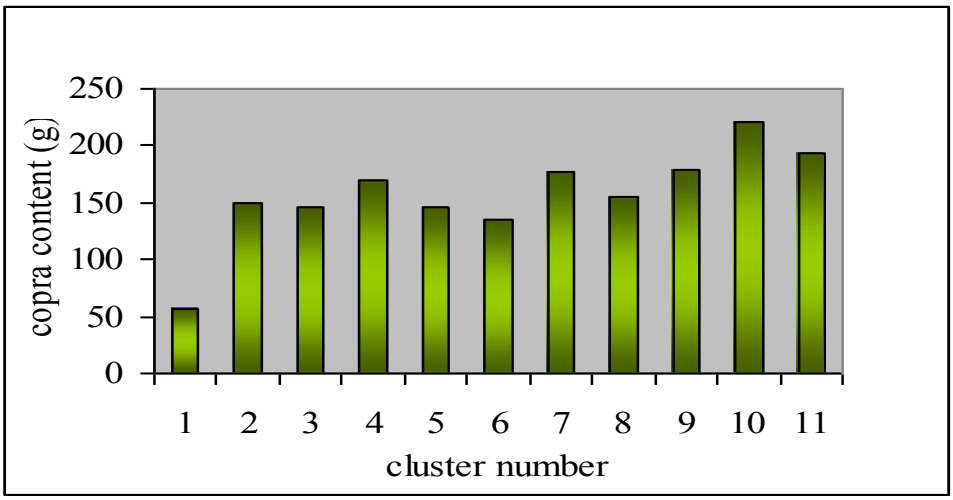

Fig.16 Mean copra content recorded in different clusters

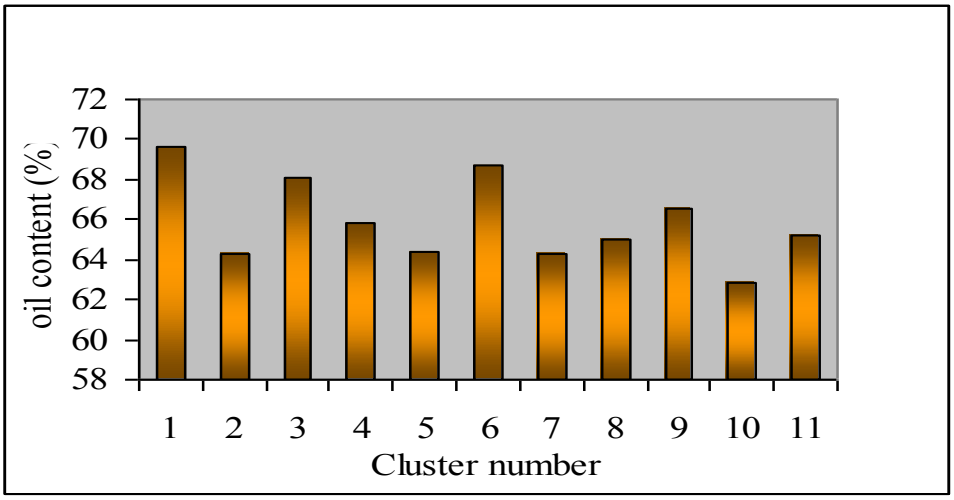

Fig.17 Mean oil content recorded in different clusters

recorded in C10 (62.84per cent) (Fig.17). Sudha (1984) reported that oil content in copra increased with nut age, to a maximum of 73 percentages in the twelfth month. The copra and oil yield palm^{-1} and copra and oil yield ha^{-1} were highest in Andaman Giant as reported by (Ganesamurthy *et al.,* 2003).

5.1.2 Biochemical characters

Biochemical characterization of coconut germplasm has also been attempted by earlier workers. In the present study, biochemical characters like leaf polyphenol content, activities of stress sensitive enzymes like acid phosphatase and glutamate oxalacetate trasnsaminase were also attempted.

The analysis of leaf polyphenol content helps to know genetic variability for polyphenols composition between ecotypes and within ecotypes (Jay *et al.,* 1991). The present study recorded that there was quantum variations in the polyphenol content. The high polyphenol content was recorded in C6 (9.50mg^{-1}g) and low in C4 (3.74 mg^{-1}g) (Fig.18). The high phenolic levels associated with Chowghat Green Dwarf correlated to its relatively better tolerance to root (wilt) diseases as reported by Chempakam and Ratnambal (1993) and Gopalakrishnan and Teresa (2004).The palms included in cluster C6 with high ploy phenol content may have better tolerance to root (wilt) diseases and palms in C4 with low polyphenol may be least tolerant to root (wilt) diseases.

The biochemical basis for drought tolerance in coconut has been reported by Shivashankar (1988). Rajagopal *et al.* (1990a) studied the morphological and biochemical responses of coconut genotypes. The result revealed that the enzyme activity of acid phosphatase and glutamate oxalacetate transaminase were enhanced during stress conditions. Under pre-stress condition the activity of APH did not vary much between tolerant and susceptible genotypes, where as with the onset of stress, the activities increased 78.6 per cent in susceptible genotypes as against 43 per cent in tolerant genotypes.

In the present study, the activity of APH enzyme was studied during April 2005. The result revealed that the cluster C6 (7.59 micro mol ml^{-1} protein at 30ºC for 30 min.) expressed high activity and cluster C4 recorded low activity (5.45 micro mol ml^{-1} protein at 30ºC for 30 min.) (Fig.19).The activity of GOT enzyme was also recorded during June 2005. The result showed that the cluster C6 (0.021 mol^{-1} ml^{-1} mg protein at 37ºC for 30 min) (Fig.20) had low GOT activity and C4 (0.089 $mol^{-1}ml^{-1}$mg protein at 37ºCfor 30 min) showed high GOT activity. The results were in agreement with that of Rajagopal *et al.* (1990b). C6 showed APH activity more during summer month (April 2005) and lowest GOT activity during rainy season (June 2005). Detailed work on this aspect is warranted.

In the present study, GOT activity was observed medium and high in high yielding groups (C3 and C4 respectively), and low in low yielding group (C1) (Table 12). In the case of APH activity, higher activity was observed in C3 and lower activity for C4, which means that the present study does not reveal any trend of high activity of APH in high yielding groups (Table 13).

Table 12. Grouping of clusters based on GOT activity (Mol ml^{-1} mg^{-1} protein at 37ºC for 30min.)

High (0.060 and above)	**Medium (0.045 to 0.060)**	**Low (Below 0.045)**
C2 (0.073)	C5 (0.045)	C1 (0.044)
C4 (0.089)	C7 (0.054)	C3 (0.044)
	C10 (0.045)	C6 (0.021)
		C8 (0.028)
		C9 (0.041)
		C11 (0.025)

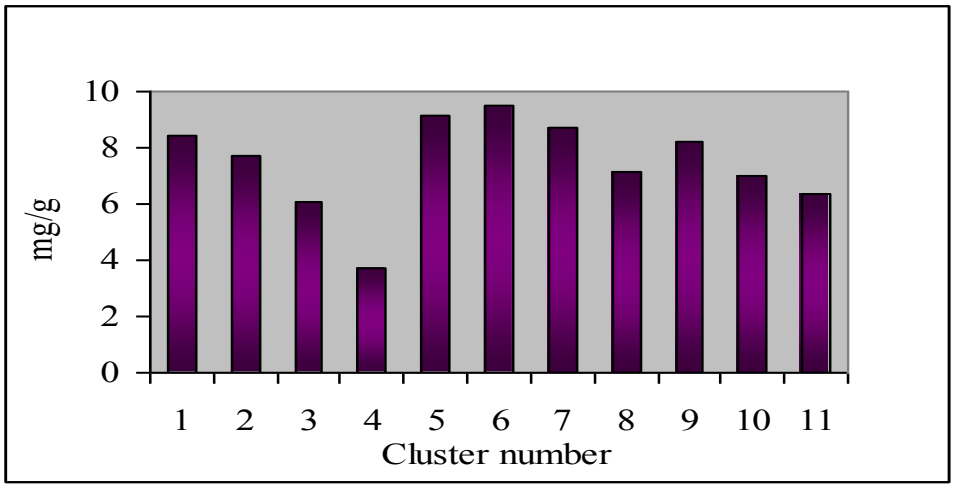

Fig.18 Mean leaf polyphenol content recorded in different clusters

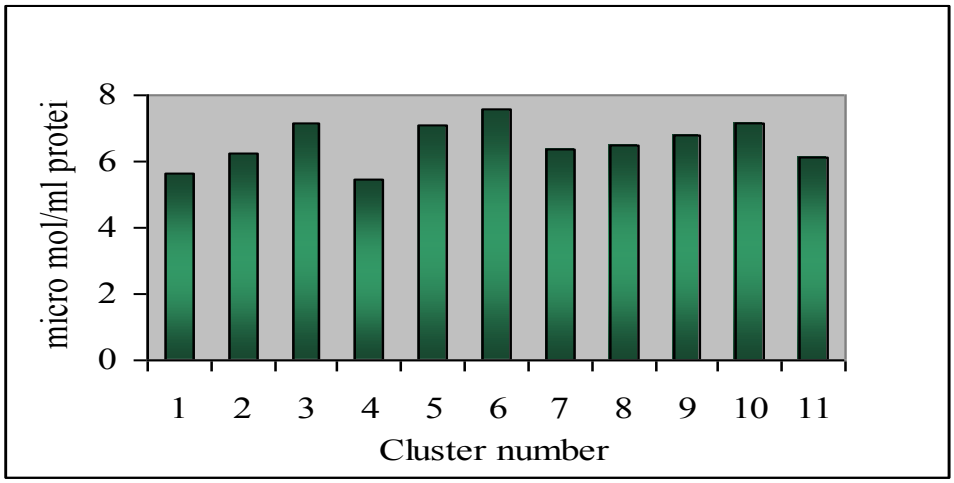

Fig. 19 Mean APH enzyme activity recorded in different clusters

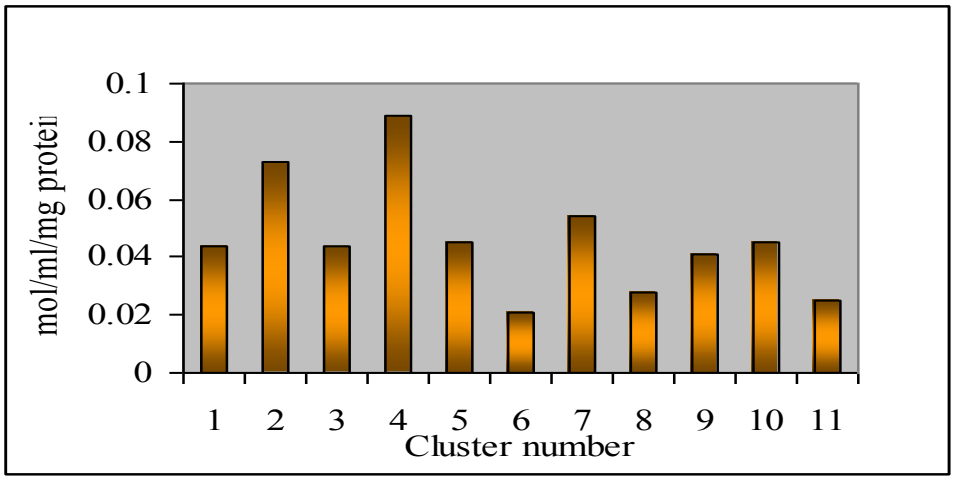

Fig. 20 Mean GOT enzyme activity recorded in different clusters

Table 13. Grouping of clusters based on APH activity (Micro mol ml^{-1} of protein at 30°Cfor 30 min.)

High (above 7.00)	**Medium (6.00 to 7.00)**	**Low (Below 6.00)**
C3 (7.17)	C2 (6.25)	C1 (5.66)
C5 (7.12)	C7 (6.37)	C4 (5.45)
C6 (7.59)	C8 (6.50)	
C10 (7.13)	C9 (6.78)	
	C11 (6.12)	

Table 14. Grouping of clusters based on Leaf poly phenol content (mg g^{-1})

High (9.00 and above)	**Medium (7.00 to 9.00)**	**Low (Below 7.00)**
C5 (9.14)	C1 (8.44)	C3 (6.09)
C6 (9.5)	C2 (7.74)	C4 (3.74)
	C7 (8.69)	C10 (6.97)
	C8 (7.13)	C11 (6.35)
	C9 (8.18)	

Considering nut yield and yield contributing characters, cluster C4 is found to be superior. This cluster include single palm (T_{22}) (Plate 2) followed by cluster C3 (Plate 3 & 4) which includes five palms (T_9, T_{10}, T_{20}, T_{21}, T_{32}). Cluster C1 recorded the poor performance in most of the characters studied and recorded poor nut yield. This cluster also include single palm (T_{33}) (Plate 6).

5.2 CORRELATION STUDIES

Karl Pearson's coefficient of correlation was carried out between different morphological and biochemical characters. Stem characters like girth of stem at one metre height had significant positive correlation with yield. Similar result was reported by Ramanathan (1984).

Plate 2. Cluster C4 (T_{22}) showing superior performance

(A) Palm

(B) Nut

(C) Dehusked nut

Plate 3. Palms included in cluster C3

(A) T_9 Palm and nut

(B) T_{10} Palm and nut

(C) T_{20} Palm and nut

Plate 4. Palms included in cluster C3

(A) T_{21} Palm and nut

(B) T_{39} Palm and nut

Plate 5. Cluster C6 (T24)

(A) palm

(B) Nut

(C) Dehusked nut

Plate 6. Cluster C1 (T_{33}) showing poor performance

(A) Palm

(B) Nut

(C) Dehusked nut

Among the leaf characters studied, number of leaves on the crown showed high positive significant correlation with the nut yield, number of nuts bunch^{-1}, bunches palm^{-1} and number of inflorescence year^{-1}. The result obtained is in agreement with that reported by Ramanathan (1984). Length of petiole had significant positive correlation with yield, female flowers inflorescence^{-1} and number of bunches palm^{-1}year^{-1} and activity of GOT enzymes. Number of leaflets in a leaf and length of leaflet bearing area showed highest positive significant correlation with nut yield.

Inflorescence characters generally showed significant positive effect on nut yield. Number of inflorescence produced palm^{-1} year^{-1} had high significant positive correlation with nut yield, number of nuts bunch^{-1}, number of bunches palm^{-1}, setting percentage, female flowers inflorescence^{-1}, kernel thickness, nut weight. Length and girth of spadix also had high positive correlation with nut yield. Female flowers inflorescence^{-1} was highly correlated with nut yield, number of nuts bunch^{-1}and weight of nut.

Inflorescence characters like number of inflorescence produced palm^{-1} year^{-1} was significantly and negatively correlated with leaf polyphenol content. Number of spikelet inflorescence^{-1} recorded high significant negative correlation with number of female flowers spikelet^{-1}.

Bunch characters like number of bunches palm^{-1} year^{-1}, length of bunch stalk and nuts bunch^{-1} also showed significant positive correlation with nut yield. Weight of nut was positively correlated with copra content whereas kernel thickness was significantly and positively correlated with copra content. Leaf polyphenol content was significantly and negatively correlated with yield. Narayanankutty and Gopalakrishnan (1991) reported that the total phenolic constituents in leaf exhibited a negative correlation with nut yield.

5.3 PATH ANALYSIS

Path analysis suggested by Dewey and Lu (1959) provides a method for separating the correlation coefficient into direct and indirect effects and it measures the relative importance of the component characters in influencing the yield. These contributing characters alter its relationship with other associated characters and finally will reflect on yield.

In the present study, path analysis was carried out using 26 characters including both morphological and biochemical characters. Mean number of female flowers inflorescence^{-1} registered very high positive direct effect on nut yield. Ramanathan (1984) reported that functional leaves, spikelets with nuts and leaflets had positive direct effect on yield in East Coast Tall coconut.

Characters like duration of female phase, bunch stalk length, petiole length and activity of GOT enzyme had low positive direct effect on nut yield. Stem girth, length of leaflet bearing area, duration of male phase, number of nuts bunch^{-1}, kernel thickness and activity of APH enzyme showed negligible positive direct effect on yield.

Number of female flowers spikelet^{-1} recorded high negative direct effect on yield and the characters like number of leaves scars in one metre stem, total number of leaves in the crown, number of inflorescence year^{-1}, copra content, oil content and leaf polyphenol content also recorded negative direct effects on yield.

Characters like number of nuts bunch^{-1}, number of bunches palm^{-1} year^{-1}, number of inflorescence palm^{-1} year^{-1}, duration of male phase, petiole length, copra content and number of leaves in the crown exhibited high positive indirect effects on yield through number of female flowers inflorescence^{-1}.

Inflorescence characters like number of female flowers spikelet^{-1} exhibited high positive indirect effect on yield through number of spikelets in an inflorescence and characters like oil content and activity of APH enzymes exhibited moderate positive indirect effect on yield through number of spikelets in an inflorescence. Pamin and Asmono (1993) reported that oil content had direct effects on nut weight, mesocarp weight and copra content.

Summary

6. SUMMARY

The study on 'Morphological and biochemical characterization of coconut germplasm' was undertaken at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during 2004- 2005. Coconut palms of 20 years old available at the Department Farm were used for the study. Forty palms were selected randomly from the germplasm based on previous years yield data.

The studies were mainly directed towards characterization of the available germplasm based on morphological, yield and biochemical characters. Cluster analysis was carried out to group the palms in to different clusters based on various morphological, yield and quality parameters. Correlation studies were carried out to find the relationship between different morphological and biochemical characters with yield. Path analysis was also carried out so as to elucidate the direct and indirect effects of different characters on yield.

The salient result of the study were summarized and presented hereunder:

The selected palms showed very high variability for the 28 characters studied. The inter cluster distance between C4 and C1 (251.81) were more and the distance between C2 and C5 (20.15) recorded was less indicating their closeness.

Stem characters like presence of surface bole was less prominent in all the palms studied. Palms included in cluster C4 recorded maximum stem girth and C6 recorded more leaves scars in one metre stem length.

Among the different leaf characters studied, C10 produced more number of leaves (37.67) and petiole length was more in C4 (121 cm). C1 produced less number of leaves (23) with shortest petiole (69cm) and lesser number of leaflets (190).

The number of inflorescence produced varied among different clusters. C3, C4, C10 and C11 produced 12 inflorescences in a year and the lowest was in C8 (10). C3 produced more female flowers spikelet^{-1}(1.43). C11 produced inflorescence with more spikelets (37). C1 recorded shortest male and female phases (16.67 days and 3 days respectively). Duration of male phase was recorded more in C7 (20.22 days) and C6 recorded longest female phase (5.37 days). C7 recorded more setting percentage (42%).

Total number of bunches palm^{-1} year^{-1} varied among the clusters. C3, C4 and C11 produced 12 bunches each in a year. Length of bunch stalk was more in C4 (47.33 cm) and C4 recorded more number of nuts bunch^{-1} (19 nuts).

It was observed that yield varied highly among different clusters. It ranged from 30 nuts to 158 nuts palm^{-1}. C4 recorded highest nut yield (158 nuts) followed by C3 (129.2 nuts). C4 included single palm T_{22}, and C3 included five palms T_9, T_{10}, T_{20}, T_{21} and T_{32}. C10 produced big nuts (1.48 kg) and thickness of kernel was more in C4 (12.67 mm). Copra content was also high in C10 (220g), where as C1 excelled for oil content (69.6%) with other types.

Among the different biochemical characters studied, leaf polyphenol content ranged from 3.74 mg g^{-1} to 9.5 mg g^{-1}. The highest value recorded was in C6 (9.6 mg g^{-1}).

The activity of APH enzyme was also high in C6 (7.59 micro mol ml^{-1} protein at 30°C for 30 min) whereas and lowest was in C4 (5.45 micro mol ml^{-1} protein at 30°C for 30 min).

Activity of GOT enzyme ranged from 0.021 to 0.089 mol ml^{-1} mg^{-1} protein at 37°C for 30 min. C4 showed the highest mean value (0.089 mol ml^{-1} mg^{-1} protein at 37°C for 30 min) and lowest in C6 (0.021 mol ml^{-1}mg^{-1} protein at 37°C for 30 min).

Among the eleven clusters, C4 was superior with respect to nut yield (158 nuts palm^{-1}), number of bunches produced in a year (12), number of nuts bunch^{-1}(19) and kernel thickness (12.67 mm). C4 which included single palm, $T_{22,}$ was followed by C3, which includes T_9, T_{10}, T_{20}, T_{21} and T_{32} recorded 129.2 nuts palm^{-1} year^{-1} from12 bunches with 16 nuts bunch^{-1}.

Among the eleven clusters C4 was superior with respect of nut yield and yield contributing characters followed by cluster C3.

C6 recorded highest polyphenol content and it included single palm T_{24}. C4 recorded lowest polyphenol content (3.74 mg g^{-1}). Highest APH enzyme activity was recorded in C6 (7.59 micro mol ml^{-1} protein at 30°C for 30 min) and lowest value for C4.

GOT activity was more in C4 (0.089 mol ml^{-1} mg^{-1} protein at 37°C for 30 min) and lowest in C6 (0.021 mol ml^{-1} mg^{-1} protein at 37°C for 30 min).

Karl Pearson's coefficient of correlation was carried out between the different morphological and biochemical characters. Among the different stem and leaf characters studied, number of leaves on the crown showed significant high positive correlation with the nut yield, number of bunches palm^{-1} year^{-1} and number of nuts bunch^{-1}. Petiole length had significant positive correlation with yield, female flowers inflorescence^{-1}, number of bunches palm^{-1} year^{-1} and the activity of GOT enzyme.

Inflorescence characters like number of inflorescence produced palm^{-1}year^{-1} had significant high positive correlation with nut yield and number of bunches palm^{-1} and negative correlation with leaf polyphenol content. Number of spikelet inflorescence^{-1} also recorded significant negative correlation with number of female flowers spikelet^{-1}.

Bunch characters like bunches palm^{-1} year^{-1}, length of bunch stalk and nuts bunch^{-1} showed positive correlation with nut yield. Nut characters like nut weight was positively correlated with copra content and kernel thickness showed positive correlation with copra content. Biochemical character like leaf polyphenol content was negatively correlated with nut yield.

Path analysis was carried out using morphological and biochemical characters. Results showed that number of female flowers inflorescence^{-1} recorded high positive direct effect on nut yield. Other characters like duration of female phase, bunch stalk length, petiole length and activity of GOT enzyme had low positive direct effect on nut yield.

Number of female flowers spikelet^{-1} recorded high negative direct effect on yield. Characters like number of nuts bunch^{-1}, number of bunches palm^{-1} year^{-1}, number of inflorescence palm^{-1} year^{-1}, duration of male phase, petiole length, copra content and number of leaves in the crown exhibited high positive indirect effect on yield through number of female flowers inflorescence^{-1}. Characters like oil content and activity of APH enzymes had moderate positive indirect effects on yield. Activity of APH enzymes had moderate negative indirect effect on yield through number of female flowers spikelet^{-1} and leaf polyphenol content had high negative indirect effect on yield through number of female flowers inflorescence^{-1}.

References

REFERENCES

Antony, A., Kumar, T.S., Insai, K.A., Sreekumar, K. and Ganesan, J.2004. Studies on genetic diversity among population of the coconut cultivar Chowghat Green Dwarf (*Cocos nucifera* L.). *Indian Cocon.J.*35(6):19-22

Ashburner, G.R., Thompson,W.K. and Halloran, G.M.1997. RAPD analysis of South Pacefic coconut palm populations.*Crop Sci.* 37:992-997

Asmono, D., Hartana, A., Guhardja, E. and Yahya, S. 1993. Genetic diversity and similarity of 35 coconut populations based on isoenzyme banding pattern analysis. *Bull. –Pasat- Penclitian- Kelapa- Sawit*, Pusat Penelitian Kelpa Sawit, Medan, Sumatra, Indonesia, 1(1): 39-54

Bai, K.V.K., Reddy, S.V.S., Ratnambal, M.J. and Laxman, R.H.2003. Factors contributing to female flower production and button shedding in coconut. *J. Plantn. Crops* 31(2): 33-36

Balakrishnan, P.C. and Namboodiri, K.M.N.1987.Genetic divergence in coconut. *Indian Cocon. J.*18 (7): 15-17

Balakrishnan, P.C. and Kannan, K. 1991.Evaluation of certain coconut (*Cocos nucifera* L.) hybrid under rainfed conditions. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium on Coconut Breeding and Management, 1988. Kerala Agricultural University, Trichur, Kerala, India, pp.109-111

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

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. Plantn. Crops 1* (suppl):1- 6

Bergmeyer, H.U.1963. Glutamate- Oxalacetate Transaminase. *Methods of Enzymatic Analysis.*Bergmeyer, H.U.(ed.) Verlag Chemie, Gmbh Weinhein, 837p.

Bhandari, M.M.1974. *Practicals in Plant Breeding : A Manual Cum Practical Record,* Oxford and IBH Pub. Co., New Delhi, India, 158 p.

Bhaskaran, V.P. and Leela, K.1964. Hybrid coconut Tall x Dwarf – A Comparitive study with parental types. *Agric. Res. J. Kerala* 1(2): 64-84

Bourdeix, R., N'cho, Y.P., Le Saint, J.P. and Sangare, A.1990. A coconut (*Cocos nucifera* L.) selection strategy I: Rundown of achievements. *Oleagineux* 45(8-9):359-371

Chan, E.1979. Growth and early yield performance of Malayan Dwarf x Tall coconut hybrids on the coastal clays of peninsular Malaysia. *Oleagineux* 17(1):65-69

Chatfield, C. and Collins, A.J.1980. *Introduction to Multivariate Analysis.*Chapman and Hall, New York, U.S.A. 239p.

Chempakam, B. and Ratnambal, M.J.1991. Variation for leaf polyphenol in coconut cultivars. *Advances in Coconut Research and Development* (eds. Nair, M.K., Khan, H.H., Gopalasundaram, P. and Rao, E.V.V.B.). Indian Society for Plantation Crops, Kasargod. Oxford and IBH Pub.,Co., New Delhi, India, pp.51-54

Chowdhury, D., Nath, J.C. and Mohan, N.K.2001. Kamarupa – a newly released coconut variety by Assam agricultural university. *Indian Cocon. J.*31(9):12-13

CPCRI.2004.*Annual Report: 2003-2004*. Central Plantation Crops Research Institute, Kasargod, Kerala, India, 58p.

Dewey, D.R. and Lu, K.H.1959. A correlation and path coefficient analysis of components of crested wheat grass and seed production. *Agron. J.*51:515-518

Foale, M.A. 1991. Coconut genetic diversity present knowledge and future research needs. Paper presented in IBPGR workshop on *Coconut Genetic Resources.* 8-11 October, 1991, Cipans, Indonesia, 77 p.

Ganesamurthy, K., Natarajan, C., Rajarathinam, S., Vincent, S. and Khan, H.H. 2002. Genetic variability and correlation of yield and nut characters in coconut *(Cocos nucifera* L.). *J. Plantn. Crops* 30(2):23-25

Ganesamurthy, K., Natarajan, C., Packiaraj, D., Rajarathinam, S. and Khan, H.H. 2003. Genetic improvement of coconut (*Cocos nucifera* L.). in Tamil Nadu. *Indian Cocon. J.*34(1):8-13

Gangolly, S.R., Satyabalan, K.and Pandalai, K.M.1957.Varieties of coconut. *Indian Cocon. J.*10(1): 3-28

Gopalakrishnan, R.2003. Coconut industry in Manado, North Sulawesi, Indonesia. *Indian Cocon.J.*34(3):14-17

Gopalakrishnan, R. 2004. Coconut in Malaysia and the shining example of united plantation Berhad. *Indian Cocon.J.*34(11):13-19

Gopalakrishnan, R. and Teresa, M.V.M. 2004. Promising unexploited coconut ecotypes for future research. *Indian Cocon. J.* 35(6): 6-18

Government of India. 2004. *Economic Survey 2004.* Ministry of Finance, Government of India, New Delhi, India, 254p.

Government of Kerala.2004. *Economic Review 2004.* State planning Board, Thiruvananthapuram, Kerala, India, 514p.

Harland,S.C.1957. The improvement of coconut palm by breeding and selection. Circulation paper No.7/57.*Bull.15.Coconut Res. Inst.* (Ceylon)

Harries, H.C.1978. The evolution, dissemination and classification of *Cocos nucifera* L.*Bot.Rev.*44:265-319

Hore, J.K.1999. Coconut research in West Bengal. *Indian Cocon.J.*30(4):1-6

Indiresh, K.M., Hanumanthappa, H., Shankar, S., Maharudrappa, K. and Palanimuthu, V. 1997. Evaluation of coconut germplasm in the Maidan tract of Karnataka. *Indian Cocon. J.* 28(8):2-4

Iyer, R.D., Rao,E.V.V.B. and Govindankutty, M.P.1979. Super yielders in coconut. *Indian Fmg.* 28(10):3-5

Iyer, R.D. and Damodaran, S.1994. Improvement of coconut. *Advances in Horticulture Vol.9-Plantation and spices crops.* Part I (eds. Chadha, K.L. and Retinam,P.).Malhotra Publishing Home, New Delhi, India, pp.217-242

Jacob, P.M. 1993.Preliminary observations on a variant form of coconut cultivar Lakshadweep Micro.*Advances in Coconut Research and Development* (eds. Nair, M.K., Khan,H.H., Gopalasundaram, P. and Rao,E.V.V.B.). Oxford and IBH Pub.Co.,New Delhi, India, pp. 55- 57

Jay,P., Bourdeix, R. and Potier, F.1991. Polymorphism of coconut leaf polyphenols. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium on Coconut Breeding and Management, 1988. Kerala Agricultural University, Trichur, Kerala, India, pp.60-68

Jayalekshmy, V.G and Sreerangaswamy, S.R.2002a. Variation in morphological traits in coconut. *Madras agric.J.* 89 (1-3): 154-157

Jayalekshmy, V.G. and Sreerangasamy, S.R.2002b.Cluster analysis in Coconut *J.Plantn. Crops.*30(2):18-22

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. 1992. Correlation among fruit characters in coconut (*Cocos nucifera* L.) cv. Dwarf Green. *Gujarat agric.Univ.Res.J.* 18(1): 78-80

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

Kumaran, P.M., Arunachalam, V., Niral, V., Jerard, B.A., Apshara, E.S. and Samsudeen, K. 2004. Genetical investigations and breeding for high yield in coconut palm. *CPCRI Annual Report:2003-2004* .Central Plantation Crops Research Institute, Kasargod, Kerala, India, pp. 22-23

Lakshmanachar, M.S.1959. A preliminary note on the heritability of yield of coconuts. *Indian Cocon.J.*12: 65-68

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

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

Mali, P.C., Desai, A.G. and Joshi, G.D.2004.Prospects of cultivating Dwarf Orange coconut cultivar for tender nut production in Lakshadweep Islands. *Indian Cocon.J.* 34(11): 3-12

Malik, C.P. and Singh, M.B.1980.*Plant Enzymology and Histo enzymology.*Kalyani Publishers, Ludhiana, Punjab, India 415p.

Manna, S., Mathew, B., Hasan, M.A. and Chatopadhyay, P.K.2003. Inflorescence and nut characters of some coconut cultivars and hybrids. *Indian Cocon. J.* 32(10): 15-16

Market, C.L. and Moller, F.1959. Multiple forms of enzymes tissue ontogenic and species patters, *Processing nat. Acad. Sci.* 45:753-763

Mathew, M.T.2005. Drought in coconut: emerging problems and striking prospects. *Procedings of the National Workshop: Drought management in plantation crops. 22-23 March, 2005*(eds. Nybe, E.V. and Rao, G.S.L.H.V.P.). Kerala Agricultural University , Thrissur, Kerala, India, pp.3-9

Mathew, T. and Gopimony, R.1991. Influence of seednut characters on seedling vigour in coconut. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium on Coconut Breeding and Management, 1988. Kerala Agricultural University, Trichur, Kerala, India, pp.92-102

Menon, K.P.V., and Pandalai, K.M. 1958. *The Coconut Palm – A Monograph.* Indian Central Coconut Committee, Ernakulam, Kerala, India, 384 p.

Meunier, J., Saint, J.P., Le Gaseon, J.P. and de Nuce de M.Lamothe. 1984. Recent advances in genetic improvement of coconut yield. *Proceedings of international Conference on Cocoa and Coconut.* Kuala Lumpur, Malaysia pp.59-62

Meunier, J.1992. Genetic diversity in coconut. A brief survey of IRHO's work. Paper presented an *IBPGR Workshop on coconut Genetic Resources*: 8-11 October, 1991, Cipans, Indonesia, pp. 59-62

Murry, D.B.1977. Coconut palm. *Ecophysiology of Tropical Crops* (eds. Alvim, P de T. and Koziowski, T.T.) Academic Press, New York, pp. 24-27

Nagwekar, D.D., Sawant, V.S., Desai, V.S., Mahadik, M.V., Khan, H.H., Joshi, G.D. and Jambhale, N.D. 2003. Benawali types of coconut of the Konkan region of Maharashtra state. *Indian Cocon. J.* 34(7): 3-5

Nair, R.V., Rajesh,M.G. and Jacob, P.M.2000.Chowghat Green Dwarf – a suitable variety for the coconut root (wilt) disease tract. *Indian Cocon. J.*31(3):55

Narain, P.1990. *Statistical Genetics.* Wiley Eastern, Ltd., New Delhi, 599p.

Narayana,G.V. and John, C.M.1949. Varieties and forms of coconut. *Madras Agric. J.*36:349-366

Narayanankutty,M.C. and Gopalakrishnan,P.K.1991.Yield components in coconut palms. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium on Coconut Breeding and Management, 1988. Kerala Agricultural University, Trichur, Kerala, India, pp.94-98

Natarajan, C., Giridharan, S. and Bhaskaran, R.2001. VHC-3 New coconut hybrid for Tamil Nadu. *Indian Cocon. J.* 31(9):10-11

Pamin, K. and Asmono, D.1993.Path analysis of oil production and its components in coconut.*Buletin Pusat Penelitan 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

Panda, K.C. and Maharana, T. 1989. Studies on developmental changes in coconut fruit from fertilization to maturity. *Orissa J. agric.Res.* 2(1): 80-81

Parthasarathy, V.A., Ratnambal, M.J. and Kumaran, P.M.1998. Coconut varietal improvement- A reflection of 50 years of research. *Indian cocon. J.*29(4):68-73

Patel, J.S.1937. Coconut breeding.*Proc. Assoc.Evon.Biol.* 5:1-16

Patel, J.S. 1938. *The coconut -A monograph.* Govt. press, Madras, India,313p.

Perera, L., Peries, R.R.A. and Padmasiri, M.H.L. 2002. Sri Lanka Brown Dwarf (SLBD) coconut: a potential coconut variety for future breeding. *Plant Genetic Newsletter 2001* (131), IPGRI, Rome, Italy, 80p.

Peter, S.D. and Jayaraman, C.1977. Variability for yield and quality of nut in a population of East Coast Tall variety of coconut. *J. Plantn. Crops* 5(1):28-30

Pillai, R.V., Rao, E.V.V.B. and Kumaran, P. M. 1991. Characterization of coconut cultivars. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium

on Coconut Breeding and Management, 1988. Kerala Agricultural University, Trichur, Kerala, India, pp. 75-82

Pomier, M. and de Taffin, G.1982.Tolerance to drought of some coconut hybrids. *Oleagineux* 37:52-62

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

Rahman, V. and Yueri, G.Y. and Tan, S.G. 1981. Identification of oil palm species using electrophoresis. *Forth International SABRAO Congress,* Kuala Lumpur, Malaysia, p.27

Rajagopal, V., Bai, K.V.K. and Voleti, S.R.1990 a. Screening of coconut genotypes for drought tolerance. *Oleagineux* 45: 215-223

Rajagopal, V., Bai, K.V.K., Voleti, S.R. and Shivashankar, S.1990 b. Water stress in coconut (*Cocos nucifera* L.) palms. *Proceeding of the international congress of plant physiology February 15-20, 1988 Volume I.* Department of Plant Physiology and Biochemistry, CPCRI, Kasargod, Kerala, India, pp. 508-512

Rajagopal, V., Voleti, S.R., Bai, K.V.K. and Shivashnkar, S.1991. Physiological and biochemical criteria for breeding for drought tolerance in coconut. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium on Coconut Breeding and Management, 1988. Kerala Agricultural University, Trichur, Kerala, India, pp.136-143

Ramachandran, M., Muralidharan, V.N. and Balasubramanian, K. 1977. A note on the new coconut variety – Ayiramkachi. *Indian Cocon. J.* 8: 4-6

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

Ramadasan, A., Balakrishnan, T.K. and Rajagopal, V.1991. Response of coconut genotypes to drought. *Indian Cocon.J.*21(12):2-5

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

Rao, G.H.S.L.V.P.1985.Drought and coconut palm. *Indian Cocon.J.*15:3-6

Rao,G.H.S.L.V.P. 1986.Effect of drought on coconut production. *India Cocon.J.*17:11-13

Rao,E.V.V.B. and Mathew, J.1981. An index for evaluation of coconut germplasm in the nursery. *PLACROSYM IV,* CPCRI, Kasargod, Kerala, India, pp.200-205

Rao,E.V.V.B. and Pillai, R.V.1983. Characterization of coconut germplasm based on fruit component analysis. Proceedings of *PLACROSYM V*, CPCRI, Kasargod, Kerala, India, pp.112-124

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

Ratnambal, M.J. and Nair, M. K. 1996. Philippines Ordinary – a high yielding coconut cultivar. *Indian Cocon.J.*26 (10):10-13

Ratnambal, M.J.1999. Malayan Dwarf coconut cultivars. *Indian Cocon.J.* 29 (10):1-3

Ratnambal, M.J., Krishnan, M. and Devadas, K. 2000.Popular cultivars of Goa. *Indian Cocon. J.*31(2):1-3

Ratnambal, M.J., Kumaran, P.M. and Krishnan, M.2002.New Caledonian coconut cultivars. *Indian Cocon.J.*33(2):3-6

Ratnambal,M.J., Arunachalam, V.and Krishnan,M.2003.Floral biology of some coconut accessions. *J. Plantn. Crops.*31 (1):14-22

Sadasivam, S. and Manickam, A.1996. *Biochemical Methods*, Newage International,Ltd.,Pub., NewDelhi, India, 256p.

Satyabalan,K. and Pillai,R.V.1977. Yield performance and nut and copra characters of eight germplasm introductions in coconut. *Indian J. agric. Sci.* 47:430-433

Sharma, T.V.R.S., Attri, B.L., Suryanarayana, M.A. and Singh, D.B. 2000. Improving the coconut productivity by genetic manipulation. *Indian Cocon. J.*31(3):10-13

Shivashankar, S.1988. Polyphenoloxidase isozyme in coconut genotypes under water stress. *Plant Physiol. Biochem.*15:87-91

Shivashankar, S.1990. Studies on soluble enzyme system of coconut (*Cocos nucifera* L.) cultivars. Ph.D thesis, Biochemistry, Mysore university, Mysore, Karnataka,India, 120p.

Shivashankar, S., Bai, K. V. K. and Rajagopal, V.1991. Leaf water potential, stomatal resistance and activity of enzymes during the development of moisture stress in the coconut palm. *Trop. Agri.* 68:106-110

Shivashankar, S. and Nagaraja, K.V.1996. Effects of water stress on enzyme activities of two coconut genotypes differing in different tolerance. *Plant Physiol. and Biochem.* 23 (2):187-193

Shylaraj, K.S., Bindu, M., Gopakumar, K. and Gopimany, R.1991. Comparing Komadan coconut type with West Coast Tall. *Coconut Breeding and Management* (eds. Silas, E.G., Aravindakshan, M. and Jose, A.I.). Proceedings of the National Symposium on Coconut Breeding and Management, 1988. Kerala Agricultural University, Trichur, Kerala, India, pp.106-107

Sindhumole, P. 1998.Genetic variability and correlation in nine divergent varieties of coconut. M.sc.(Agri.) thesis. Kerala Agricultural University, Vellanikkara, Thrissur, Kerala, India, 68p.

Sindhumole, P. and Ibrahim, K.K. 2001. Correlation studies in coconut (*Cocos nucifera* L.). *J. Plantn.Crops* 29(1):37-38

Snedecor, G.W. and Cochran, W.G.1967. *Statistical Methods,* Oxford and IBH Pub. Co.,New Delhi, India, 593 p.

Sreelatha, P.C.1987. Variability studies on certain Tx COD F_1 hybrids of coconut (*Cocos nucifera* L.) M.sc.(Agri.) thesis, Kerala Agricultural University, Trichur, Kerala, India, 96 p.

Sudha, V.R.1984. Photosynthetic contribution of exocarp to the development of the nut in coconut. M.sc. (Agri.) thesis,Kerala Agricultural University, Trichur, Kerala, India, 80 p.

Sukumaran, C.K., Narasimhayya, G. and Vijayakumar, G.1981. Path coefficient analysis in coconut. *Proc. PLACROSYM IV*. Central Plantation Crops Research Institute, Kasargod, Kerala, India, pp.191-199

Thampan, P.K.1975. *Handbook on Coconut Palm.* Oxford and IBH publishing Co., New Delhi, India, 305p.

Tisseral, B. and Torres, A.M.1979. Isozymes as genetic indicators of date palms. Report of fourth annual date grower's institute. California, USA,pp.224-228

Vanaja, T.1993.Effect of harvesting time on seed nut characters in coconut. M.sc.(Agri.) thesis, Kerala Agricultural university, Trichur, Kerala, India,72p.

Vanaja, T. and Amma, J.S. 1997. Evaluation of WCT coconut and Komadan coconut. *Indian Cocon. J.*28(8):5-7

Vijayakumar, G. and Satyabalan,K. 1982. Yield and nut characteristics of open pollinated progeny of West Coast Tall and its hybrids with Chowghat Dwarf Orange and Gangabondam. *PLACROSYM V*. Indian Society for Plantation Crops, CPCRI, Kasargod, Kerala, India, pp.52-58

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

Whitehead, R.A.1968.Selection and breeding of coconut resistant to lethal yellowing disease. A review of recent research in Jamaica. *Euphytica* 17:81-101

Zille, R. and Pravot, P.1962. Foliar diagnosis: A method of studying mineral nutrition – its application to the coconut palm. *Indian Cocon. J.*15:156-159

Appendices

APPENDIX-I

Field serial number of selected palms

Treatment number	Serial number of palm
T_1	160
T_2	149
T_3	187
T_4	199
T_5	129
T_6	198
T_7	220
T_8	38
T_9	15
T_{10}	12
T_{11}	59
T_{12}	33
T_{13}	177
T_{14}	108
T_{15}	52
T_{16}	93
T_{17}	112
T_{18}	76
T_{19}	239
T_{20}	130
T_{21}	25
T_{22}	23
T_{23}	154
T_{24}	110
T_{25}	114
T_{26}	39
T_{27}	98
T_{28}	46
T_{29}	171
T_{30}	139
T_{31}	251
T_{32}	14
T_{33}	13
T_{34}	174
T_{35}	213
T_{36}	120
T_{37}	217
T_{38}	111
T_{39}	218
T_{40}	252

APPENDIX-II

Weather parameters during period of study (May 2004 - June 2005)

	Temperature (°C)		Relative humidity (%)	Total rainfall (mm)	Total sunshine hours	Rainy days
	Maximum	Minimum				
May-04	34.4	22.0	84	578.3	104.3	21
Jun-04	31.3	21.6	85	786.0	98.9	24
Jul-04	31.8	21.6	85	369.6	66.4	24
Aug-04	31.3	21.5	83	386.9	137.1	14
Sep-04	32.8	22.6	80	208.8	154	10
Oct-04	33.8	20.8	73	493.2	185.3	11
Nov-04	32.8	21.4	65	71.7	211.9	3
Dec-04	33.6	18.6	55	0.0	279.9	0
Jan-05	35.0	19.8	56	7.6	264	1
Feb-05	37.6	17.4	53	00.0	280.7	0
Mar-05	38.2	22.0	42	00.0	193.2	0
Apr-05	36.7	22.8	74	171.4	208.2	10
May-05	35.5	21.5	72	89.2	217.5	5
Jun-05	33.2	21.8	86	711.4	94.3	23

MORPHOLOGICAL AND BIOCHEMICAL CHARACTERIZATION OF COCONUT (*Cocos nucifera* L.) GERMPLASM

by

P.V. Sreejith

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

DEPARTMENT OF PLANTATION CROPS AND SPICES
COLLEGE OF HORTICULTURE
KAU P.O., THRISSUR - 680 656
KERALA

2006

ABSTRACT

The field experiment entitled 'Morphological and biochemical characterization of coconut (*Cocos nucifera* L.) germplasm was conducted at Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during the period from 2004 to 2005. The objectives of the study include morphological and biochemical characterization of coconut germplasm available in the college farm and to asses the variability so as to identify the superior types. Based on previous years yield data, forty palms of twenty years old were selected randomly and subjected to cluster analysis for grouping the selected palms. Karl Pearson's coefficient of correlation and path analysis were also carried out to study the degree of association of different characters.

In the present study, the palms under investigation showed high variability for all the 28 characters studied. The cluster analysis of the selected palms showed that C1 and C4 were placed distant by as compared to other clusters. Among the different morphological and biochemical characters studied, cluster C4 recorded superiority over other clusters with respect to yield and yield contributing characters like total nut yield (158 nuts palm^{-1} year^{-1}), number of bunches produced (12), number of nuts bunch^{-1}(19), stem and leaf characters like stem girth (87cm), number of leaves (37) and petiole length (121cm), followed by cluster C3 with respect to nut yield (129 nuts palm^{-1} year^{-1}). The study also revealed that cluster C1 was inferior with respect to above characters such as total nut yield (30nuts palm^{-1} year^{-1}), number bunches produced (6), number of nuts bunch^{-1}(5.67), stem and leaf characters like stem girth(62cm), number of leaves (23) and petiole length (69cm). Cluster C4 included single palm (T_{22}), C3 was comprised of five palms (T_9, T_{10}, T_{20}, T_{21} and T_{32}) and cluster C1 included single palm (T_{33}).

Biochemical characters like leaf polyphenol content and APH enzyme activity were more in the cluster C6 during summer season (April, 2005). The activity of GOT enzyme at the onset of rainy season (June, 2005) was more in C4.

Characters like number of leaves on the crown showed highly significant positive correlation with nut yield, number of bunches produced $year^{-1}$ and number of nuts $bunch^{-1}$. Inflorescence characters like number of inflorescence produced $palm^{-1}year^{-1}$ showed highly significant positive correlation with nut yield and number of bunches $palm^{-1}$. Bunch characters like number of bunches $palm^{-1}$ $year^{-1}$, length of bunch stalk and nuts $bunch^{-1}$showed positive correlation with nut yield. Nut weight was positively correlated with copra content. However, the leaf polyphenol content was negatively correlated with nut yield.

Female flowers $inflorescence^{-1}$, duration of female phase, bunch stalk length, petiole length and activities of GOT enzyme during onset of rainy season had recorded positive direct effects on nut yield revealing the role of these characters in selection. Number of female flowers $spikelet^{-1}$ showed direct negative effect on nut yield and leaf polyphenol content had high negative indirect effect on nut yield through number of female flowers $inflorescence^{-1}$.