INTRA-VARIETAL VARIABILITY IN KOMADAN COCONUT (*Cocos nucifera* L.) PALMS

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"INTRA-VARIETAL VARIABILITY IN KOMADAN COCONUT (*Cocos nucifera* L.) PALMS"** 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.

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CERTIFICATE

Certified that this thesis entitled **"INTRA-VARIETAL VARIABILITY IN KOMADAN COCONUT (*Cocos nucifera* L.) PALMS"** is a record of research work done independently by Mr. Sathishkumar. S (2014-11-242) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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SATHISHKUMAR S

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LIST OF ABBREVIATIONS

%	-	per cent
^{0}C	-	Degree Celsius
&	-	and
ANOVA	-	Analysis of Variance
DAP	-	Days After Planting
CD (0.05)	-	Critical Difference at 5 % level
cm	-	centimeter
m	-	meter
d.f	-	degrees of freedom
et al.	-	and co-workers/co-authors
Fig.	-	Figure
g	-	gram
kg	-	kilogram
ha.	-	hectare
i.e.	-	that is
KAU	-	Kerala Agricultural University
No	-	Number
per se	-	in itself
SE	-	Standard Error

Sl. No.	-	Serial number
sp. or spp.	-	Species
viz.	-	namely

Introduction

1. INTRODUCTION

In India, coconut has a documented history of about three thousand years and is acclaimed to be a small-holder's crop. Coconut is unique among all horticultural crops as a source of food, drink, shelter, fibre, medicine and a variety of raw materials for industrial exploitation. It is considered as the tree of life and is eulogised as 'Kalpavriksha', the all giving tree or the Tree of Heaven. Coconut fruit is considered as 'Lakshmi Phal', the fruit of wealth. The crop assumes considerable significance in the national economy in view of its contribution to the rural employment. About 10 million people in the country are engaged in coconut cultivation, processing, marketing and trade related activities. It is the richest source of edible vegetable oil with oil yield of 65 per cent of the kernel weight and the contribution of the crop to the edible oil pool in India is around 6 per cent (Thampan, 2000; Singh, 2001). Tender coconut water is becoming more and more popular as a health drink replacing the artificial health hazardous soft drinks. Thus, the crop is attaining more significance due to its unique qualities. Coconut is an eco-friendly crop too, and plays a major role in conserving the ecosystem.

The major coconut growing state in the country is Kerala. The other three southern states *viz.* Karnataka, Tamil Nadu and Andhra Pradesh are also important contributors. These four states together contribute 90 per cent of the total area and production in the country (Nampoothiri and Singh, 2000). Other traditional coconut growing states are Orissa, West Bengal, Assam and Union Territories of Andaman and Nicobar Islands, Pondicherry and Lakshadweep. The crop was once considered as a coastal crop which cannot be grown away from sea coast. However, of late the crop has been introduced in the Central, North and North-Eastern regions of the country like Madhya Pradesh, Bihar, Tripura, Nagaland, Manipur and Meghalaya. The growing demand for coconut and coconut products in the entire country irrespective of its confinement in cultivation is the reason for spreading the crop across the country.

Based on the stature, the coconut cultivars are broadly categorized into two groups, the Tall and the Dwarf. These two varieties are found to grow in all the coconut growing countries. Several variants of the two types have been recognized in the regions of their distribution. Because of heterozygous nature of coconut, the yield capacity due to its genetic makeup varies from plant to plant even within the same cultivar or type (Dash *et al.,* 1995). Indigenous cultivars belonging to these types are being cultivated for coconut production and breeding purpose (Nampoothiri and Singh, 2000).

In the holdings in Kerala, apart from the distinctive varieties of talls and dwarfs, different high yielding genetically superior palms of different ecotypes are available (Thampan, 1999). These ecotypes are especially of the tall variety. The local farmers value them for their high yielding potential and multiple uses. Many progressive farmers believe that nearly five percent of the high yielding palms are distinctly different from the rest of the palms in productivity, nut qualities and resistance to pest and diseases and hence, these ecotypes are considered as unique category or improved ecotypes and the farmers value them for their preferential characteristics. The ecotype is defined by a group of individuals from the same environment showing morphological similarities (Ohler, 1999). The most popular coconut variety grown by the farmers of Kerala is Tall and the cultivar West Coast Tall (WCT) occupies over 95 per cent of the area under coconut. The other tall types grown are 'Laccadive Ordinary', 'Laccadive Micro', 'Kappadam' and the ecotypes 'Komadan', 'Kuttiyadi Tall' and 'Jappanan'. (Thampan, 1999).

However, the ecotypes viz. Kuttiyadi Tall, Komadan, Jappanan, King Coconut etc. have not that much been utilized for the crop improvement studies by the researchers. Dependable information on such ecotypes are very scanty. So, in order to decipher the myths and mysteries behind one of the local coconut type called Komadan which is very popular in the erstwhile Central Travancore region of Kerala for the last many decades.

The first record on this variety was seen in the old crop plan register of the Instructional Farm of College of Agriculture, Vellayani. According to this register

50 seedlings of a new coconut type called Komadan were brought from Thiruvalla by Sri.John, the then Superintendent of the Farm. These were planted in a contiguous plot in the 'D' Block of the Instructional Farm during 1957. These palms were seen grown to maturity and started yielding from the fifth to eight year of planting i.e., from 1970 itself. The higher productivity of the palms in comparison to the West Coast Tall trees growing in the same block has attracted the attention of the officers in charge of the farm. It is seen from the records that these Komadan palms were used for collection of seednuts from 1977 onwards for producing quality coconut seedling for distribution to farmers as a separate variety. The variety got good response among farming community because of high yielding ability over the West Coast Tall variety. An interesting fact about the growing popularity of Komadan coconut among the farming community of Kerala is that it is purely based on this personal experience over the performance of the second and third generation Komadan palms growing in and around the Vellayani campus of the Kerala Agricultural University.

Coconut is a highly cross pollinated crop, showing great variation in its yield potential. Possibly desirable variations can be utilized for better yield, which may be achieved through hybridisation as well as selection. A knowledge of the associations among floral per reproductive characters, vegetative characters and yield of nuts is a pre requisite for any selection programme. Since, coconut is a cross pollinated crop, the variability studies play an important role in crop improvement programme. The ecotype Komadan have been rarely used in crop improvement programme. In order to make use of these ecotypes as major resource base in the crop improvement, variability studies are important.

Varietal improvement in coconut has been the priority area of research, from the very beginning itself. A range of coconut germplasm with 241 accessions, comprising of 101 exotic and 140 indigenous, is now available in the country and the accessions are being utilized for varietal improvement through intra-varietal and inter-varietal crossing (Rajagopal, 2001). Considering these facts, the present study seeks to examine the intra-varietal variability in coconut variety Komadan.

Hence the present investigation was undertaken with the objective to assess the intra-varietal variability in Komadan coconut palms for yield and other attributes.

Review of Literature

2. REVIEW OF LITERATURE

In the year 1916, when the first Coconut Research Centre in the world was established simultaneously at Nileswar, Kasargod, Padannakad and Pilicod in South India, the scientific enquiry into the mysteries of one of the most useful and beautiful trees in the world was initiated. The early works were mainly on the morphological and floral biological aspects, but now, molecular studies are also there in coconut improvement programme. An overview of the voluminous literature on origin, variation and diversification of coconut accumulated during the last five decades are presented below.

2.1 EVOLUTION OF COCONUT

The evolutionary history of a species, which has been pressed since antiquity into the human economy, surviving as wild fragment populations in a minute number of locations, has to be necessarily highly speculative. Nevertheless, the separation of the coconut from a cluster of ancestral palms located on what later became the dispersing land fragments of the super-continent of Gondwana, and the subsequent development of a whole suite of unique and interesting features, excites the scientific imagination to wonder how nature could generate such an outcome (Foale, 2004). Through a process of natural selection, over a period of perhaps 80 million years, the coconut developed the means to disperse across vast expanses of ocean and take hold firmly on the perilous boundary between land and sea, adapting to fierce windstorms and periodic inundation, thriving unassisted by any other fauna and flora, and delivering its fruit in turn to the ocean vehicle for further dispersal. The very components of the fruit that enabled this species to successfully conquer the open ocean and take firm hold of the land on arrival became for humans the source of nourishing food and drink, and raw materials for fuel and tools of many kinds ranging from ropes to cups and buttons. The sandy berm on the land edge of the strand (the zone between high and low ocean tides), built of sand by raging storm tides, retains little water or nutrients to support a seedling attempting to become established.

The coconut evolved to defeat these environmental shortcomings by developing a huge endosperm, larger than found in any other plant with the exception of the 'double coconut' of Seychelles. There is sufficient energy and nutrients in the coconut seed to support growth of the seedling for more than one year, providing the opportunity for the roots to extend through the berm to the underlying soil layer that is bathed by the fluctuating fresh water table, which responds to the twice daily tidal rise and fall of the ocean. The coconut is most 'at home' in an environment where the roots are thus intermittently immersed in ground water, which has accumulated the essential plant nutrients released by the decay of plant residues. The endosperm or kernel of the coconut, evolved to enable the palm to colonise new habitats, also proved to be highly supportive of human colonisation of new habitats and a subsequent major support for the prosperity of human communities (Foale 2004; Foale and Ashburner 2003). The cohabitation of human and coconut populations ushered in a new era for the evolution of the coconut. Selection, especially for enhanced food and drink qualities, moved the coconut away from some of the critical traits that had enabled it to successfully disperse over a vast portion of the globe on a geological time scale. Before human arrival, the coconut had undoubtedly reached thousands of islands and mainland shore locations stretching over most of the tropical Pacific Ocean, throughout the islands of Southeast Asia, and probably to some shores of the Indian Ocean (Foale 2004).

2.2 ORIGIN OF THE COCONUT

Few plants are more widely distributed in the nature than the coconut palm, which is found throughout the tropics wherever local conditions are favourable. Guppy (1906) was of the opinion that the coconut originated on the Pacific coast of tropical America, whereas Cook (1910) favoured an origin among the Cocoid palms in the valleys of the Andes in Colombia with subsequent dispersal by primitive people to the Island of Pacific and Indian Oceans. Ridley (1930) also suggested a tropical American origin in his treatise 'The dispersal of plants throughout the world'.

Heyerdahl (1950) from his famous Kon-Tiki expedition showed that coconuts could have been taken from South America to the Tuamot Archipelago in the South Pacific on a raft of balsa wood. Corner (1966) opined a southern migration via Antarctica which was supported by the discovery of fossil nuts in the form of small coconuts in the late Tertiary (Miocene- Pliocene) beds on North Island, New Zealand. Purseglove (1968) agreeing with an Indo- Pacific origin, suggested that the most numerous relatives of the coconut are the Cocoid palms, originally placed in the genus *Cocos*, in north western South America. Its ancestor with fibrous mesocarp enabling it to float and establish under suitable conditions could have been carried by ocean currents from America to Polynesia.

2.3 VARIETAL DIVERSITY:

Taxonomic studies and investigations of monocotyledon anatomy show *Cocos nucifera* to monotypic. However, different varieties and cultivars are recognized.

John and Narayana (1949) recognized five different varieties of coconut.

1. Typica-tall bearing palms with both male and female flowers.
2. Nana-dwarf, delicate palms bearing in 3 years.
3. Javanica-dwarf palms bearing in 4 years.
4. Spicata-tall palms with unbranched inflorescences or inflorescences having one or two small spikes only.
5. Androgena palms with male flowers only.

Fremond *et al.* (1966) divided the coconuts into two groups, the allogamic or cross pollinating ones and autogamous. Various studies revealed that no clear division can be made between allogamic and autogamic coconuts and that there are several forms in between showing that this classification is not ideal either (Rognon, 1976).

According to Harries, (1978) coconut cultivars are grouped into different categories and they broadly based on:

1. Size of the palm: Tall, Dwarf and Semi -Dwarf.

2. Productivity: Low (40), Medium (40-80) and High (80 & above) nuts per palm per year.
3. Colour of husk: Green, Orange, Yellow and Red.
4. Husk and Shell thickness: Thick, Medium and Thin
5. Shape of nut: Globular, Triangular, Spindle-shaped and Elongated
6. Size of nut: Micro (below 6000 nuts) and Macro (above 6000 nuts)
7. Age of maturity: Early, Medium and Late.
8. Colour of leaf and spathe: Green, Orange and Red.

Harries (1978) identified two main groups of coconuts, the "Niu kafa" that evolved naturally, and the "Niu vai" that arose under cultivation. He opined that dwarf varieties have been selected and maintained in cultivation by man. The Niu kafa has the capability of being disseminated by floating in the sea and to sprout on the beach where it has been thrown onto, without rolling down into the water again. Such palms have relatively few, large, angular shaped slow-germinating fruits with thick husks, spindle-shaped nuts with thick shells, and thick dense endosperm with a high oil content. The Niu vai palms carry more fruits which are round, have thinner shell, thinner husk and germinate earlier.

Murthy and Arunachalam (1966) while studying accessions collected from different islands reported that no correlation exists between genetic diversity and geographical diversity. Absence of correlation between genetic diversity and geographic diversity was also reported by Louis and Chopra (1989). Ovasuru *et al.* (1991) analysed coconut germplasm of Papua New Guinea and reported the same.

Rao *et al.* (1983) reported that in all the ten cultivars, leaf and inflorescence characters and fruit components were found to be consistent within a population but stem characters were highly variable. The Andaman Tall and Benaulim were falling in two separate clusters while all the rest of the Tall population formed into a single large cluster in the D^2 analysis, based on fruit components.

Balakrishnan and Namboodiri (1987) reported that the 24 cultivars of coconut fell into six different clusters based on the genetic distances among them. Cultivars of the same place of origin fell into different clusters while those of diverse origin fell into same cluster. The clusters showing maximum diversity (clusters IV and VI) came under the Niu vai and the Niu kafa types, thereby confirming that there was wide range of genetic variation between clusters IV and VI.

Kumaran *et al.* (2000) clustered coconut population of Indian Ocean islands of Madagascar, Mauritius and Seychelles using principal component analysis. A total of 28 vegetative, reproductive and fruit characters were used for analysis and obtained five clusters. Jayalekshmy and Rangasamy (2002(b)) clustered 30 genotypes in coconut based on twenty morphological traits into six clusters. They found nut characters to be more efficient in assessing genetic divergence in coconut. Meerow *et al.* (2003) reported that allogamous Nio Leka dwarf had shown the highest genetic diversity among dwarf samples analyzed.

Ratnambal *et al.* (2005) reported that important characters that cause divergence as obtained from the canonical analysis were weight of fruit, length of fruit, volume of cavity, weight of shell and per cent of husk to fruit weight.

Arunachalam *et al.* (2005) studied 206 individuals which belong to seven tall groups and four dwarf groups, representing seven island territories. Diversity estimate was the highest in Nicobar tall group whereas it was low in tall genotypes of Fiji and Tonga. Thickness of leaf sheath fiber of weft and warp strands had shown high diversity estimates.

2.3.1 Tall Varieties

The most popular coconut variety grown by the farmers of Kerala is tall and the cultivar West Coast Tall (WCT) occupies over 95 per cent of the area under coconut. The other tall types grown are 'Laccadive Ordinary', 'Laccadive Micro', 'Kappadam' and the ecotypes 'Komadan', 'Kuttiyadi Tall' and 'Jappanan'. In addition to these, Chowghat Green Dwarf, Chowghat Orange Dwarf, King Coconut, TxD and DxT hybrids and Natural Cross progenies of Dwarf (NCD) are also grown; but are sparsely distributed (Thampan, 1999). Tall coconut palms in Southeast Asia and the Pacific, this group is characterized by palms with a more slender, more flexuous stem, producing generally more elongated fruits containing a high proportion of fibre, and dormancy (Bourdeix *et al.* 2005).

The Tall variety is a common type, known as "typical" which is most extensively grown on a plantation scale in all the coconut tracts of the world. It tolerates diverse soil and climatic conditions and are successfully grown under rain-fed conditions. It is fairly resistant to diseases and pests. It begins to bear in 6 to 7 years from planting, attains steady bearing in about 12 to 15 years; lives upto an age of 80 to 90 years. The nuts mature within 12 months after pollination. Different cultivators, grown in different locations are designated by the locations where they are grown, like West Coast Tall, African Tall, Jamaica Tall etc. (Mubarak, 2012).

2.3.2 Dwarf Palms

The oldest known description of Dwarf coconut palms in India dates back to 1885 (Shortt, 1885), but scientific research on the coconut palm did not begin until 1916. In the coconut palm, dwarfism is a syndrome combining numerous common characteristics like slow vertical growth, reduced organ size, preferential self- fertilization, early bearing and rapid bunch production. Because of these characteristics, Dwarf palms play a major role in breeding programmes. All the Dwarf cultivars were originated from Asia or the Pacific, and were imported into the other regions 100 to 300 years ago.

The Dwarf types are short in stature with attractive colour of nuts and there are distinct forms according to colour of inflorescence and fruit viz., green, orange and yellow. The palm grows rapidly and it starts bearing in about 3 to 3 ½ years after planting and attains steady bearing in 9 to 10 years. It is susceptible to drought and has a tendency for irregular bearing; copra is softer, leathery and thus of poor quality. Hence, it is often harvested in the tender nut stage for the sweet water which is a refreshing drink. The copra content is 85g per nut with 65 per cent oil content. The economic life of Dwarf is only 30 to 40 years (Mubarak, 2012).

2.3.3 Intermediate Varieties

Rao and Koyamu (1955) reported that Gangabondam variety has characters which resemble those of the tall. According to Gangolly *et al.* (1957) Gangabondam belongs to the medium dwarf of semi-tall type with about 230g of copra per nut and a high oil percentage of 72. Ratnam (1968) reported that this variety comes from the east Godavary District in Andhra and it breeds 95 per cent true to type. Nelliat (1978) reported that Gangabondam has a copra content of about 150g per unit.

Varietal improvement in coconut for achieving higher production and productivity is of paramount importance. In coconut research in India varietal improvement has been the priority area from the very beginning. A range of germplasm with 241 accessions, comprising of 101 exotic and 140 indigenous ones, is now available in the country and the accessions are being utilized for varietal improvement through intra-varietal and inter-varietal crossing (Rajagopal, 2001). Rajagopal and Arul (2002) observed opportunities of evaluation of large number of germplasm for a given purpose of utilization, excellent scope for product diversification and value addition in coconut industry.

2.4 KOMADAN COCONUT PALM STUDIES

Komadan is a local coconut off-type from the progeny of Chowghat Orange Dwarf (COD) open pollinated by the WCT, popular in the erstwhile central Travancore area of Kerala associated with the family history of an old 'Tharavadu' called 'Komattu house' in the Thottappuzhassery area of Aranmula village of Thiruvalla taluk (Gopimony, 1982). Komadan showed superiority in nut and copra yield (Vanaja and Amma, 2002).

The high heritability observed for nut yield in the Komadan coconut was reported by Meunier *et al.* (1984).

Gopimony (1984) reported mean values of morphological characters of 'Komadan' which showed the superiority for all the nine quantitative characters compared to WCT and also 'Komadan' type further exhibited superior seedling vigour, in terms of germination percentage, height, collar girth, mean number of total leaves and mean number of split leaves. Nandi and Sugata (2000) observed that unusual early flowering was observed in Komadan.

Komadan type showed superior mother palm characteristics especially in number of bunches and number of nuts per palm per year (Shylaraj *et al.* 1991). Alternate bearing habit was found to exist in Komadan palms; but at a very low frequency when compared to dwarf and TxD palms. Thickness of meat, weight of copra and oil content were high in Komadan. The seedlings of Komadan were more vigorous with high seedling vigour index and they showed early splitting of leaves. About 71 to 82 per cent of seedlings showed moderate brown colour (bronze) in the petiole. Seedling selection for this character is essential to maintain the purity of Komadan. Komadan types occupied an area mid-way between NCD and WCT with a clear progression through generations towards better weight of unhusked nut. This indicates the origin of Komadan from the natural cross between WCT and yellow dwarf and its stabilized genetic position in between NCD and WCT. Komadan has been treated as good as or even better than the WCT cultivar in productivity, kernel quality, toddy yield and fibre output.

Manju (1992) observed significant superiority in Komadan in majority of the mother palm characteristics especially number of bunches and spadices and number of nuts per palm per year. High heritability combined with moderate to high genetic advance were recorded for nut yield per palm per year and number of female flowers per bunch indicating the predominance of additive genes for these characters. The brown colour of Komadan nuts observed in the study indicated the distinction of this ecotype as a separate group from WCT and NCD. The Komadan types were significantly superior to WCT in all seednut characters except in oil content, thickness of husk and husk: nut ratio. This ecotype has stabilized its genetic position in between the natural cross progenies of dwarf and the WCT (Thampan, 1999).

Manju and Gopimony (2001) studied genetic parameters of Komadan coconut and reported that the phenotypic coefficient of variation was higher than the genotypic coefficient of variation. It was also they revealed that medium to high phenotypic and genotypic coefficients of variation were observed for number of nuts per palm per year, number of female flowers per bunch and number of nuts per bunch.

Selvaraju and Jayalekshmi (2011), based on D^2 analysis reported that the local cultivar WCT and NCD were clustered together and the well preferred cultivar Komadan got clustered along with Laccadive Ordinary. Maximum divergence was reported between Komadan and NCD. Komadan was found to be a superior palm on par with Laccadive ordinary.

2.5 ANALYSIS OF COCONUT PALM CHARACTERISTICS

The coconut palm exhibits wide variability in productivity ranging from 30 nuts to 400 nuts per palm per year. This is mainly due to the efficiency of the palms in the dry matter production and partitioning towards yield. Patel (1938) was the first to report this aspect in coconut and relationship between height of the palm, number of leaves and the annual yield was highlighted. This reveals that leaf area and leaf dry matter production are important parameters regulating the production potential of coconut palm.

Jacob *et al.* (1988) observed that the month of February to April, when variation is the least, was the critical period for collection of nuts. It was reported that a minimum of 16 nuts per variety was required for minimizing the error. Friend and Corley (1994) harvested the nuts by shaking the palms and collected those nuts which have fallen, for the dry matter determination.

Satyabalan and Rajagopal (1990) reported the need for selection of parents based on the husk and shell content for hybridization and higher hybrid recovery. It was indicated that for obtaining maximum number of hybrid seedlings (Dwarf x Tall), use of pistillate parents which yield nuts having low shell content and a high copra content was preferable. Corley (2001) stressed the importance of increased partitioning of the total dry matter towards the copra at the expense of other nut components for yield improvement. He calculated maximum values for the partitioning of dry matter in the whole nut as 62 per cent and the endosperm (copra) 26 per cent which contained 38 per cent of the total energy fixed.

The harvest index has been considered as an important criterion in biological and economic yield (Donald and Hamblin, 1976). Ramadasan and Mathew (2003) worked out harvest index in coconut by taking into account annual increment in dry matter production. Because of the limitation in estimating the total biomass including the roots, the term Annual Productivity Index (API) was coined and it was expressed as the ratio of the dry weight of the economic product to total dry matter production.

Kasturi (1993) calculated the harvest indices based on the total dry matter production. It revealed that local Tall variety as well as the hybrids gave higher harvest indices and it is based on the copra out turn. It ranged from 0.13 to 0.23. The highest harvest index was observed in the hybrids indicating better nut composition in the hybrids than the varieties.

Sindhumole and Ibrahim (2000) studied nine coconut cultivars and revealed the absence of significant variation among most of the 15 characters observed. Economic characters showed higher genotypic coefficients of variation (16 to 22 per cent) compared to vegetative and reproductive characters. Among all the characters, heritability was maximum for petiole length (52 per cent) followed by the economic characters, percent oil content and nut yield (45 per cent each).

Jayalekshmy and Rangasamy (2002(a)) studied variability in twenty morphological traits in 30 genotypes of coconut and observed significant differences for both vegetative and reproductive characters. It was reported that the range of mean values for all the characters studied were much wider in the tall varieties than in the dwarf ones.

Pillai *et al.* (2002) prepared a model descriptor for characterization of 18 genotypes of coconut based on fruit component analysis and other measurable phenotypic characters. Five major groups of characters were taken into consideration viz., age at flowering, leaf characters, inflorescence characters, breeding behaviour, nut characters and its ratios. Ratnambal *et al.* (1995) published an exhaustive descriptor using 14 vegetative, 21 reproductive, 24 fruit and 2 biochemical characters for 48 accessions of coconut.

Vanaja and Amma (2002) reported that the number of female flowers varied with the season and the season had no effect on the average nut production per bunch.

Ramadasan and Mathew (2003) after destructive sampling of five palms developed a method to estimate the area and dry weight of the leaf non-destructively. The area of 18 leaflets where three leaflets were collected from each side of the rachis from the top, middle and basal portions, was measured by using Li-Cor 3000 leaf area meter. The leaflets were dried in a hot air oven at 80°C and the dry weights determined. It was estimated the dry matter production of the apical portion of the trunk just below the crown, as it is this portion which contributes to the growth of the stem.

Nampoothiri *et al.* (2007) viewed that the physiological evaluation of yield and all related production processes like photosynthesis, dry matter partitioning and harvest index play a major role in identifying the desirable genotypes with stable and high yield. This approach has to be made applicable in coconut, oil palm, rubber, coffee, tea etc., which help the breeders for selection of suitable materials for breeding for high yield.

Genotypes × environment interactions indicate the inconsistency of relative performance of genotypes over environments (Odewale *et al.* 2012).

2.5.1 Fruit Component Analysis

Umali (1940) reported high germination percentage and better quality seedlings from thin husked nuts than from the nuts with husk thickness of 3.0 cm or above. Similarly nuts with less weight germinated late and produced poor quality seedlings compared to heavy nuts.

Panse (1957) concluded high heritability combined with high genetic advance were observed for nut yield, whole nut weight, dehusked nut weight and moderate genetic advance for copra weight. This indicates the predominance of additive gene effect.

Liyanage and Sakai (1961) studied that the heritability of nut weight (0.95) and copra (0.67) was high, stem girth (0.45), inflorescence production (0.47), female flower production (0.52), number of nuts per bunch (0.50) and yield of nuts (0.48) were intermediate.

Fruit morphology measurements have been the most extensively used set of criteria to characterise coconut diversity because they are simple to measure, are environmentally stable, and have been subjected to strong selection pressures from both natural and human influences (Whitehead, 1966). Other morphological characters have been recommended for characterising diversity in coconut germplasm, such as vegetative and floral characters (IBPGR, 1992), but are strongly influenced by environmental conditions.

Rao and Pillai (1982) reported that measurements in terms of absolute values of palm height, leaf length and bunch production depend more on the age of the palm and need repeated recording, whereas the fruit components were more or less stable throughout the stabilized yield period. The kernel was given higher importance, whereby the selection pressure was always in the direction of bigger nuts with lesser husk.

Louis and Ramachandran (1981) concluded that the tall varieties, in general, recorded high oil content with a few exception. Oil content in the hybrids were medium and it was closer to the female parents. The dwarf varieties though possess leathery copra which slips away in the rotary making it difficult to extract the oil, possesses comparatively good percentage of oil.

Davis and Gosh (1982) reported that the female flowers getting fertilized during the dry months of July was 4-5 months old when the palm receives heavy rains which has the beneficial effect on the fast enlarging young fruits and this contributes to larger size of fruit that yields more copra per nut.

Bourdeix (1988) stated that copra per nut was a high heritable character while number of nuts and copra per tree present significantly low heritability.

Paul (1990) concluded that the value of copra was dependent on the drying of the nuts and the quality of oil was dependent on the quality of copra. It was also stated that quality of dehydrated or hot air dried copra was better than sun dried copra because greater rapidity of the process gives lesser time for the occurrence of enzymic or other changes which may likely to injure the fruit. Good quality copra was obtained by drying the nuts at an average air temperature of 60^0 C, above which the copra showed a tendency to char. For maximum shelf life the moisture content of the copra should not exceed 6 per cent.

Rajagopal (1990), opined that the coconut palm exhibits wide variability in the production of nuts, ranging from 30 to 200 nuts per palm per year, with elite palms yielding even up to 470 nuts per palm per year. This variability is due to the genotypes and their response to water and nutrient management.

Bourdeix *et al.* (1991) stated that yield expressed as copra per palm can be broken down into three multiplicative factors: number of bunches, number of nuts per bunch and copra per nut. Copra per nut was usually the most heritable character and number of nuts per bunch was the most variable character.

Mathew and Gopimony (1991) noticed extremely high heritability was estimated for weight of unhusked nut, husked nut, meat and diameter of eye whereas thickness of meat registered low heritability value.

Shylaraj *et al.* (1991) reported that seednut characters of the two coconut types viz., Komadan and WCT did not show any significant difference. Nut production and number of flowers per spadix were reported to be more variable than other characters by Ovasuru *et al.* (1991). But Pillai *et al.* (1991) reported that there was not much variation in the number of female flowers produced in an inflorescence between cultivars. Absence of significant variation for kernel thickness in the 13 genotypes studied was reported by Patil *et al.* (1993).

The brown colour of Komadan nuts observed in the study indicated the distinction of this ecotype as a separate group from WCT and NCD. The Komadan types were significantly superior to WCT in all seednut characters except in oil content, thickness of husk and husk: nut ratio (Manju, 1992). This ecotype has stabilized its genetic position in between the natural cross progenies of dwarf and the WCT (Thampan, 1999).

Manju and Gopimony (1998) reported that fifty mother palms belonging to the five coconut types can be grouped into three clusters based on the seedling characters when subjected to D^2 analysis. All the WCT and NCD palms were found constellated in cluster I which may be due to the common heritage. The Komadan palms belonging to the three generations were seen distributed in all the three clusters indicating the comparative unstable genetic identity of Komadan as against WCT and NCD.

Fruit characteristics are generally indicative of the amount of artificial selection that occurred in a coconut population, and were correlated with other artificially selected and agriculturally important traits, such as early germination, precocity of flowering and resistance to strong wind, insects and diseases (Harries, 2000).

Ganesamurthy *et al.* (2002) analysed genetic variability of nut and copra yield along with six other nut characters in 14 genotypes of coconut and reported high degree of variability for copra yield, dehusked nut weight, nut yield and whole nut weight. All these characters showed high heritability and genetic advance.

Zizumbo *et al.* (2006) reported the pattern of morphological variation of *Cocos nucifera*. Forty one populations were analyzed, using 17 morphological fruit characters. Principal components and cluster analyses indicated four main groups of coconut populations.

Ashburner *et al.* (2000) reported that samples from 29 distinct South Pacific populations revealed continuous variation in fruit morphology and cluster analysis arbitrarily divided the continuum into discrete groups such as in Melanesia, Western Polynesia and Eastern Polynesia which were consistent with geographic affinities.

Sankaran *et al.* (2015) concluded that high heritability coupled with high genetic advance was observed for fruit weight, weight of dehusked fruit, kernel weight, shell weight and plant height which had direct influence on the copra yield per palm in coconut.

2.5.2 Correlation Studies on Palm Morphological Characters

Nampoothiri *et al.* (1975) observed significant genotypic correlation between production of spathes and female flower which were also positively correlated with yield, and height and age at first flowering, height and flowering leaf axil as well as age at first flowering and flowering leaf axil.

Ramanathan (1984) studied the correlation of yield per plant with eight of its components in four dwarf and 26 tall cultivars and observed that the characters were positively correlated with yield.

Satyabalan and Mathew (1984) reported that correlation alone does not provide the true contribution towards the yield. The genotypic correlation coefficients were partitioned into direct and indirect effects through path-coefficient analysis.

A correlation study on length of leaf and yield of nuts by Nambiar and Govindan (1989) revealed that the high yielding palms had significantly more number of leaves than low yielding ones and that the longer the leaf, the higher was the yield. Under favourable conditions, the leaves of good yielders had a life span of 36 to 42 months. It was reported that when every leaf produces an inflorescence in the axil, the palm was considered to be a regular bearer. Vijayaraghavan and Ramachandran (1989) reported that the barren nut production was highest during the peak bearing period of South West monsoon, in both Tall and hybrids.

Significant positive correlation was observed between nut yield and barren nut production in both Tall and hybrids.

Balakrishnan *et al.* (1991) reported high correlation between total number of leaf production and total number of nut production.

Liyanage (1991) reported that the genetic correlation between yield of nuts and copra per palm, was high and positive. The correlation was high and negative between the flowering period and yield of copra.

Mathew and Gopimony (1991) stated that number of leaves in palms showed positive correlation with number of bunches whereas number of nuts per bunch showed negative correlation with most of the important nut and seedling characters.

Narayanankutty and Gopalakrishnan (1991) reported that there was significant positive correlation for total number of leaves retained by the palm and length of leaves with yield in coconut.

Manju (1992) reported that the number of bunches and spadices was significantly and positively correlated with number of female flowers per bunch, number of nuts per bunch and number of nuts per palm per year and indicated the scope for selection based on these characters.

N'cho *et al.* (1993) reported that the inflorescence characters are positively correlated with yield and it can be effectively used as selection indices in coconut.

Multi-spatheate palms have been reported at Hainan Island of China. These multi-spatheate palms provide sufficient mechanical strength to the inflorescence to protect it from insect attack in the early stage of development. Presence of this trait may offer protection against wind and reduce buckling (instead of being erect) of bunches. (Mao and Lai 2000).

Sindhumole and Ibrahim (2000) reported direct effect of each component character on oil yield in coconut which was affected by the indirect effects through other characters, resulting in lower correlation coefficients between oil yield and its components. Both direct effects and correlation coefficients were in the same direction. The highest direct effect was exhibited by trunk height. It was also observed that the genotypic correlation was mostly negative with respect to vegetative characters but positive for other pairs. Only nut yield among the four economic characters was correlated with both vegetative and reproductive characters. Other economic characters viz., copra yield, oil content (per cent) and oil yield were dependent only on vegetative characters. Correlation and regression analysis suggested that reproductive characters had less effect on economic characters.

Zizumbo *et al.* (2005) studied Mexican palm and revealed that weight and water percentage showed the highest values of correlated (0.88 and 0.883), with a strong correlation the mass and the roundness of fruit and seed.

According to Namboothiri *et.al.* (2007) significant positive correlation was observed between nut yield and functional leaves. The leaf length also showed significant positive correlation with the characters studied. Similarly, nut length and nut breadth showed significant positive correlation with all the characters except number of functional leaves and petiole length. Highly significant positive correlations were observed among whole nut weight, dehusked nut weight and copra weight.

Natarajan *et al.* (2010) studied correlation between morphometric characters in eight coconut genotypes which revealed a high degree of variability for nut yield, whole nut weight, dehusked nut weight and copra weight. Nut yield exhibits positive correlation with number of functional leaves, length of leaves and petiole. Path coefficient analysis revealed that the direct effect of number of functional leaves on nut yield was positive and high followed by petiole length and leaf length.

Geethanjali *et al.* (2014) characterized 43 coconut germplasm accessions for nut yield and fruit component traits. Correlation analysis showed that most of the fruit traits viz., fruit length, fruit breadth, fruit weight, nut weight, kernel weight and copra weight per nut were positively correlated with each other; but showed significant negative correlation with the number of nuts produced per palm per year. Shell thickness and husk thickness were not correlated with any of the fruit component traits. Path analysis revealed that nut yield and copra content per nut had positive direct effects on the total copra yield per palm.

2.5.3 Oil Estimation by Nuclear Magnetic Resonance (NMR):

Alexander *et al.* (2001) concluded that wide line nuclear magnetic resonance (NMR) spectroscopy provided a rapid accurate, and non-destructive method for determining oil in multiple or even single kernel samples of corn.

Vigli *et al.* (2003) reported that combination of 1H NMR and 31P NMR spectroscopy and multivariate statistical analysis were used to classify 192 samples from 13 types of vegetable oils, namely, hazelnut, sunflower, corn, soybean, sesame, walnut, rapeseed, almond, palm, groundnut, safflower, coconut, and virgin olive oils. This model resulted in a significant discrimination among the different classes of oils, whereas 100 per cent of correct validated assignments for 64 samples were obtained.

Rolletschek *et al.* (2015) opined that nuclear magnetic resonance (NMR) was used for high-accuracy measurement of safflower oil content, carbohydrate content, water content and both fresh and dry weight of seeds.

Praduman and Muthy, (2016) studied six genotypes of each sunflower, safflower and castor were used for oil estimation by NMR technique and stated that it was one of the best method for indirect oil estimation.

2.5.4 Principle Component Analysis Studies

The pattern of morphological variation of *Cocos nucifera* in Mexico was statistically and numerically evaluated. Forty-one populations were analysed, using 17 morphological fruit characters. Principal components and cluster analyses indicated four main groups of coconut populations that showed high similarity with four different genotypes (Daniel and Daniel, 2000).

Evgenidis *et al.* (2011) studied cluster and principal component analyses based on morphophysiological data, yield and quality and combining abilities on tomato. Principal Component 1, resulted in the largest group with positive loading which included, yield components, general and specific combining ability, whereas the largest negative loading was obtained by qualitative and descriptive traits. The Principal Component 2 revealed two smaller groups, a positive one with phenotypic traits and a negative one with tolerance to inbreeding.

Marijana *et al.* (2009) reported twenty seven populations and cultivars of alfalfa and evaluated thirteen phenotypic traits which revealed that the first four principle components contributed to 89.02 per cent of the total variability among the populations and cultivars. The yields of green mass and dry matter, vigour, growth habit, plant regeneration and length of central leaflet were the most important traits for the genetic variability, representing 58.21 per cent of the total variability in the first principle component variable. The second PC explained 16.24 per cent of the total variability and was associated with number of stems, shape of leaf and width of central leaflet.

Piyasundara *et al.* (2008) studied twenty morphological characters of two hundred tea germplasm accessions and reported based on Principle Component Analysis (PCA), 16 out of 20 descriptors were informative and contributes significantly to the variation. Cluster analysis based on significant principle components further revealed that viz., type of serration of leaf margin, waviness of the leaf margin, pigmentation in young leaf, pigmentation in leaf petiole, size of the leaf and leaf angle were the most discriminating descriptors in distinguishing accessions into phenotypically diverse groups.

Ten corn genotypes were studied for quantitative traits associated with grain yield using factor analysis through principal component analysis and the result was six factors was showed 98.74 per cent of the total variation (Houman, 2011).

Sarkar *et al.* (2012) studied morphometric characterization of coconut germplasm and PCA revealed that days to spathe opening, days to male phase and number of nuts per palm contributed for 66.73 per cent of the observed variation. Twenty seven entries of coconut were grouped into seven clusters. The largest cluster VII included nine palms, cluster VI, V and II included eight, four and three palms respectively while cluster I, III and IV included one palm.

Zdenek and Karol (2012) studied multivariate morphometric analysis of the *Potamogeton* spp. and reported that number of flower whorls and the length of the fruiting spikes showed distinct gaps between the species variation ranges and there was only a small overlap in variation in peduncle length.

Perera and Perera (2015) studied six coconut varieties and morphological data were scored for stem girth (at 20 and 150 cm) and inflorescence (numbers of female flowers, spikelets with and without female flowers, lengths of central axis and spikelets) and first two principle components revealed that stem and inflorescence traits showed 98.3 per cent of the variation among accessions.

Omena *et al.* (2015) reported intraspecific variabilities in 40 accessions of and carried out principal component analysis. The first five principal component axes explained 69.7 per cent of the total variation with PC1 and PC2 contributing 38.9 per cent to the total variation.

Ulaganathan and Nirmalakumari (2015) reported intra-variability in finger millet which revealed that first four components of principle component analysis with eigen value of greater than 0.65 contributed about 87.8 per cent of total variability. The proportions of the total variance attributable to the first four principal components were 66.7, 10.7, 5.5 and 5.0 per cent respectively.

Jacob *et al.* (2016) analysed that phenotypic intraspecific variability in 40 accessions of drumstick of and its 30 morphometric traits were studied. The first five principal component axes explained 61.40 per cent of the total variation with PC1 (23.92 per cent) and PC2 (14.19 per cent) contributing 38.11 per cent of the total variation.

2.6 SEEDLING ANALYSIS

Fernando *et al.* (1993) studied the variation in seedling characters of three different coconut cultivars. Diagnostic traits are necessary to detect the illegitimates among hybrid coconut seedlings and for sorting out the types. Seedlings of dwarf, tall and the hybrid, dwarf x tall were studied to distinguish the types. The important indicators are the rate of leaf production, length and width of leaves and time to first leaf splitting.

Research was carried out since 1960s to identify prepotent palms based on the early stages of growth of progeny in the nursery. Observations made by Satyabalan and Mathew (1984) on growth rate and seedling vigour in seedlings of 16 selected high yielding families (WCT) indicated significant differences in growth rate of progenies between families.

According to Liyanage and Abeywardena (1987) nuts should not be rejected on the basis of size, quantity of nut water or shape. Identification of nuts as empty (devoid of nut water) or immature and therefore unlikely to germinate were also often inaccurate.

2.6.1 Seedling Growth Analysis

Selection of early germinating and vigorous seedling in the nursery, for planting in the field and discarding of later germination and less vigorous seedlings has been practised for long time, based on intuition than on yield data of palms selected.

Ninan and Pankajakshan (1961) reported that it was possible to isolate high yielders on the basis of seedling performance. So a switch over from mass selection to progeny row breeding will be necessary to identify high yielders of outstanding breeding merit for use in propagation as well as breeding works.

2.6.2 Germination

Jack and Sands (1929) found that earlier germination of seednuts in coconut was associated with early bearing and there was consequent enhancement of production in terms of nut yield. Hence early germination should be given the consideration it deserves while formulating the criteria for selection of seedlings.

Maceda (1933) reported that round nuts germinated earlier and produced more vigorous seedling than oblong nut of the same volume.

Pattel (1938) concluded that there was difference in total germination between nuts from the top or bottom and from the middle of the bunch.

Davis and Anandan (1957) opined that a nut may be considered to have germinated when the embryo broke the lid of the soft eye and this took place usually six weeks after the nut was sown.

Liyanage and Sakai (1961) found that it was advantageous to select seednuts for early sprouting in that it bring about a higher nut production, apart from early flowering.

Charles (1968) observed that seedlings derived from seednuts with a high copra content have an advantage over seedlings sprouted from nuts with a low copra content.

Foale (1968) studied the growth of young coconut palm and the role of the seed and photosynthesis on seedling growth upto 17 months. The contribution by the endosperm fell at four months after germination to a level that remained roughly constant upto 17 months. By four months, the haustorium had reached the full size, but thereafter, relative contribution from the endosperm via the haustorium gradually diminished.

Silva and George (1970) analysed the influence of nut age and size using fallen nuts in first and second bunches and concluded that within the first two months, the rate of sprouting was strongly influenced by the two factors but between the second and third month there was a rapid increase in the sprouting rate of the two less mature categories (second and first bunch nuts), and the influence of maturity was less visible. It was also reported that at the end of the sixth month in the nursery, significant effect of maturity on sprouting appeared as a dominant factor, with the first bunch nuts showing superiority over the more mature fallen nuts and the less mature second bunch nuts. Medium sized nuts from the first bunch had the best overall germination rate (95 per cent). During 10^{th} to 16^{th} weeks, 70 per cent of second bunch nuts also sprouted irrespective of size.

Dutta (1974) observed that the upper end of the embryo develops into a small shoot. The speed with which this process happens varied with cultivars and this was one of the important factors to be taken into account in seedling selection.

Sento (1974, 76) reported that the optimum temperature and days to germination for coconut was found to be 30-35 ^{0}C and 107 days respectively.

Anilkumar and Pillai (1989) observed significant difference in germination percentage between treatments after three, four and eight months of sowing. Germination percentage of Komadan seednuts was found to be significantly higher than that of WCT seednuts after third and fourth months of sowing. Though significant difference was not observed between WCT and Komadan seednuts after fifth and sixth months of sowing, Komadan seednuts after fifth month and WCT seednuts after sixth month recorded higher values. The germination percentage of WCT seednuts was found to be significantly higher than that of Komadan seednuts after eight months of sowing. This was found to be the case with total germination percentage as well. It was also observed that there was wide range of variations on the rate and germination percentage of WCT and Komadan seed coconuts under identical field conditions.

Reddy *et al.* (2001) observed that coconut seedlings developed from nuts that germinated within a period of four months had more leaves than those germinated later. The splitting of leaves into leaflets also was noticed to occur earlier in these seedlings. Such seedlings should be selected for planting so as to resolve a superior late stage performance.

Ugbah *et al.* (2003) noted that horizontally planted nuts with some husk removed from over the germpore germinated faster than untreated horizontally placed nuts.

2.6.2.1 Correlation Studies on Germination of Seednuts

Liyanage (1955) noticed highly significant positive correlation between sprouting of seednuts and flowering of palms and negative correlation between sprouting and yield thereby showing that seednuts sprouted early give rise to palms that flower in a short period and are more productive than those sprouted later.

Liyanage (1966) observed that there was positive correlation between periods taken for sprouting of seednuts and flowering of the palms and a negative correlation between sprouting and yield.

Louis and Annappan (1985) studied the correlation between the various nut characteristics with the seedling characters and observed that irrespective of the size and shape, nuts of low or medium weight had the highest germination (99-100 per cent), which overall ranged from 90 to 100 per cent.

Valsala and Kannan (1990) reported that number of days taken for germination was negatively correlated with seedling character. It showed negative correlation coefficient with collar girth. Early germinated nuts produced seedlings having more collar girth and faster leaf production.

Thomas (2003) concluded that the time taken for germination and number of leaves were negatively correlated. It was suggested that apart from the rate of leaf production, this could be due to the increased duration of the time between germination and transplanting in the case of early germinating nuts.

2.6.3 Height of Seedling

As in any other crop, plant height is an important phenotypic manifestation of growth in coconut seedlings also.

Liyanage and Abeywardena (1957) elucidated that mother palm selection could be made more efficient by selecting trees which would produce a higher percentage of tall vigorous seedlings.

Menon and Pandalai (1958) reported the average height of seedlings of Tall, Tall x Dwarf origin to be 83.56, 103.63 and 87.54 cm respectively.

Ramadasan *et al.* (1980) reported that although seedling height and number of leaves per seedling were highly correlated with shoot dry weight, their direct effects were negligible. It was found girth that at collar had a high direct effect on the shoot dry weight of seedling.

Louis (1981) studied the phenotypic and genotypic variability in coconut in a collection of 25 varieties and two hybrids and observed a high genotypic coefficient of variation for the height of seedlings in the third year indicating that this character is less affected by environment.

In a seedling progeny analysis of Komadan and WCT, Gopimony (1982) observed that the seedlings of Komadan exhibited superior seedling vigour in terms of height, collar girth, number of leaves, mean number of split leaves and germination percentage compared to WCT.

Shylaraj (1982) concluded that tall seedlings with a good collar girth measurement that bear relatively larger number of split leaves are to be selected preferentially in 'Komadan'.

Balachandran and Arumughan (2000) reported that the seedling height at nine months was the greatest (92 cm) in seedlings from normal round uniform nuts weighing 115.17 g., and at 12 months the height was greatest (147 cm) in seedlings from medium uniform round nuts weighing 1045.36 g.

2.6.4 Number of Leaves

Charles (1959) stated that seedling selection was based on the vigour of seedlings as judged at the four-leaf-stage by the spread and colour of leaves and other measurable characters like collar girth, rapidity of growth and overall sturdiness of seedlings.

Marar (1960) proposed the establishment of elite seed gardens for producing quality coconut seedlings from open pollinated nuts collected from desirably identified mother palms and to make a rigorous selection among the seedlings where one of the impotent criteria of selection was increased number of leaves.

Satyabalan *et al.* (1968) observed that Tall x Dwarf Green and Tall x Dwarf Orange produced 6.70 and 7.00 leaves in a year respectively while comparing the different dwarf parents for use in Tall x Dwarf hybrid production.

Srinivasa and Ramu (1971) concluded that coconut seedlings developed from nuts that germinated within a period of four months had more leaves than those germinated later. Such seedlings should be selected for planting so as to resolve a superior late stage performance.

Ramadasan *et al.* (1980) reported that leaf number could be used as a component in computing seedling vigour in terms of shoot dry weight, based on linear multiple regression equation incorporating other seedling characters like height, girth at collar and leaf area.

Louis (1981) reported that moderately high genetic advance was combined with moderately high heritability for the length of leaf and number of leaves in the crown indicating the predominance of additive genes, which was considered as a desirable feature for selection.

Adkins *et al.* (2010) noted that rate of leaf production was constant with time after tracking the growth of young coconut palms up to 17 months of age.

2.6.5 Age at Leaf Splitting

Age at leaf splitting was another sign of vigour in the seedlings. Menon and Pandalai (1958) concluded that early splitting of leaves was a sign of precocity since the seedlings which commenced to produce leaves which tend to split into leaflets when the seedlings had eight to ten leaves showed early flowering.

Srinivasa and Ramu (1971) reported that nuts which germinated early (within four months) produced seedling where splitting of leaves into leaflets occurred earlier.

2.6.6 Girth at Collar

Menon and Pandalai (1958) observed that girth at collar of Tall, Tall x Dwarf and Dwarf seedlings were 9.14, 10.67 and 9.65 cm respectively. It was also reported that girth at collar was the most important selection character.

Menon and Pandalai (1958) observed that girth at collar was more correlated with weight of seedling (an indication of vigour) than any other character studied.

Pankajakshan and George (1961) noticed positive correlations between girth at collar with both height and leaf number. About 60 per cent of the variation in girth was controlled by the combined influence of height and number of leaves.

Silva and George (1970) reported that fallen over ripe nuts with large size (20 cm short axis) produced seedlings with maximum collar girth.

Satyabalan and Mathew (1977) concluded that it was possible to identify palms of superior genetic value, based on collar girth and leaf production of progenies recorded from the fifth month after germination.

Nampoothiri *et al.* (1975) studied phenotypic and genotypic correlations of certain characters with yield in coconut and found that girth at collar was the only seedling character which showed significant phenotypic correlation. This study therefore formed the basis of the recommendation that seedling selection should be practiced in favour of number of leaves and girth at collar.

Louis (1981) reported that in spite of high heritability for girth at collar, the genetic advance varied, but was considerably high and it was concluded that selection was possible for such characters.

Louis and Annappan (1985) observed that the mean collar girth was the greatest (10.7 cm) in seedlings from egg shaped nuts weighing 960g, in a study on seedling vigour in relation to the size and shape of seednuts in Tall variety of coconut palm.

Ramadasan *et al.* (1985) reported that since the girth at collar is mostly contributing to seedling vigour, the suitability of choosing girth at collar alone as the seedling selection character was worth exploring.

Satyabalan (1984) based on detailed studies of progenies had reported high and positive correlation of growth characters like collar girth and leaf production from the fifth month after germination with those of later months.

Valsala and Kannan (1990) while studying the influence of seednut characters on seedling vigour observed that the girth at collar showed high significant positive correlation with height and total number of leaves produced.

Manju (1992) reported that the collar girth, height of seedling, number of leaves and total leaf area were found significantly and positively correlated among themselves.

Chattopadhyay and Hore (2012) reported the horizontal method of planting with higher nut weight gave higher germination and better seedling as compared to vertical method of planting under gangetic plains of West Bengal and nut weight had positive correlation with germination percentage, collar girth, leaf number, length of leaves and seedling height.

Materials and Methods

3. MATERIALS AND METHODS

The study was conducted in the Department of Plant Breeding and Genetics. College of Agriculture, Vellayani, Thiruvananthapuram during 2014-2016 to estimate the intra-varietal variability in Komadan coconut (*Cocos nucifera* L.) palms. The research was done by conducting two experiments where in experiment-I was to evaluate the fifty Komadan coconut palms for variability in morphological characters and experiment-II was to analyse hundred Komadan seedlings for variability.

3.1 EXPERIMENT I: EVALUATION OF KOMADAN COCONUT PALMS FOR INTRA-VARIETAL VARIABILITY IN YIELD AND OTHER MORPHOLOGICAL CHARACTERS

3.1.1 Materials

The materials for the experiment were selected from the second generation Komadan palms growing in the Instructional Farm, College of Agriculture, Vellayani.

3.1.2 Methods

3.1.2.1 Biometric Observations

The following observations were recorded on all 50 individual palms during the period from February 2015 to February 2016.

1. Number of Leaves per Year

   Number of leaves on the crown was counted for one year.

2. Length of Leaves (m)

   Each individual leaf was measured using a measuring tape from the tip of the leaflet to bottom of the petiole.

3. Number of Leaflets per Leaf

Number of leaflets was counted from three fully opened leaves and the mean value was calculated.

4. Girth of Trunk (cm)

Trunk girth or circumference was measured using a measuring tape at a height of five feet above from the base of trunk of all palms (Nedunchezhiyan, 2008)..

5. Number of Spadices per Year

Number of spadices or bunches was counted throughout the year.

6. Number of Female Flowers per Inflorescence

Female flowers on the youngest inflorescence with male or female flowers in anthesis were counted and the mean number of female flowers per inflorescence was obtained.

7. Number of Female Flowers per Spikelet

Female flowers on the spikelets were counted and the mean was calculated.

8. Setting Percentage

Number of female flowers and number of nuts per bunch were counted from three bunches in a year at random and from this percentage was calculated.

9. Number of Spikelets per Spadix

The number of spikelets per inflorescence in each accession was counted and the average was worked out.

10. Length of Peduncle (cm)

Length of peduncle was measured from the bottom of fully opened mature leaf to first leaflet of the leaf by using measuring tape.

11. Number of Nuts per Palm per Year

The total number of nuts in a palm was counted from the oldest bunch to the youngest bunch where the nuts were in button stage.

12. Nut Polar Length (cm)

The length of the nut from one pole to the other was measured by setsquare blocking of the nut and measuring the distance using a meter scale.

13. Nut Polar Circumference (cm)

The circumference of the nut was measured around the nut length via pole to pole using non-extend string (twine) and length of twine was measured by measuring scale.

14. Nut Equatorial Length (cm)

The breadth of the nut at the middle portion was measured by setsquare blocking of the nut and measuring the distance using a meter scale.

15. Nut Equatorial Circumference (cm)

The circumference of nut at the middle portion was measured by using non-extend string (twine) and length of twine was measured by measuring scale.

16. Weight of Nuts (kg)

Unhusked nuts were weighed in a pan balance and mean weight was expressed in kilograms.

17. Weight of Husked Nuts (g)

The nuts were husked, cleaned, weighed and mean weight was expressed in grams.

18. Thickness of Husk (cm)

This was recorded by piercing the husk with a sharp needle till it reached the shell and the mean length of the needle from the shell to the outer surface of the husk.

19. Husk : nut Ratio

The weight of husked nut divided by weight of unhusked nut gave the husk: nut ratio.

20. Endosperm Thickness (mm)

Nuts were opened and kernels were removed from shells. The thickness of kernel or endosperm was measured by Screw gauge.

21. Colour of the Midrib and Tender Coconut

Pigmentation was scored as per standards fixed in the "Nickerson Colour Fan (1957)" available at Horticultural College and Research Institute, Periyakulam. The number of palms having the same colour index for midrib and tender coconut was found out and its percentage was obtained.

22. Number of Nuts per Bunch

Nuts were counted on all bunches upto button stage of each palm and mean number of nuts per bunch was obtained.

23. Copra Content per Nut

The kernel was excised out of the shell was dried at an air temperature of 60°C for three days and weight was recorded in grams.

24. Oil Content per Nut

The copra from each of the three nuts from every palm was cut into small pieces and a random sample of 50g of copra was taken from each nut for estimation of oil content. The estimation of oil content in nuts was on the basis of the pulsed nuclear magnetic resonance (NMR) signal of hydrogen in the liquid fraction. One sample was analysed from each nut making a total of three samples from a palm and the mean value gave the oil percentage.

3.2 EXPERIMENT II: STUDY FOR INTRA-VARIETAL VARIABILITY IN KOMADAN SEEDLINGS

3.2.1 Materials

The materials for the study consisted of 100 Komadan coconut seedlings raised in the coconut nursery of Instructional Farm, Vellayani.

3.2.2 Methods

3.2.2.1 Seedling Growth Analysis

Observations on five characters were recorded from all the seedlings in the nursery at 9th and 12th months after germination from January 2015 to March 201

1. Number of Days for Germination

Number of days taken for germination of each seednut was recorded from the date of sowing. Emergence of beak at the stalk end was considered as the sign of germination.

2. Number of Leaves at 9 Months and 12 Months Age

Number of leaves present on each seedling was recorded at age of 9th and 12th month.

3. Number of Days for Splitting of Leaflets

The seedlings were continuously observed for splitting of leaf into leaflets and observations were recorded as number of days for splitting of each seedling after sowing.

4. Collar Girth at 9 Months and 12 Months Age (cm)

A non-extendable string (twine) was used to measure collar girth. The string was wound three times around the collar, unwound and length was measured. This measurement divided by three gave the girth at collar.

5. Height of Seedling at 9 Months and 12 Months Age (cm)

Height of seedling was observed at age of 12 months seedling. This was measured from the base of the emerging shoot to the highest extremity, using a graduated meter scale.

3.3 STATISTICAL ANALYSIS

3.3.1 Estimation of Summary Statistics

Statistical analysis of data was performed using Microsoft Excel. This included the calculation of standard deviations, mean, coefficient of variations (CVs), and Pearson correlation coefficients. Coefficient of variations were calculated by dividing the standard deviation of a set of values by the mean of those values and then expressed as percentage by multiplying by 100.

3.3.2 Estimation of Correlation

Character association refers to the association of characters *i.e.*, a change in one character is accompanied by a change in the other character

3.3.3 Categories and Range for Various Characters

The important characters related to yield classified into three different categories (low, medium, high) based on individual character mean and standard deviation classification given below. Range was fixed with different limit and sorted the yield value based on category, significant different between categories was found by Generalised Linear Model.

Category	Range
Low	Below (Mean-SD)
Medium	Between (Mean± SD)
High	Above (Mean + SD)

SD- Standard Deviation

3.3.4 Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) was carried out for various categories of palm characters such as number of leaves per year, length of leaves (cm), number of leaflets per leaf, girth of trunk (cm) and length of peduncle (cm). (Panse and Sukhatme, 1967).

To test the significance of difference among the different categories with respect to number of nuts per palm per year.

3.3.5 Principal Component Analysis

The principle component analysis is a technique which identifies traits that contribute most of the observed variation within a group (Ulaganathan and Nirmalakumari, 2015). It is a multivariate technique for examining relationships among several quantitative variables. The PRINCOMP procedure performs principal component analysis in SAS System 9.3 software. As input can use raw data of correlation matrix. The output data sets containing eigenvalues, eigenvectors, and standardized or unstandardized principal component scores (Rao, 1964).

3.3.6 Clustering Using Dendrogram

Principal components were used as input variables for a cluster analysis using Ward's Method to generate a dendrogram using the Proc Cluster procedure in SAS Version 9.3 (SAS Inst., 2004). This method involves an agglomerative clustering algorithm. It will start out at the leaves and work its way to the trunk, so to speak. It looks for groups of leaves that it forms into branches, the branches into limbs and eventually into the trunk. Ward's method starts out with 'n' clusters (n- number of palms) of size 1 and continues until all the observations are included into one cluster.

Results

4. RESULTS

Fifty Komadan palms and hundred seedlings were evaluated for various morphological characters. The evaluation was conducted in two parts. First evaluation dealt with evaluation of 50 Komadan palms and clustering them using dendrogram. In the second evaluation, 100 Komadan seedlings were studied to find the correlation between morphological characters. The results of the study are presented in this chapter.

4.1 EXPERIMENT I

4.1.1.1 Mean Performance and Other Summary Statistics of Komadan Coconut Palms

The mean value of 50 Komadan palms on quantitative characters are given in Table 1.

1. Number of Leaves per Year

The Komadan palms C9, C19, C20, C21, C23, C31, C32, and C35 showed the maximum value for number of leaves per year (15) and palm C50 produced the lowest number of leaves per year (11) with mean value of 13.4.

2. Length of Leaves (m)

Average length of leaves of 50 palms was 4.2 m. Palm C50 produced the lowest mean length of leaf (2.30 m) and palm C17 showed the highest mean length of leaf (5.46 m).

3. Number of Leaflets per Leaf

The palm C17 had the highest number of leaflets per leaf (240) and C50 showed the lowest number of leaflets per leaf with mean value of 208.4.

4. Girth of Trunk (cm)

The girth of trunk for 50 palms varied from 71.2 cm to 103.2 cm. The average value of girth was 83.5 cm. The palm C43 exhibited the highest value of girth (103.2 cm) and palm C25 had the lowest value (71.2 cm).

5. Number of Spadices per Year

The number of spadices per year varied from 11 to 15. The palm C50 produced the lowest spadices (11) and the palms C9, C19, C20, C21, C23, C31, C32, and C35 exhibited the highest number of spadices per year (15).

6. Number of Female Flowers per Inflorescence

The palm C40 produced maximum number of female flowers per inflorescence (123) and the palm C24 exhibited minimum number of female flowers (3). The mean value of number of female flowers were recorded (35).

7. Number of Female Flowers per Spikelet

The average number of female flowers per spikelet was 1. The palm C40 produced the highest number of female flowers per inflorescence (3.32) and palm C24 had the lowest number (0.11).

8. Setting Percentage (%)

The palm C24 produced the highest setting percentage (66.67) and palm C40 exhibited the lowest setting percentage (6.5) with general mean value of 34.9.

9. Number of Spikelets per Spadix

Number of spikelets per spadix varied from 21 to 63. The palms C27, C42 and C50 showed the lowest number of spikelets (21). The palms C23 and C35 exhibited the highest number of spikelets per spadix (63).

10. Length of Peduncle (cm)

The mean value of length of peduncle was 112.8 cm. The palm C43 showed the highest length (150.2 cm) followed by C42 (148.3 cm) and C17 (148.3 cm).

The palm C50 exhibited the lowest length of peduncle (59.2 cm) followed by C25 (73.9 cm).

11. Number of Nuts per Palm per Year

The number of nuts per palm per year ranged between 25 (C15) and 154 (C32). The palm C32 produced maximum number of nuts per year (154) followed by C17 (140) and C9 (139). The palm C15 had the lowest value (21) followed by C10 (26) and C50 (29).

12. Nut Polar Length (cm)

The average nut polar length was 21.7 cm. The palm C48 had the highest nut polar length (28.9 cm) and the palm C39 exhibited the lowest value (16.50 cm).

13. Nut Polar Circumference (cm)

The nut polar circumference varied from 45.3 cm to 69 cm. The palm C10 exhibited the lowest polar circumference (45.3 cm) and the palm C48 had the highest circumference (69 cm).

14. Nut Equatorial Length (cm)

The palm C21 had the lowest nut equatorial length (9.20 cm) followed by C39 (10.4 cm) and C26 (11 cm). The palm C2 exhibited the highest equatorial length (17.5 cm) followed by C25 (17.2 cm) and C48 (16.9 cm) with mean value of 13.4 cm.

15. Nut Equatorial Circumference (cm)

The mean value of nut equatorial circumference was observed as 45.7 cm. The highest nut equatorial circumference was recorded in the palm C19 (55.1 cm) and it was followed by C32 (53.9 cm) and C20 (51.3 cm). The lowest nut equatorial circumference was observed in C46 (33.5 cm).

16. Weight of Nuts (kg)

The highest weight of nut was recoded in C9 (1.38 kg) and the lowest weight of nut was recorded in C50 (0.54 kg) with mean value of 0.9 kg.

17. Weight of Husked Nuts (g)

Weight of husked nut range varied from 239 g (C30) to 812 g (C19). The palm C19 showed maximum weight (812 g) followed by C32 (791 g) and C23 (785 g).

18. Thickness of Husk (cm)

The palm C17 produced minimum husk thickness (1 cm) followed by C38 (1.25 cm) and C10 (1.72 cm). The palm C30 showed maximum husk thickness (3.9 cm) followed by C36 (3.52 cm) and C20 (3.52 cm) with mean value of 2.7 cm.

19. Husk : nut Ratio

Husk: nut ratio ranged from 0.12 (C17) to 0.76 (C30). The maximum husk: nut ratio was observed in palm C30 (0.76) followed by C14 (0.701) and C22 (0.627) and the minimum value of husk: nut ratio was recorded by C17 (0.12) followed by C18 (0.180) and C10 (0.203).

20. Endosperm Thickness (mm)

The mean value of endosperm thickness was 12.1 mm. The palm C23 (9 mm) had the lowest value of endosperm thickness. The palm C18 and C11 exhibited the highest endosperm thickness (15.2 mm).

21. Number of Nuts per Bunch

Number of nuts per bunch varied from 1 (C15 and C50) to 17 (C17). The maximum nuts per bunch was recoded in C17 (17) followed by C25 (16), C32 (16), and C30 (15). The palm C15 and C50 exhibited the lowest nuts per bunch (1) followed by C10 (2), C12 (2), C16 (2), C24 (2) and C42 (2).

22. Copra Content per Nut (g)

The highest copra content per nut was found in C18 (216 g) and the lowest copra content per nut was observed in palm C40 (79 g) with mean value of 136.7 g.

23. Oil Content per Nut (%)

The oil content per nut varied from 52.6 per cent (C6) to 65.8 per cent (C20). The lowest oil content was recorded in C6 (52.6 per cent) followed by C5 (55 per cent) and C29 (55.1 per cent). The palm C20 produced the highest oil content per nut (65.8 per cent) followed by palm C50 (65.6 per cent) and C3 (65.5 per cent).

24. Weight of Nuts per Year (kg)

The palm C50 exhibited the lowest weight of nuts per year (15.66 kg) and the highest weight was recorded in palm C32 (197.12 kg) with mean value of 80.6 kg.

25. Weight of Husked Nuts per Year (kg)

The mean value of weight of husked nuts per year was 47.4 kg. The maximum weight was observed in palm C32 (121.81 kg) and minimum weight of husked nuts per year was recorded in palm C50 (9.8 kg).

26. Weight of Copra per Year (kg)

Weight of copra per year ranged from 3.48 kg (C50) to 28 kg (C17). The palm C17 showed the highest copra content (28 kg) and the lowest copra content was recorded in the palm C50 (3.48 kg) with average value of 12.1 kg.

The mean, standard deviation, range and coefficient of variation for 26 quantitative traits in 50 palms are presented in Table 2.

Husk: nut ratio showed the lowest standard deviation (0.11) followed by weight of nuts (0.21) and thickness of husk (0.608). The highest standard deviation was obtained in weight of husked nuts (134.51) followed by weight of nuts per year (44.28) and copra content per nut (35.23).

Table 1. Observation on fifty Komadan palms

Palm number	Number of leaves per year	Length of leaves (m)	Number of leaflets per leaf	Girth of trunk (cm)	Number of spadices per year	Number of female flower per inflorescence	Number of female flower per spikelet
C1	14	3.50	198	78.10	14	17	0.65
C2	13	4.40	226	76.20	13	21	0.84
C3	14	3.50	196	77.90	14	26	0.90
C4	13	4.72	208	81.00	13	29	1.12
C5	13	4.82	218	79.10	13	31	1.11
C6	13	4.36	218	83.00	13	28	1.04
C7	14	4.20	210	97.10	14	45	1.41
C8	13	4.38	212	81.00	13	38	1.36
C9	15	3.59	198	73.10	15	55	1.38
C10	13	4.42	212	80.60	13	8	0.29
C11	14	3.55	190	85.30	14	28	0.93
C12	14	3.95	204	82.40	14	7	0.21
C13	13	4.91	214	80.00	13	23	0.88
C14	14	4.56	226	94.20	14	26	0.74
C15	13	4.92	222	89.10	13	9	0.31
C16	14	4.72	210	96.30	14	8	0.24
C17	12	5.46	240	92.00	12	45	1.80
C18	13	4.70	220	87.00	13	35	1.21
C19	15	3.86	180	90.40	15	28	0.62
C20	15	3.68	190	74.60	15	30	0.59
C21	15	3.84	194	81.20	15	33	1.00
C22	13	4.55	200	74.00	13	28	0.90
C23	15	3.21	182	72.30	15	23	0.37
C24	14	3.10	174	83.20	14	3	0.11
C25	14	3.51	172	71.20	14	38	0.81

Table 1. Continued

Palm number	Number of leaves per year	Length of leaves (m)	Number of leaflets per leaf	Girth of trunk (cm)	Number of spadices per year	Number of female flower per inflorescence	Number of female flower per spikelet
C26	13	3.71	196	76.30	13	9	0.39
C27	13	3.80	178	79.50	13	45	2.14
C28	12	5.36	228	88.20	12	8	0.35
C29	13	3.58	192	73.90	13	29	0.85
C30	14	4.68	208	88.50	14	54	1.69
C31	15	3.90	204	74.50	15	25	0.81
C32	15	3.60	174	88.40	15	104	2.81
C33	12	4.27	230	76.10	12	18	0.49
C34	13	4.15	220	83.20	13	19	0.46
C35	15	3.65	232	98.10	15	45	0.71
C36	14	3.17	224	82.30	14	67	1.12
C37	13	3.99	220	78.10	13	65	1.35
C38	13	3.62	224	85.20	13	32	0.71
C39	12	4.05	212	94.30	12	37	1.23
C40	13	4.46	238	99.10	13	123	3.32
C41	13	4.71	218	75.30	13	53	0.88
C42	12	4.35	210	85.10	12	7	0.33
C43	12	4.80	228	103.20	12	60	1.82
C44	14	4.58	224	84.30	14	66	1.40
C45	14	5.13	230	92.30	14	72	1.85
C46	13	4.73	212	96.30	13	80	1.90
C47	14	4.13	218	78.20	14	27	0.87
C48	13	4.72	224	74.60	13	9	0.36
C49	12	4.10	204	84.30	12	23	0.88
C50	11	2.30	160	76.20	11	10	0.48
Mean	13.40	4.20	208.40	83.50	13.40	35.00	1.00

Table 1. Continued

Palm number	Setting percentage (%)	Number of spikelets per spadix	Length of peduncle (cm)	Number of nuts per palm per year	Nut polar length (cm)	Nut polar circumference (cm)	Nut equatorial length (cm)
C1	41.18	26	102.30	78	26.80	64.30	14.40
C2	42.86	25	120.30	92	19.90	57.00	17.50
C3	61.54	29	103.50	122	23.50	58.00	12.50
C4	44.83	26	132.50	86	21.50	52.60	14.40
C5	48.39	28	140.20	109	20.50	56.50	12.00
C6	42.86	27	122.40	97	23.80	61.70	14.50
C7	28.89	32	121.60	98	23.10	58.50	11.20
C8	34.21	28	128.30	79	19.90	54.60	14.50
C9	30.91	40	123.60	139	20.10	54.90	11.80
C10	25.00	28	137.50	26	19.20	45.30	13.20
C11	46.43	30	82.40	109	25.60	61.30	12.90
C12	28.57	34	97.30	35	22.50	57.60	13.50
C13	52.17	26	139.20	90	22.10	61.90	13.90
C14	57.69	35	121.90	119	21.90	53.80	15.90
C15	11.11	29	110.90	25	20.90	47.20	13.20
C16	25.00	34	115.20	32	17.80	51.90	12.90
C17	53.33	25	148.30	140	18.60	52.50	11.50
C18	31.43	29	120.20	96	20.70	55.30	14.10
C19	50.00	45	122.10	109	24.70	59.20	13.70
C20	53.33	51	100.60	128	22.30	57.20	12.10
C21	39.39	33	97.50	118	18.90	50.10	9.20
C22	28.57	31	122.40	70	17.20	48.30	12.30
C23	56.52	63	76.70	112	23.00	57.90	12.50
C24	66.67	27	78.80	32	20.60	53.90	13.20
C25	42.11	47	73.90	124	21.90	57.70	17.20

Table 1. Continued

Palm number	Setting percentage (%)	Number of spikelets per spadix	Length of peduncle (cm)	Number of nuts per palm per year	Nut polar length (cm)	Nut polar circumference (cm)	Nut equatorial length (cm)
C26	55.56	23	79.20	65	20.00	55.10	11.00
C27	31.11	21	107.60	119	19.90	50.50	12.50
C28	37.50	23	140.60	52	17.20	53.10	12.20
C29	27.59	34	97.20	66	24.50	61.00	15.50
C30	27.78	32	128.30	109	20.90	53.80	15.80
C31	36.00	31	98.00	76	25.70	62.30	12.20
C32	22.12	37	104.50	154	26.00	63.00	15.00
C33	38.89	37	122.60	61	20.80	59.60	13.10
C34	52.63	41	110.10	74	18.50	47.50	12.50
C35	37.78	63	97.50	135	22.10	55.30	11.70
C36	23.88	60	97.90	120	25.50	61.50	13.00
C37	20.00	48	98.10	105	21.90	48.20	14.30
C38	37.50	45	112.60	99	22.20	49.70	15.30
C39	29.73	30	102.30	85	16.50	49.20	10.40
C40	6.50	37	113.40	76	23.70	59.20	15.20
C41	28.30	60	120.70	120	21.70	55.90	14.80
C42	28.57	21	148.30	39	19.50	45.50	11.00
C43	16.67	33	150.20	87	21.50	55.00	12.50
C44	25.76	47	124.60	119	22.60	54.90	14.50
C45	22.22	39	133.50	112	28.50	64.50	15.50
C46	16.25	42	123.40	93	19.90	50.80	12.90
C47	18.52	31	110.70	75	19.40	52.30	14.30
C48	33.33	25	114.60	44	28.90	69.00	16.90
C49	17.39	26	105.10	56	19.20	47.50	11.30
C50	10.00	21	59.20	29	20.90	51.50	13.90
Mean	34.90	34.70	112.80	88.70	21.70	55.30	13.40

Table 1. Continued

Palm number	Nut equatorial circumference (cm)	Weight of nuts (kg)	Weight of husked nuts (g)	Thickness of husk (cm)	Husk : nut ratio	Endosperm thickness (mm)	Number of nuts per bunch	Copra content per nut(g)
C1	48.80	1.05	566	3.50	0.46	10.50	7	92
C2	51.00	0.85	627	2.50	0.26	11.00	9	127
C3	44.50	0.90	490	3.50	0.45	13.50	11	171
C4	44.70	0.84	601	2.50	0.28	14.00	12	191
C5	41.90	0.75	485	2.50	0.35	10.50	14	83
C6	49.80	0.74	410	2.70	0.44	13.00	12	161
C7	43.50	0.91	495	3.10	0.45	11.00	10	82
C8	46.20	0.70	379	2.60	0.45	12.00	10	138
C9	51.20	1.38	721	3.51	0.47	10.10	13	82
C10	43.80	0.73	582	1.72	0.20	15.00	2	192
C11	44.90	0.84	581	2.40	0.30	15.20	10	194
C12	48.60	1.05	642	2.58	0.38	13.50	2	181
C13	47.20	0.72	432	2.54	0.40	12.00	9	128
C14	47.60	0.90	269	3.50	0.70	12.50	11	140
C15	45.80	0.72	432	2.65	0.40	13.20	1	157
C16	45.60	0.97	624	2.78	0.35	13.50	2	162
C17	41.00	0.68	599	1.00	0.11	14.10	17	200
C18	45.70	0.73	460	2.12	0.37	15.20	11	216
C19	55.10	1.37	812	3.22	0.40	13.10	9	133
C20	51.30	1.32	712	3.52	0.46	10.00	12	91
C21	49.30	1.17	573	3.26	0.51	15.00	11	210
C22	44.10	0.83	310	3.50	0.62	13.40	8	131
C23	50.70	1.26	785	3.12	0.37	9.00	13	92
C24	42.90	0.93	522	3.12	0.43	10.50	2	112
C25	50.40	0.89	492	2.99	0.44	13.50	16	172

Table 1. Continued

Palm number	Nut equatorial circumference (cm)	Weight of nuts (kg)	Weight of husked nuts (g)	Thickness of husk (cm)	Husk : nut ratio	Endosperm thickness (mm)	Number of nuts per bunch	Copra content per nut(g)
C26	40.10	0.69	374	2.31	0.45	11.40	5	124
C27	43.50	0.84	570	2.32	0.32	12.50	14	136
C28	44.20	0.63	431	1.94	0.31	10.10	3	119
C29	47.50	0.81	512	2.50	0.36	14.80	8	163
C30	46.70	0.98	239	3.90	0.75	11.00	15	112
C31	45.10	0.92	532	3.00	0.42	13.00	9	145
C32	53.90	1.28	791	3.15	0.38	12.40	16	140
C33	45.10	0.69	374	2.55	0.45	10.50	7	110
C34	41.50	0.63	404	2.51	0.35	13.20	9	147
C35	49.20	1.14	682	3.25	0.40	12.00	11	132
C36	48.90	1.05	432	3.52	0.58	13.70	12	164
C37	44.90	0.82	612	2.30	0.25	11.20	8	128
C38	39.20	0.752	617	1.25	0.18	10.20	9	100
C39	39.00	0.59	395	2.01	0.33	11.50	8	110
C40	48.50	0.72	521	2.00	0.27	9.50	8	79
C41	48.70	0.83	465	3.00	0.44	10.00	7	105
C42	38.50	0.64	407	2.39	0.36	10.30	2	114
C43	45.50	0.63	369	2.90	0.41	13.50	10	151
C44	45.90	0.92	581	2.54	0.36	12.20	13	135
C45	48.50	0.97	588	2.52	0.39	13.50	12	178
C46	33.50	0.73	409	3.00	0.44	11.50	10	123
C47	45.10	1.05	721	2.22	0.31	12.10	5	134
C48	49.90	0.81	501	2.53	0.38	10.50	3	123
C49	35.20	0.62	419	1.92	0.32	10.50	4	104
C50	40.80	0.54	338	2.03	0.37	11.00	1	120
Mean	45.70	0.90	517.70	2.70	0.40	12.10	7.80	136.70

Table 1. Continued

Palm number	Oil content per nut (%)	Weight of nuts per year (kg)	Weight of husked nuts per year (kg)	Weight of copra per year (kg)
C1	60.00	81.90	44.14	7.17
C2	62.00	78.20	57.68	11.68
C3	65.50	109.80	59.78	20.86
C4	62.80	72.24	51.68	16.42
C5	55.00	81.75	52.86	9.04
C6	52.60	71.78	39.77	15.61
C7	57.20	89.18	48.51	8.03
C8	56.10	55.30	29.94	10.90
C9	62.10	191.82	100.21	11.39
C10	60.40	18.98	15.13	4.99
C11	64.50	91.56	63.32	21.14
C12	59.00	36.75	22.47	6.33
C13	63.40	64.80	38.88	11.52
C14	62.30	107.10	32.01	16.66
C15	61.40	18.00	10.80	3.92
C16	58.60	31.04	19.96	5.18
C17	56.90	95.20	83.86	28.00
C18	61.20	70.08	44.16	20.73
C19	65.10	149.33	88.50	14.49
C20	65.80	168.96	91.13	11.64
C21	60.10	138.06	67.61	24.78
C22	58.10	58.10	21.70	9.17
C23	59.80	141.12	87.92	10.30
C24	65.10	29.76	16.70	3.58
C25	62.30	110.36	61.00	21.32

Table 1. Continued

Palm number	Oil content per nut (%)	Weight of nuts per year (kg)	Weight of husked nuts per year (kg)	Weight of copra per year (kg)
C26	58.10	44.85	24.31	8.06
C27	59.90	99.96	67.83	16.18
C28	65.20	32.76	22.41	6.18
C29	55.10	53.46	33.79	10.75
C30	57.20	106.82	26.05	12.20
C31	62.10	69.92	40.43	11.02
C32	65.40	197.12	121.81	21.56
C33	55.90	42.09	22.81	6.71
C34	55.30	46.62	29.89	10.87
C35	58.30	153.90	92.07	17.82
C36	65.10	126.00	51.84	19.68
C37	60.90	86.10	64.26	13.44
C38	63.40	74.44	61.08	9.90
C39	62.90	50.15	33.57	9.35
C40	59.20	54.72	39.59	6.00
C41	65.00	99.60	55.80	12.60
C42	65.40	24.96	15.87	4.44
C43	64.20	54.81	32.10	13.13
C44	63.20	109.48	69.13	16.06
C45	61.20	108.64	65.85	19.93
C46	59.60	67.89	38.03	11.43
C47	63.60	78.75	54.07	10.05
C48	64.10	35.64	22.04	5.41
C49	62.90	34.72	23.46	5.82
C50	65.60	15.66	9.80	3.48
Mean	61.10	80.60	47.40	12.10

Table 2. Patterns of variability for 26 quantitative traits of 50 Komdan coconut palms

Characters	Mean	SD	Minimum	Maximum	Range	CV
Number of leaves per year	13.40	0.99	11.00	15.00	4.00	7.39
Length of leaves (m)	4.20	0.63	2.30	5.46	3.16	15.21
Number of leaflets per leaf	208.40	18.64	160.00	240.00	80.00	8.95
Girth of trunk (cm)	83.50	8.07	71.20	103.20	32.00	9.66
Number of spadices per year	13.40	0.99	11.00	15.00	4.00	7.39
Number of female flowers per inflorescence	35.00	24.94	3.00	123.00	120.00	71.32
Number of female flowers per spikelet	1.00	0.65	0.11	3.32	3.21	65.28
Setting percentage (%)	34.90	14.22	6.50	66.67	60.16	40.77
Number of spikelets per spadix	34.70	10.94	21.00	63.00	42.00	31.55
Length of peduncle (cm)	112.80	20.33	59.20	150.20	91.00	18.03
Number of nuts per palm per year	88.70	33.59	25.00	154.00	129.00	37.87
Nut polar length (cm)	21.70	2.78	16.50	28.90	12.40	12.85
Nut polar circumference (cm)	55.30	5.40	45.30	69.00	23.70	9.77
Nut equatorial length (cm)	13.40	1.76	9.20	17.50	8.30	13.18
Nut equatorial circumference (cm)	45.70	4.41	33.50	55.10	21.60	9.66
Weight of nuts (kg)	0.90	0.21	0.54	1.38	0.84	24.14
Weight of husked nuts (g)	517.70	134.51	239.00	812.00	573.00	25.98
Thickness of husk (cm)	2.70	0.60	1.00	3.90	2.90	22.68
Husk : nut ratio	0.40	0.11	0.12	0.76	0.64	28.85
Endosperm thickness (mm)	12.10	1.65	9.00	15.20	6.20	13.67
Number of nuts per bunch	7.80	5.68	1.00	17.00	23.00	53.01
Copra content per nut (g)	136.70	35.23	79.00	216.00	137.00	25.78
Oil content per nut (%)	61.10	3.41	52.60	65.80	13.20	5.59
Weight of nuts per year (kg)	80.60	44.28	15.66	197.12	181.46	54.94
Weight of husked nuts per year (kg)	47.40	25.91	9.80	121.81	112.01	54.71
Weight of copra per year (kg)	12.10	5.98	3.48	28.00	24.52	49.32

SD- Standard Deviation; CV-Coefficient of variation

Plate 1. Leaf size variation

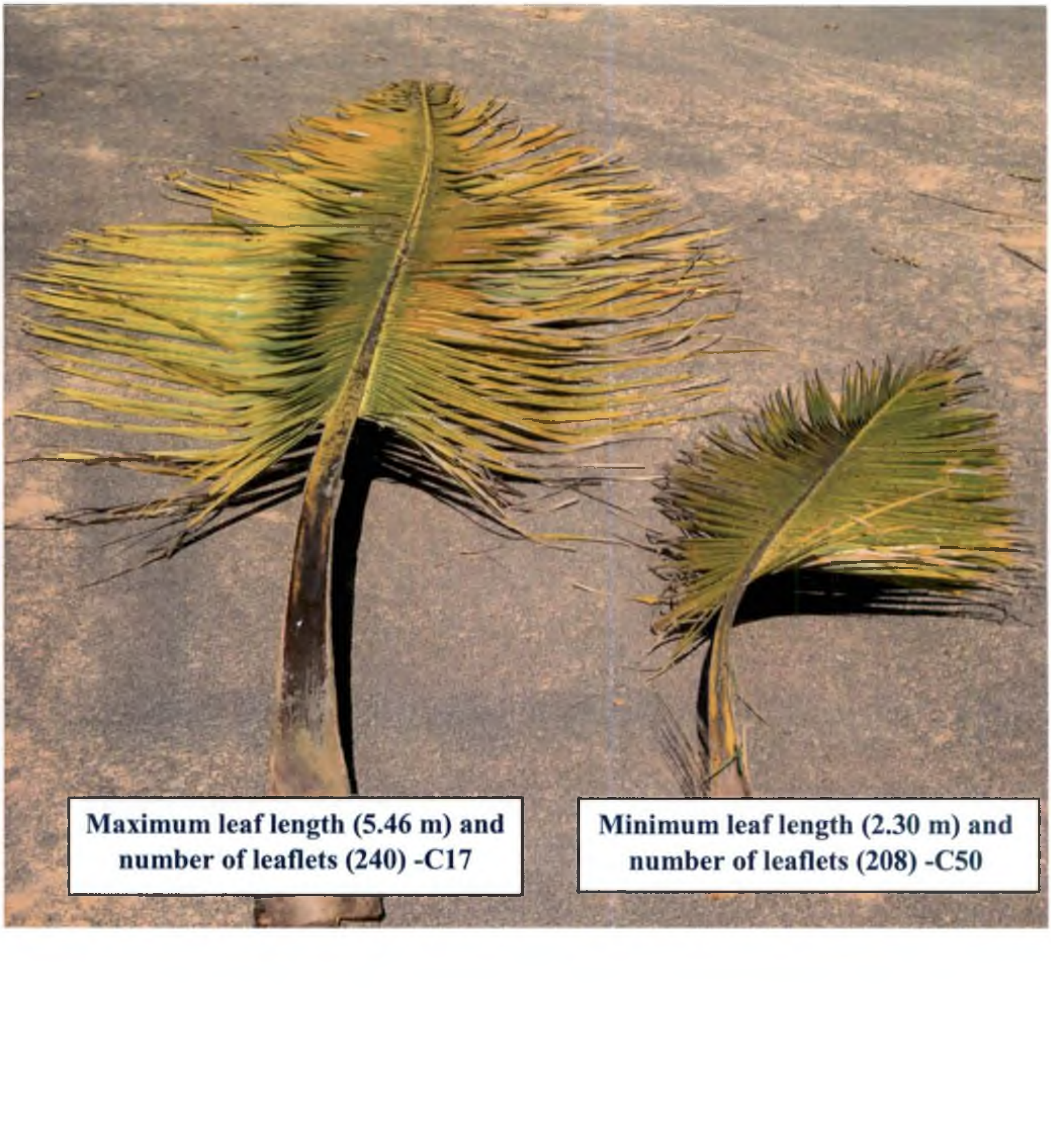


Plate 2. The highest number of nuts per palm per year (154) of palm C32

Plate 3. The lowest number of nuts per palm per year (25) of palm C15

Plate 4. The highest number of leaves and spadices per palm per year (15) of palm C19

Plate 5. The lowest number of leaves and spadices per palm per year of palm C50

Plate 7. Variation in endosperm thickness

The highest endosperm thickness-15.2 mm (palm C18)

The lowest endosperm thickness-9 mm (palm C23)

The coefficient of variation was studied among 26 quantitative characters. The oil content per nut recorded the lowest coefficient of variation (5.59) followed by number of spadices per year (7.39), number of leaves per year (7.39) and number of leaflets per leaf (8.95). Number of female flowers per inflorescence was found to have the highest coefficient of variation (71.32) followed by weight of nuts per year (54.94), weight of husked nuts per year (54.71), number of nuts per bunch (53.01) and weight of copra content (49.32).

4.1.1.2 Colour of the Midrib

The colour of midrib of 50 Komadan coconut palms are given in Table 3.

The 50 Komadan coconut palms had midrib colour ranging from 5 GY 4/3 (moderate olive green) to 5 YR 3/3 (moderate brown) and these palms were classified into different groups based on midrib colour. Among 50 palms, 12 palms (C4, C8, C13, C17, C21, C25, C28, C35, C38, C42, C45 and C49) produced moderate olive green colour (5 GY 4/3), 22 palms (C1, C3, C6, C9, C12, C15, C16, C18, C20, C22, C24, C29, C30, C33, C37, C39, C40, C43, C46, C47, C48 and C50) had light olive colour (5 Y 5/6), 10 palms (C5, C11, C14, C26, C27, C31, C32, C36, C41 and C44) expressed moderate olive colour (7.5 Y 4/3) and 6 palms (C2, C7, C10, C19, C23 and C34) exhibited moderate brown (5 YR 3/3).

4.1.1.3 Colour of the Tender Coconut

The variation in the colour of tender coconut was noticed in 50 Komadan coconut palms (Table 4).

The range of colour differed from brownish orange (2.5 YR 5/9) to greyish olive green (2.5 GY 3/1) and the fifty palms fell to in five different gradients of colour (Plate 1). The 13 palms (C2, C6, C9, C12, C16, C20, C24, C27, C30, C32, C36, C41 and C47) produced brownish orange colour (2.5 YR 5/9), 7 palms (C3, C10, C15, C22, C29, C38 and C43) expressed moderate olive brown (2.5 Y 4/4), 9 palms (C4, C7, C17, C18, C19, C28, C34, C42 and C46) exhibited moderate olive colour (10 Y 4/3), 14 palms (C1, C5, C8, C11, C14, C23, C31, C35, C39, C44, C45,

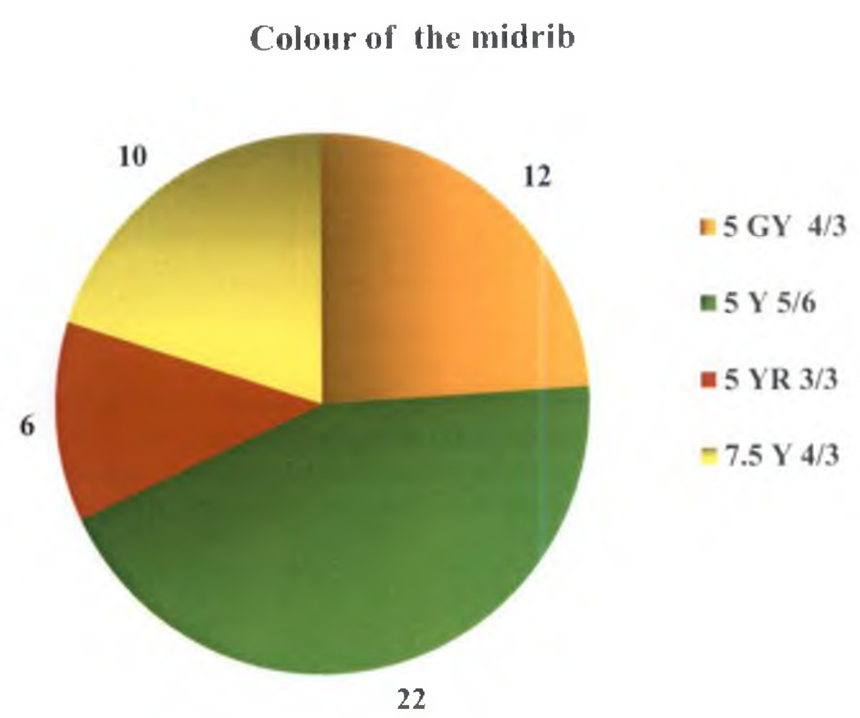
Table 3. Colour of the midrib

Sl. No.	Colour index	Colour	Palm number	Number of palms
1.	5 GY 4/3	Moderate olive green	C4, C8, C13, C17, C21, C25, C28, C35, C38, C42, C45, C49	12
2.	5 Y 5/6	Light olive	C1, C3, C6, C9, C12, C15, C16, C18, C20, C22, C24, C29, C30, C33, C37, C39, C40, C43, C46, C47, C48, C50	22
3.	7.5 Y 4/3	Moderate olive	C5, C11, C14, C26, C27, C31, C32, C36, C41, C44	10
4.	5 YR 3/3	Moderate brown	C2, C7, C10, C19, C23, C34	6

Table 4. Colour of the tender coconut

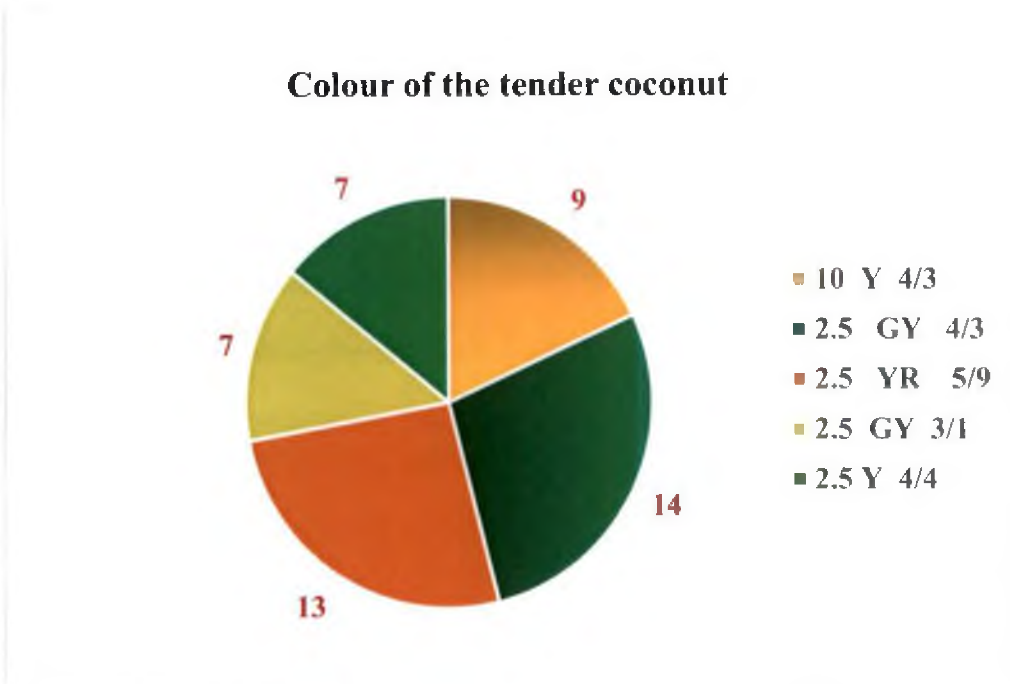
Sl. No.	Colour index	Colour	Palm number	Number of palms
1.	2.5 YR 5/9	Brownish orange	C2, C6, C9, C12, C16, C20, C24, C27, C30, C32, C36, C41, C47	13
2.	2.5 Y 4/4	Moderate olive brown	C3, C10, C15, C22, C29, C38, C43	7
3.	10 Y4/3	Moderate olive	C4, C7, C17, C18, C19, C28, C34, C42, C46	9
4.	2.5 GY 4/3	Moderate olive green	C1, C5, C8, C11, C14, C23, C31, C35, C39, C44, C45, C48, C49, C50	14
5.	2.5 GY 3/1	Greyish olive green	C13, C21, C25, C26, C33, C37, C40	7

Fig. 1. Colour of midrib of 50 Komadan coconut palms



Colour	Colour index
Moderate olive green	5 GY 4/3
Light olive	5 Y 5/6
Moderated olive	7.5 Y 4/3
Moderate brown	5 YR 3/3

Fig. 2. Colour of tender coconut of Komadan coconut palms



Colour	Colour index
Brownish orange	2.5 YR 5/9
Moderate olive brown	2.5 Y 4/4
Moderate olive	10 Y 4/3
Moderate olive green	2.5 GY 4/3
Greyish olive green	2.5 GY 3/1

Plate 8. Colour of tender coconut

C48, C49 and C50) produced moderate olive green (2.5 GY 4/3) and 7 palms (C13, C21, C25, C26, C33, C37, C40) exhibited greyish olive green colour (2.5 GY 3/1).

4.1.2 Correlation among Quantitative Characters of Palms

Correlation among 26 quantitative characters of Komadan coconut palms are presented in Table 5.

In Komadan coconut palms, number of leaves per year was found significantly and positively correlated with number of spadices per year (1.00), setting percentage (0.280), number of spikelets per spadix (0.495), number of nuts per palm per year (0.481), nut polar length (0.411), nut polar circumference (0.370), nut equatorial circumference (0.625), weight of nuts (0.907), weight of husked nuts (0.599), thickness of husk (0.650), husk: nut ratio (0.341), number of nuts per bunch (0.402), weight of nuts per year (0.734), weight of husked nuts per year (0.609) and weight of copra per year (0.339). It was significantly and negatively correlated with length of leaves (-0.305) and number of leaflets per leaf (-0.284).

Length of leaves had highly significant and positive correlation with number of leaflets per leaf (0.709), girth of trunk (0.389), length of peduncle (0.831), weight of nuts (0.348). It showed negative correlation with number of spadices per year (-0.306), number of spikelets per spadix (-0.233), nut polar length (-0.218), weight of nuts (-0.348), weight of husked nuts (-0.242), thickness of husk (-0.257), oil content per nut (-0.228), weight of nuts per year (-0.248) and weight of copra per year (-0.204). Among this number of spadices per year (-0.306) and weight of nuts (-0.348) exhibited highly significant and negative correlation.

The number of leaflets per leaf was observed negatively correlated with number of spadices per year (-0.284), weight of nuts (-0.346), weight of husked nuts (-0.211), thickness of husk (-0.307), oil content per nut (-0.250) and weight of nuts per year (-0.207). It was showed highly significant and positive correlation with girth of trunk (0.423) and length of peduncle (0.635).

Girth of trunk had highly significant and positive correlation with number of female flowers per inflorescence (0.381), number of female flowers per spikelet

(0.400) and length of peduncle (0.367). It showed maximum negative correlation with setting percentage (-0.276) and nut equatorial circumference (-0.184).

Number of spadices per year was found significantly and positively correlated with setting percentage (0.280), number of spikelets per spadix (0.495), number of nuts per palm per year (0.481), nut polar length (0.411), nut polar circumference (0.370), nut equatorial circumference (0.625), weight of nuts (0.907), weight of husked nuts (0.599), thickness of husk (0.650), husk: nut ratio (0.341), number of nuts per bunch (0.402), weight of nuts per year (0.734), weight of husked nuts per year (0.609) and weight of copra per year (0.339). There was significant and negative correlation with length of leaves (-0.305) and number of leaflets per leaf (-0.284).

Strong positive correlation of number of female flowers per inflorescence was obtained with number of female flowers per spikelet (0.912), number of spikelets per spadix (0.396), number of nuts per palm per year (0.591), number of nuts per bunch (0.615), weight of nuts per year (0.490), weight of husked nuts per year (0.491) and weight of copra per year (0.416). It was highly significant and negative correlation with setting percentage (-0.427).

Number of female flowers per spikelet had highly significant and negative correlation with setting percentage (-0.391) and highly significant and positive correlation was noticed with number of nuts per palm per year (0.522), number of nuts per bunch (0.564), weight of nuts per year (0.361), weight of husked nuts per year (0.399) and weight of copra per year (0.415).

No interrelationship of setting percentage was observed with number of spikelets per spadix (-0.005), nut polar length (0.01) and endosperm thickness (-0.002). It had positive correlation with number of nuts per palm per year (0.254), weight of nuts (0.199), nut polar circumference (0.191), number of nuts per bunch (0.248), weight of nuts per year (0.224), weight of husked nuts per year (0.209) and weight of copra per year (0.250). It was negatively correlated with length of peduncle (-0.101) and nut equatorial length (-0.104).

Number of spikelets per spadix had maximum negative correlation with length of peduncle (-0.224), endosperm thickness (-0.142) and copra content per nut (-0.150). It was significantly and positively correlated with number of nuts per palm per year (0.494), nut equatorial circumference (0.373), weight of nuts (0.508), weight of husked nuts (0.361), thickness of husk (0.356), number of nuts per bunch (0.451), weight of nuts per year (0.570) and weight of husked nuts per year (0.516). It shown no significant but positive correlation with nut polar length (0.232) and weight of copra per year (0.255).

Length of peduncle had negative correlation with nut polar length (-0.191), weight of nuts (-0.223), thickness of husk (-0.164) and weight of husked nut (-0.154). It showed positive correlation with number of nuts per bunch (0.142).

Number of nuts per palm per year was significantly and positively correlated with nut equatorial circumference (0.376), weight of nuts (0.494), weight of husked nuts (0.324), thickness of husk (0.317), number of nuts per bunch (0.961), weight of nuts per year (0.893), weight of husked nuts per year (0.860) and weight of copra per year (0.804).

Strong significant and positive correlation of nut polar length was obtained with nut polar circumference (0.825), nut equatorial length (0.450), nut equatorial circumference (0.505), weight of nuts (0.359), weight of nuts per year (0.14) and weight of husked nuts per year (0.295).

Nut polar circumference had significant and positive correlation with nut equatorial length (0.403), nut equatorial circumference (0.596), weight of nuts (0.343), thickness of husk (0.308), weight of nuts per year (0.315), and weight of husked nuts per year (0.282). Nut equatorial length was significant positive correlation with nut equatorial circumference (0.410).

Nut equatorial circumference was significantly and positively correlated with weight of nuts (0.702), weight of husked nuts (0.478), thickness of husk (0.493), number of nuts per bunch (0.306), weight of nuts per year (0.588), weight of husked nuts per year (0.496) and weight of copra per year (0.296).

Weight of nuts had maximum significant and positive correlation with weight of husked nuts (0.709), thickness of husk (0.631), husk: nut ratio (0.298), number of nuts per bunch (0.398), weight of nuts per year (0.808), weight of husked nuts per year (0.698) and weight of copra per year (0.291).

Weight of husked nuts had highly significant and negative correlation with husk: nut ratio (-0.454). It was observed positive correlation with number of nuts per bunch (0.261), oil content per nut (0.212), weight of nuts per year (0.549), weight of husked nuts per year (0.736) and weight of copra per year (0.218). Among this characters, weight of nuts per year (0.549) and weight of husked nuts per year (0.736) were noticed highly significant.

Thickness of husk had maximum negative correlation with copra content per nut (-0.158). It showed highly significant and positively correlation with husk: nut ratio (0.832) and weight of nuts per year.

Husk: nut ratio had negative correlation with copra content per nut (-0.128) and weight of husked nuts per year (-0.134). It was positively correlated with weight of nuts per year (0.251).

Endosperm thickness was observed highly significant with positive correlation with copra content per nut (0.924) and weight of copra per year (0.539).

Number of nuts per bunch had strong significant and positive correlation with weight of nuts per year (0.817), weight of husked nuts per year (0.803) and weight of copra per year (0.813).

Copra content per nut had highly significant and positive correlation with weight of copra per year (0.577). Oil content per nut had very less correlation with all other characters. It was noticed maximum correlation with weight of nuts per year (0.157) and weight of husked nuts per year (0.162). Weight of nuts per year shown highly significant and positive correlation with weight of husked nuts per year (0.918) and weight of copra per year (0.644). Weight of husked nuts per year had highly significant and positive correlation with weight of copra per year.

Table 5. Correlation among 26 quantitative characters of palms

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	1.000														
X2	-0.305*	1.000													
X3	-0.284*	0.709**	1.000												
X4	-0.084	0.389**	0.423**	1.000											
X5	1.000**	-0.306*	-0.284*	-0.084	1.000										
X6	0.179	0.099	0.197	0.381**	0.179	1.000									
X7	0.020	0.199	0.156	0.400**	0.020	0.912**	1.000								
X8	0.280*	-0.128	-0.185	-0.276	0.280*	-0.427**	-0.391**	1.000							
X9	0.495**	-0.233	0.072	0.006	0.495**	0.396**	0.038	-0.005	1.000						
X10	-0.275	0.831**	0.635**	0.367**	-0.275	0.140	0.246	-0.101	-0.224	1.000					
X11	0.481**	-0.059	-0.004	0.042	0.481**	0.591**	0.522**	0.254	0.494**	0.046	1.000				
X12	0.411**	-0.218	-0.073	-0.076	0.411**	0.263	0.162	0.010	0.232	-0.191	0.234	1.000			
X13	0.370**	-0.102	-0.037	-0.136	0.370**	0.190	0.150	0.191	0.125	-0.121	0.269	0.825**	1.000		
X14	0.016	0.080	0.082	-0.152	0.016	0.175	0.127	-0.104	0.077	-0.003	0.034	0.450**	0.403**	1.000	
X15	0.625**	-0.127	-0.127	-0.184	0.625**	0.177	0.065	0.139	0.373**	-0.090	0.376**	0.505**	0.596**	0.410**	1.000
X16	0.907**	-0.348*	-0.346*	-0.143	0.907**	0.184	0.026	0.199	0.508**	-0.223	0.494**	0.359*	0.343*	0.012	0.702**
X17	0.599**	-0.242	-0.211	-0.104	0.599**	0.138	0.048	0.108	0.361**	-0.157	0.324*	0.278	0.209	0.017	0.478**
X18	0.650**	-0.257	-0.307*	-0.103	0.650**	0.109	-0.031	0.187	0.356*	-0.164	0.317*	0.270	0.308*	0.016	0.493**
X19	0.341*	-0.117	-0.174	-0.055	0.341*	0.028	-0.051	0.101	0.154	-0.094	0.154	0.105	0.186	0.025	0.252
X20	0.102	0.105	-0.030	0.122	0.102	-0.057	0.015	-0.002	-0.142	0.039	0.046	0.040	-0.026	-0.028	0.087
X21	0.402**	0.038	0.044	0.105	0.402**	0.615**	0.564**	0.248	0.451**	0.142	0.961**	0.222	0.251	0.050	0.306*
X22	0.035	0.158	0.032	0.070	0.035	-0.110	-0.046	0.045	-0.150	0.026	0.016	0.030	-0.032	0.036	0.088
X23	0.085	-0.228	-0.250	-0.038	0.085	0.002	-0.096	-0.042	0.079	-0.144	0.038	0.171	0.024	0.065	0.090
X24	0.734**	-0.248	-0.207	-0.053	0.734**	0.490**	0.361**	0.224	0.570**	-0.091	0.893**	0.314*	0.315*	-0.001	0.588**
X25	0.609**	-0.204	-0.158	-0.040	0.609**	0.491**	0.399**	0.209	0.516**	-0.071	0.860**	0.295*	0.280*	-0.009	0.496**
X26	0.339*	0.035	0.018	0.093	0.339*	0.416**	0.415**	0.250	0.255	0.029	0.804**	0.209	0.214	0.036	0.296*

Table 5. Continued

	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26
X16	1.000										
X17	0.709**	1.000									
X18	0.631**	-0.010	1.000								
X19	0.298*	-0.454**	0.832**	1.000							
X20	-0.022	0.000	-0.041	-0.025	1.000						
X21	0.398**	0.261	0.251	0.116	0.122	1.000					
X22	-0.065	0.032	-0.158	-0.128	0.924**	0.086	1.000				
X23	0.179	0.212	0.061	-0.072	-0.125	-0.046	-0.038	1.000			
X24	0.808**	0.549**	0.516**	0.251	-0.019	0.817**	-0.060	0.157	1.000		
X25	0.698**	0.736**	0.207	-0.134	-0.012	0.803**	-0.016	0.162	0.918**	1.000	
X26	0.291*	0.218	0.127	0.045	0.539**	0.813**	0.577**	0.032	0.644**	0.653**	1.000

X1 Number of leaves per year
X2 Length of leaves (m)
X3 Number of leaflets per leaf
X4 Girth of trunk (cm)
X5 Number of spadices per year
X6 Number of female flower per inflorescence
X7 Number of female flower per spikelet
X8 Setting percentage
X9 Number of spikelets per spadix
X10 Length of peduncle cm)
X11 Number of nuts per palm per year
X12 Nut polar length (cm)
X13 Nut polar circumference (cm)
X14 Nut equatorial length (cm)
X15 Nut equatorial circumference (cm)
X16 Weight of nuts (kg)
X17 Weight of husked nuts (g)
X18 Thickness of husk (cm)
X19 Husk: nut ratio
X20 Endosperm thickness (mm)
X21 Number of nuts per bunch
X22 Copra content per nut
X23 Oil content per nut
X24 Weight of nuts per year
X25 Weight of husked nuts per year
X26 Weight of copra per year

* significant at 5% level ** significant at 1% level

4.1.3 Generalised Linear Model analysis for Number of Nuts per Palm per Year

The mean value of the number of nuts per palm per year with regarding to various categories (low, medium, high) of other characters (Number of leaves per year, length of leaves, number of leaflets per leaf, girth of trunk, length of peduncle) are given in Table 6.

The high number of leaves per year (14<) showed maximum number of nuts per palm per year (121.37). They were significantly superior to medium (85.73) and low (68.62) number of leaves per year. Low (<12) and medium (13-14) leaf per year on par with each other.

Length of leaves, number of leaflets per leaf, girth of trunk and length of peduncle did not show any significant difference among the different categories of number of nuts per year.

4.1.4 Principal Component Analysis for 12 Yield and Yield Related Traits

The yield related traits were considered for the principle component analysis. Number of leaves per year, number of spadices per year, number of female flowers per inflorescence, length of peduncle, number of nuts per palm per year, weight of nuts, endosperm thickness, number of nuts per bunch, copra content per nut, weight of nuts per year, weight of husked nuts per year and weight of copra per year were showed high correlation to yield. These 12 characters were used to analyse the principle component and Eigen value. The Eigen value, proportion of variation and cumulative effective of variation are given in Table 7. The first four principle component of all 12 traits are presented in Table 8.

The result of PCA revealed that the first 4 components contributed about 92.08 per cent of the total variability in 50 palms involving 12 quantitative traits. The cumulative variance of 96.4 per cent by the first five PC axes with Eigen value of > 0.52 indicates that the identified traits within the axes exhibited great influence on variation within the palms (Table 7).

Table 6. Mean value of number of nuts per palm per year with regard to categories of other characters

categories	X1		X2		X3		X4		X5	
	Intervel	NNPPY	Intervel	NNPPY	Intervel	NNPPY	Intervel	NNPPY	Intervel	NNPPY
Low	Low (< 12)	68.62	Low (< 3.54)	88.14	Low (< 189)	97.00	Low (< 75.44)	97.66	Low (< 92.46)	78.50
Medium	Medium (13-14)	85.73	Medium (3.53-4.79)	89.44	Medium (190-227)	85.91	Medium (75.45-91.58)	83.19	Medium (92.47-133.12)	91.91
High	High (> 14)	121.37	High (> 4.80)	83.80	High (> 228)	94.71	High (> 91.59)	97.70	High (> 133.13)	81.87
Mean		91.91		87.13		92.54		92.85		84.09
F ratio	6.55**		0.06		0.43		1.10		0.59	
S.E	15.53		1.70		3.37		4.82		4.02	
C.D (0.01)	40.17		-		-		-		-	

NNPY -Number of nuts per palm per year

** Significant at 1% level

X1 Number of leaves per year

X2 Length of leaves (m)

X3 Number of leaflets per leaf

X4 Girth of trunk (cm)

X5 Length of peduncle (cm)

The first principle component contributed for 50.22 per cent in total variation with Eigen value of 6.03. Weight of nuts per year (0.39), number of nuts per palm per year (0.37), weight of husked nuts per year (0.37), number of nuts per bunch (0.35), number of leaves per year (0.32), number of spadices per year (0.32) and weight of nuts (0.32) had the highest loadings in PC1. All other characters contributed minimum to the first component.

Second principal component accounted for 19.46 per cent of the total variation with Eigen value of 2.34. Characters that contributed to the second component include copra content per nut (0.58), endosperm thickness (0.56) and weight of copra per year (0.40). Weight of nuts (-0.24), number of spadices per year (-0.19) and number of leaves per year (-0.19) contributed negatively to PC2.

The third principle component contributed for 15.78 per cent of the total variation with Eigen value of 1.89 in the 50 palms. Number of leaves per year and number of spadices per year had the highest value (0.35) followed by endosperm thickness (0.32) and copra content per nut (0.31). Number of female flowers per inflorescence (-0.40), length of peduncle (-0.38) and number of nuts per bunch (-0.29) accounted negatively to PC3.

Likewise, the fourth principle component contributed 6.62 per cent of the total variation with Eigen value of 0.79. The major characters that accounted highly to the variation include length of peduncle (0.90) and weight of nuts (0.22).

The fifty palms were subjected to clustering using dendrogram based on PCA by Ward's Minimum Variance Cluster Analysis (Fig. 1).

4.2 EXPERIMENT II

Hundred Komadan seedlings and its eight morphological characters were studied to find the patterns of variability and correlation between characters (Table 9).

Fig. 3. Dendrogram of 50 Komadan coconut palms based on Ward's Minimum Variance Cluster Analysis

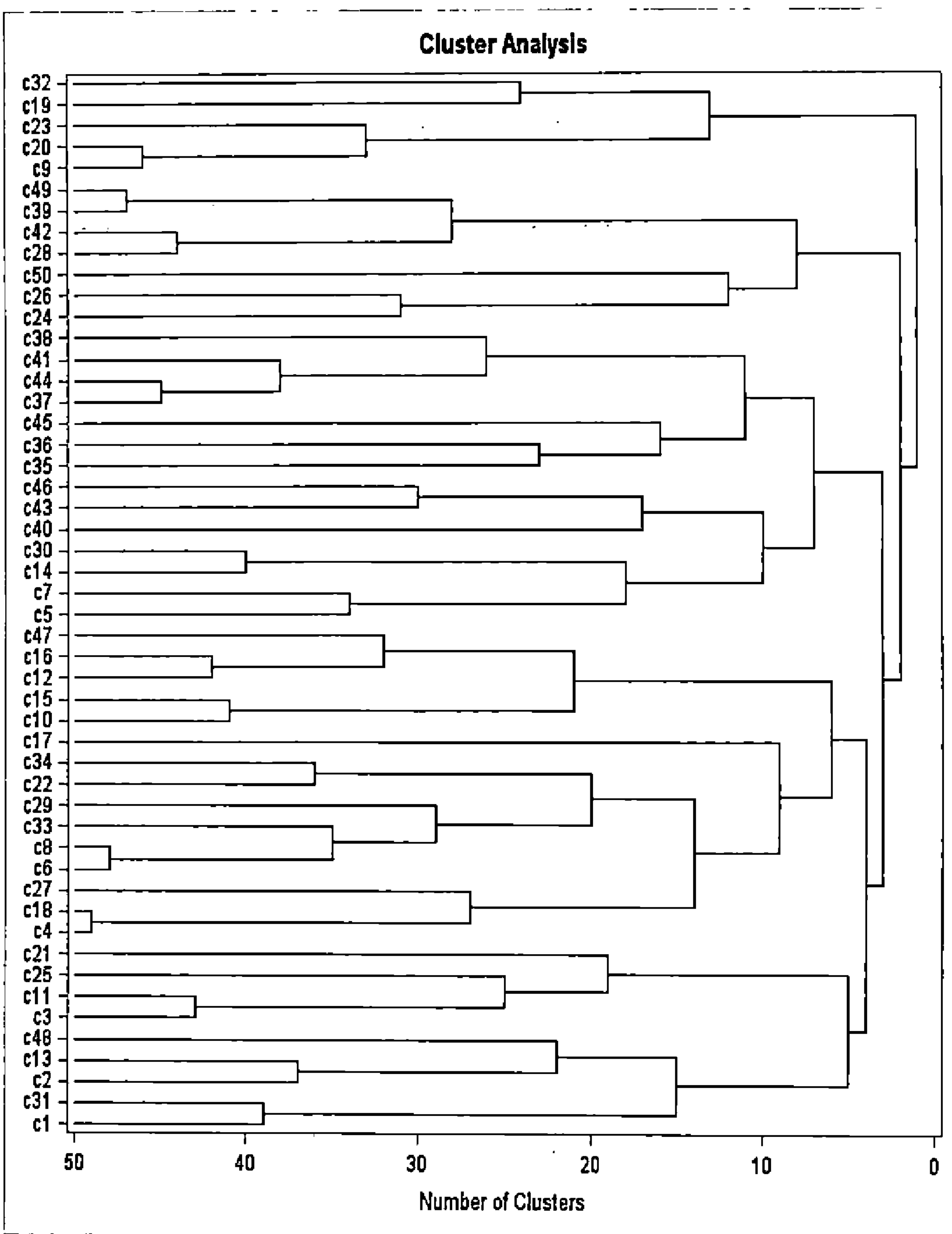


Table 7. Principle components showing the Eigen values, proportion of variation and cumulative effective of variation

Principle component	Eigen value	Variation (%)	Cumulative %
1	6.03	50.22	50.22
2	2.34	19.46	69.68
3	1.89	15.78	85.46
4	0.79	6.62	92.08
5	0.52	4.32	96.40
6	0.20	1.69	98.09
7	0.09	0.75	98.84
8	0.08	0.67	99.50
9	0.04	0.30	99.81
10	0.02	0.13	99.94
11	0.01	0.06	100.00
12	0.00	0.00	100.00

Table 8. Principal component analysis for 12 yield and yield related traits of 50 Komadan coconut palms

Sl. No.	Character	Principal component (PC)			
		PC1	PC2	PC3	PC4
1.	Number of leaves per year	0.32	-0.19	0.35	0.19
2.	Number of spadices per year	0.32	-0.19	0.35	0.19
3.	Number of female flower per inflorescence	0.22	0.03	-0.40	-0.12
4.	Length of peduncle (cm)	-0.04	0.18	-0.38	0.90
5.	Number of nuts per palm per year	0.37	0.07	-0.25	-0.12
6.	Weight of nuts (kg)	0.32	-0.24	0.28	0.22
7.	Endosperm thickness (mm)	0.06	0.56	0.32	0.07
8.	Number of nuts per bunch	0.35	0.14	-0.29	-0.06
9.	Copra content per nut	0.04	0.58	0.31	0.01
10.	Weight of nuts per year	0.39	-0.09	-0.05	0.01
11.	Weight of husked nuts per year	0.37	-0.05	-0.11	-0.07
12.	Weight of copra per year	0.30	0.40	-0.06	-0.17

4.2.1 Patterns of Variability for Eight Quantitative Characters

The patterns of variability (mean, standard deviation, minimum, maximum, range and coefficient of variation) are given in Table 10.

1. Number of Days for Germination

The seedling S3 noted minimum number of days for germination (97) and seedling S37 showed maximum number of days for germination (134) with mean value 112.7.

2. Number of Leaves at 9 Months Age

The average number of leaves at nine months age was calculated of 4.1. The seedlings S7, S16, S17, S18, S23, S26, S27, S28, S32, S33, S37, S38, S39, S40, S47, S48, S55, S74, S77, S78, S89 and S91 produced minimum number of leaves (3) and seedlings S2, S6, S11, S12, S13, S15, S29, S36, S43, S49, S50, S56, S58, S63, S64, S68, S70, S71, S76, S85, S86, S87, S88, S94, S95, S96 and S100 noticed maximum number of leaves at nine months age (5).

3. Collar Girth at 9 Months Age (cm)

The mean collar girth at nine months age was 12.3 cm. The seedling S71 exhibited maximum collar girth at nine months age (13.32 cm) and S10 showed minimum collar girth at nine month age (11.23).

4. Height of Seedling at 9 Months Age (cm)

Height of seedling at nine months age varied from 102.2 cm to 129.6 cm. The seedling S18 showed the lowest height (102.2 cm) and seedlings S68 and S70 produced the highest height of seedlings at nine month age.

5. Number of Days for Splitting of Leaflets

The average days for splitting of leaflets was 383.2. The seedlings S1 and S4 showed early splitting (350 days) and seedling S37 noticed late splitting of leaflets (429).

6. Number of Leaves at 12 Months Age

Number of leaves at 12 months age varied from 5 to 8. The seedlings S18 and S40 noticed minimum number of leaves (5) and seedlings S2, S12, S15, S56, S58, S63, S68, S70, S71, S76, S85, S87, S94, S96 and S100 produced maximum number of leaves at 12 months age (8).

7. Collar Girth at 12 Months Age (cm)

The general mean collar girth at 12 months age was 13.4 cm. The seedlings S12, S68 and S100 showed the highest collar girth (14.3 cm) and S9 exhibited the lowest collar girth at 12 months age (12.27 cm).

8. Height of Seedling at 12 Months Age (cm)

The 12 month age old seedlings height ranged from 110.4 cm to 139.1 cm. The highest height was recorded in S88 (139.1 cm) and the lowest height was observed S18 (110.4 cm) with general mean height 126.9 cm.

Collar girth at 12 months age was showed the lowest standard deviation (0.43) followed by collar girth at nine months age (0.47), number of leaves at nine months age (0.70) and number of leaves at 12 months (0.73). The highest standard deviation was noted in number of days for germination (11.30) followed height of seedling at nine months age (5.92) and height of seedling at 12 months age (5.83).

The coefficient of variation ranged from 3.18 to 17.3. The highest variation was observed in number of leaves at nine months age (17.3) followed by number of leaves at 12 months age (10.7) and number of days for germination (10). The lowest coefficient variation was noticed for collar girth at 12 months age (3.18) followed by number of days for splitting of leaflets and collar girth at nine months age (3.8).

4.2.2 Correlation Studies on Komadan Seedling Characters

Correlation among eight morphological characters of Komadan coconut seedlings are presented in Table 11.

Table 9. Observations on seedling characters

Seedling number	Number of days for germination	Number of leaves at 9 months age	Collar girth at 9 months age(cm)	Height of seedling at 9 months age(cm)	Number of days for splitting of leaflets	Number of leaves at 12 months age	Collar girth at 12 months age(cm)	Height of seedling at 12 months age(cm)
S1	99	4	12.40	119.10	350	7	13.57	126.50
S2	98	5	13.01	125.40	381	8	14.00	133.60
S3	97	4	12.45	117.60	351	7	13.68	123.30
S4	100	4	12.34	119.90	350	7	13.72	127.20
S5	110	4	12.56	111.40	386	6	13.23	118.10
S6	112	5	12.26	122.10	389	7	13.24	129.10
S7	131	3	11.32	112.50	390	6	12.54	120.70
S8	112	4	12.32	118.90	392	7	13.27	127.80
S9	131	4	11.24	116.50	401	6	12.27	122.90
S10	119	4	11.23	111.60	410	6	12.57	119.30
S11	119	5	13.12	126.90	405	7	14.20	131.40
S12	99	5	13.21	128.10	352	8	14.30	134.50
S13	99	5	12.36	121.30	353	7	13.17	130.70
S14	98	4	12.21	120.90	352	7	13.28	128.50
S15	100	5	12.86	129.20	361	8	13.97	135.60
S16	125	3	11.79	116.20	386	6	12.92	122.30
S17	125	3	11.92	111.90	391	6	12.87	118.50
S18	128	3	12.36	102.20	402	5	13.28	110.40
S19	113	4	12.46	117.30	382	7	13.51	125.30
S20	129	4	12.22	119.90	406	7	13.44	129.20
S21	113	4	12.12	123.30	375	7	13.29	131.10
S22	114	4	11.96	112.50	369	6	13.01	119.30
S23	128	3	11.99	114.20	402	6	13.21	121.70
S24	126	4	12.23	120.10	405	7	13.33	127.90
S25	123	4	12.36	121.10	382	7	13.42	128.00

Table 9. Continued

Seedling number	Number of days for germination	Number of leaves at 9 months age	Collar girth at 9 months age(cm)	Height of seedling at 9 months age(cm)	Number of days for splitting of leaflets	Number of leaves at 12 months age	Collar girth at 12 months age(cm)	Height of seedling at 12 months age(cm)
S26	125	3	11.89	112.20	386	6	12.92	120.40
S27	128	3	11.57	113.30	397	6	12.97	122.30
S28	126	3	11.96	111.60	392	6	13.02	119.20
S29	99	5	12.25	122.50	353	7	13.42	129.10
S30	112	4	12.36	124.70	382	7	13.59	131.24
S31	114	4	11.74	116.20	385	6	12.97	123.35
S32	126	3	11.86	113.50	401	6	12.99	120.23
S33	132	3	11.32	110.90	421	6	12.87	118.47
S34	128	4	12.18	120.50	412	7	13.21	127.56
S35	102	4	12.11	113.50	364	6	13.02	120.78
S36	109	5	12.36	127.10	377	7	13.32	132.23
S37	134	3	12.12	117.60	429	6	13.09	123.37
S38	128	3	12.20	126.20	414	6	13.07	124.62
S39	125	3	12.05	112.90	409	6	13.11	121.91
S40	126	3	11.61	107.30	405	5	12.57	112.34
S41	122	4	11.96	120.30	396	7	13.29	127.75
S42	124	4	12.12	114.90	398	6	13.06	121.26
S43	109	5	12.11	122.50	372	7	13.32	128.67
S44	112	4	11.89	115.30	386	6	13.02	120.58
S45	117	4	12.21	122.10	389	7	13.59	129.69
S46	119	4	12.01	113.60	385	6	12.99	119.30
S47	126	3	11.89	111.50	406	6	12.92	118.42
S48	125	3	11.56	115.90	410	6	12.97	125.25
S49	100	5	12.21	121.90	352	7	13.44	129.32
S50	98	5	12.32	124.10	361	7	13.41	130.41

Table 9. Continued

Seedling number	Number of days for germination	Number of leaves at 9 months age	Collar girth at 9 months age(cm)	Height of seedling at 9 months age(cm)	Number of days for splitting of leaflets	Number of leaves at 12 months age	Collar girth at 12 months age(cm)	Height of seedling at 12 months age(cm)
S51	112	4	12.11	118.10	379	7	13.29	128.32
S52	110	4	12.21	117.60	381	6	13.04	123.23
S53	112	4	11.69	118.30	389	6	13.01	123.72
S54	117	4	11.99	121.60	395	7	13.27	129.81
S55	119	3	11.96	114.20	397	6	13.11	119.95
S56	98	5	13.21	128.40	361	8	14.05	135.23
S57	98	4	12.95	119.90	351	7	13.72	127.92
S58	99	5	13.21	128.60	365	8	14.04	136.41
S59	102	4	12.86	124.00	369	7	13.66	131.52
S60	117	4	12.25	122.90	385	7	13.69	130.57
S61	118	4	11.95	115.90	389	6	13.12	121.32
S62	112	4	12.32	121.50	381	7	13.55	129.61
S63	102	5	13.01	128.40	375	8	14.20	136.53
S64	104	5	12.56	120.90	380	7	13.69	130.42
S65	99	4	11.85	111.00	362	6	13.09	121.32
S66	112	4	12.51	125.30	382	7	13.77	132.1
S67	109	4	12.11	121.50	383	7	13.69	128.3
S68	102	5	13.26	129.60	381	8	14.30	137.2
S69	112	4	12.32	118.20	389	7	13.71	129.5
S70	100	5	13.20	4.00	362	8	14.20	135.3
S71	98	5	13.32	125.90	361	8	14.10	133.5
S72	117	4	12.32	119.90	391	7	13.62	129.7
S73	99	4	11.95	112.30	370	6	13.12	121.5
S74	122	3	12.11	110.20	401	6	13.13	119.2
S75	98	4	12.36	118.70	362	7	13.59	128.75

Table 9. Continued

Seedling number	Number of days for germination	Number of leaves at 9 months age	Collar girth at 9 months age(cm)	Height of seedling at 9 months age(cm)	Number of days for splitting of leaflets	Number of leaves at 12 months age	Collar girth at 12 months age(cm)	Height of seedling at 12 months age(cm)
S76	100	5	12.74	128.40	369	8	13.92	136.20
S77	122	3	12.01	112.30	399	6	12.99	121.70
S78	131	3	12.52	119.90	409	7	13.52	129.30
S79	102	4	11.97	111.00	379	6	12.97	119.80
S80	101	4	12.44	120.90	375	7	13.52	129.50
S81	112	4	12.11	125.30	389	7	13.62	131.30
S82	114	4	12.56	119.90	390	7	13.69	130.70
S83	115	4	12.23	120.30	392	7	13.71	128.40
S84	119	4	12.32	118.40	390	7	13.49	126.30
S85	102	5	13.01	125.60	392	8	13.99	133.50
S86	101	5	12.21	116.90	372	7	13.52	125.90
S87	100	5	12.89	126.30	370	8	13.98	132.90
S88	98	5	12.65	129.00	361	7	13.71	139.10
S89	126	3	11.99	109.80	391	6	13.09	118.30
S90	121	4	12.36	119.50	389	7	13.56	126.90
S91	132	3	11.56	110.90	405	6	12.96	119.20
S92	109	4	12.42	120.90	380	7	13.47	128.30
S93	119	4	12.54	119.30	392	7	13.63	127.90
S94	102	5	13.21	128.30	383	8	14.00	135.20
S95	104	5	12.62	124.60	385	7	13.69	131.20
S96	100	5	12.32	126.90	375	8	13.89	134.90
S97	98	4	12.26	123.10	369	7	13.63	130.10
S98	121	4	12.11	114.20	392	6	13.06	123.20
S99	122	4	12.76	121.90	392	7	13.81	130.30
S100	99	5	13.20	128.30	369	8	14.30	134.70

Table 10. Patterns of variability of 100 Komdan coconut seedling characters

characters	Mean	SD	Minimum	Maximum	Range	CV
Number of days for germination	112.70	11.30	97.00	134.00	37.00	10.00
Number of leaves at 9 months age	4.10	0.70	3.00	5.00	2.00	17.30
Collar girth at 9 months age(cm)	12.30	0.47	11.23	13.32	2.09	3.80
Height of seedling at 9 months age(cm)	119.40	5.92	102.20	129.60	27.40	4.96
Number of days for splitting of leaflets	383.60	13.44	350.00	429.00	89.00	3.50
Number of leaves at 12 months age	6.80	0.73	5.00	8.00	3.00	10.70
Collar girth at 12 months age(cm)	13.40	0.43	12.27	14.30	2.03	3.18
Height of seedling at 12 months age(cm)	126.90	5.83	110.40	139.10	28.70	4.60

SD-Standard Deviation: CV-Coefficient of Variation

Plate 9. General view of Komadan seedling nursery

Plate 10. General view of Komadan seedling nursery at nine months age

Plate 11. General view of Komadan seedling nursery at twelve months age

Plate 12. The highest and the lowest height variation at 12 months age seedlings

Plate 13. Early splitting of leaflet in Komadan seedling

In seedlings, number of days for germination was significantly and negatively correlated with number of leaves at nine months age (-0.767), collar girth at nine months age (-0.606), height of seedling at nine months age (-0.565), number of leaves at 12 months age (-0.633), collar girth at 12 months age (-0.618) and height of seedling at 12 months age (-0.597). It was highly significant and positive correlated with number of days for splitting of leaflets (0.871).

Interrelationship of number of leaves at nine months old was significantly and positively correlated with collar girth at nine months age (0.668) and 12 months age (0.682), height of seedling at nine months age (0.761) and 12 months age (0.767). It was noted negatively correlated with number of days for splitting of leaflets (-0.600).

Collar girth at nine months age was found significantly and positively correlated with height of seedling at nine months age (0.737) and 12 months age (0.743), number of leaves at 12 months age (0.802) and collar girth at 12 months age (0.916). It had highly significant and negative correlation with number of days for splitting of leaflets (-0.480).

Strong positive correlation of height of seedling at nine months age was obtained with number of leaves at 12 months age (0.891), collar girth at 12 months age (0.799) and height of seedling at 12 months age (0.961). It was found negatively correlated with number of days for splitting of leaflets (-0.418).

Number of day for splitting of leaflets was obtained highly significant and negative correlation with all other characters (number of leaves at 12 months age (-0.492), collar girth at 12 months age (-0.478) and height of seedling at 12 months age (-0.442)).

Number of leaves at 12 months age had highly significant and positive correlation with collar girth at 12 months age (0.882) and height of seedling at 12 months age (0.930). The collar girth at 12 months age was found to have strong positive correlation with height of seedling at 12 months age (0.829).

Table 11. Correlation studies on Komadan seedling characters

Characters	X1	X2	X3	X4	X5	X6	X7	X8
Number of days for germination (X1)	1.000							
Number of leaves at 9 months age (X2)	-0.767**	1.000						
Collar girth at 9 months age (X3)	-0.606**	0.668**	1.000					
Height of seedling at 9 months age (X4)	-0.565**	0.761**	0.737**	1.000				
Number of days for splitting of leaflets (X5)	0.871**	-0.600**	-0.480**	-0.418**	1.000			
Number of leaves at 12 months age (X6)	-0.633**	0.777**	0.802**	0.891**	-0.492**	1.000		
Collar girth at 12 months age (X7)	-0.618**	0.682**	0.916**	0.799**	-0.478**	0.882**	1.000	
Height of seedling at 12 months age (X8)	-0.597**	0.767**	0.743**	0.961**	-0.442**	0.930**	0.829**	1.000

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

Discussion

5. DISCUSSION

In any crop improvement programme an assessment of the nature and extent of variability will be of immense value in identifying superior genotypes and formulating breeding procedure. The evolution in cultivated crop species have revealed that heritable variations occurred both before and after the beginning of cultivation. Natural hybrids occurred when such variants were grown side by side and greater number of variants resulted on which the farmers applied further selection (Allard, 1960). This basic principle of crop evolution is applicable to coconut cultivation also. Whether the Komadan palms exhibit any variability among themselves was the basic question which led to the present study. Accordingly 50 Komadan palms and 100 Komadan seedlings were analysed for intra-varietal variability. The analysis of variability or genetic diversity in coconut has been assessed by using morphological traits (Meunier *et al.* 1992). The palm and seedling morphological traits were subjected to statistical analysis. The results obtained are discussed in the following section.

5.1 EXPERIMENT I

5.1.1 Variability for the Morphological Traits of Fifty Komadan Coconut Palms

Komadan is a robust palm, with tall slender and thick stem and massive crown with large number of leaves bearing bunches of nuts in its axis. Variability existed among Komadan palms for morphological traits. Twenty six quantitative traits and two qualitative traits were used to find the intra-varietal variability under study.

5.1.1.1 Variability among Quantitative Traits

There was remarkable difference among the palms for number of leaves per year with a range of 11 to 15. Similar findings were reported by Ramadasan and Mathew (2003). Increase in number of leaves is to serve advantageously in assessing the future yields similar results were reported by Liyanage (1966).

The average length of leaves of individual showed a considerable amount of variation among palm ranging between 2.30 m and 5.46 m and number of leaflets per leaf also showed a considerable variation. It ranged between 160 and 240. The girth of trunk and length of peduncle showed an impressive variation among the palms. These variation leads to change in yield of palms. This result is in conformity with findings of Patel (1938). He reveals that leaf area and leaf dry matter production are important parameters regulating the production potential of coconut palm. Komdan ecotype maintained high dry matter production, high partitioning of dry matter towards yield, thus maintaining higher yield stability. So these ecotypes could be utilized as mother palms in the seedling production programme (Manju, 1992).

A high rate of spadices per year production has been observed in regular bearers of Komadan. (Satyabalan *et al.* 1968). The present study showed that the number of spadices per year ranged from 11 to 15. Number of spikelets per spadix ranged from 21 to 63. This character highly significantly varied among the ecotypes (Ouvrier and Ochs, 1980).

The impressive variability was observed in average female flowers per inflorescence. It ranged between 3 and 123 and the average number of female flowers per spikelets was observed (1). It was varied from 3.32 to 0.11. The number of female flowers varied with the season and the season had no effects on the average nut production per bunch (Vanaja and Amma, 2002). Peries (1934) and Liyanage (1962, 91) suggested this character as reliable and important for mother palm selection. The first generation Komadan had more numbers of female flowers which varies between 20-40 as reported by Ohler (1999) who suggested that the great variability noticed in this characters, which apart from being genetically controlled, is also strongly influenced by growing condition. Marar and Pandalai (1957) observed yield as a function of number of female flowers production and setting percentage, factors affecting any one of these characteristics will influence the final yield. The present study revealed that the 50 Komadan palms having average setting percentage 34.9. The female flower getting more fertilized during the dry months of July was 4-5 months old when the palm receives more rain (Davis and Gosh, 1982).

Annual nut yield per tree is one of the most important criteria for mother palm selection (Smith, 1933). In present study fifty Komadan palms were found to have a number of nuts per palm per year ranged between 25 and 154. The average nuts per palm per year was observed (88.7). This is in agreement with the findings of Gopimony (1982) where more than 99 percentage of Komadan palms gave more than 80 nuts per tree per year. This character is controlled by additive genetic variation (Nambiar and Nambiar, 1970) and that non-additive gene action was low and selection practised for this character might be indirectly based on component characters (Ohler, 1999).

There was considerable variability observed in nut polar length with range of 16.5 cm to 28.9 and nut equatorial length ranging between 9.2 cm to 16.9 cm. The weight of nut ranged of 0.54 kg to 1.38 kg with mean value of 0.9 kg. This is in conformity with the findings of Manju, 1992. The weight of husked nuts per year ranged from 9.8 kg to 121.81 kg. Variability in equatorial diameter of nut has been reported by Foale (1987). Higher equatorial length of nut is reported to be an indication of high copra content (Balakrishnan and Vijayakumar, 1988). This prediction has been proved in the present study also as Komadan palms which has the high equatorial length and polar length showed high copra content. It ranged between 79 g and 216 g. Bourdeix (1988) stated that copra content per nut was a high heritable character.

The weight of husked nuts varied from 239 g to 812 g and average husk thickness was 2.7 cm. The husk: nut ratio ranged between 0.12 to 0.701 and the average endosperm thickness was 12.1 mm. This is in agreement with the findings of Manju (1992). It also revealed that high heritability and genetic advance was noticed in husk: nut ratio and weight of husked nut, which indicated the predominance of additive gene effect.

The copra content per nut varied from 79 g to 216 g. This is in agreement with the findings of Thampan (2000). Weight of copra per year of the 50 Komadan palms ranged between 3.48 kg and 28 kg.

The highest number of nuts per bunch observed in 50 Komadan palms was 17. It was because of size of nuts. The nuts equatorial size was more than that of polar length so as to accommodate more number of nuts in a single bunch. The same view was reported by Bourdeix *et al.* (1991) and it was revealed that number of nuts per bunch was the most variable character.

The oil content per nut ranged between 52.6 per cent and 65.8 per cent. This is in agreement with the findings of Louis and Ramachandran (1981). It was also reported that the oil content in tall varieties was higher than that in the hybrids. The present study revealed the average oil per cent of 50 Komadan palms 61.1. This is lower than the other coconut ecotypes (Anonymous, 1986).

The maximum coefficient of variation was found in number of female flowers per inflorescence (71.32). This trait indicated the highest range of variation among 50 Komadan palms. Characters with high variability are expected to provide high level of gene transfer during breeding programs (Guei *et al.* 2005).

5.1.1.2 Variability among Qualitative Traits

5.1.1.2.1 Colour of the Midrib

It is seen that about 88 per cent of the palms in 50 Komadan palms exhibited olive shade for the midrib while only 12 per cent of the palms showed variation in this character.

5.1.1.2.2 Colour of the Tender Coconut

The 50 palms had different shades of brown and olive. The 40 per cent of palms had two different shades of brown colour viz., brownish orange and moderate olive brown. Lamothe and Rognon (1977) have called these 'brown' while Harries (1976) mentioned it as 'bronze'. Bronze colour was reported to be the product of hybridization between green and red or orange palms homozygous for these colours

(Lamothe and Rognon, 1977). The remaining 60 per cent of palms had different shades of olive colour which may be the result of segregation of genes for tender coconut colour.

5.1.2 Correlation Studies on Palms Characters

Correlation provides information on the nature and extent of relationship among the various characters. The simple correlation in the present study serves the purpose of orientation rather than prediction (Table 5). In 50 Komadan coconut palms, all the characters except weight of nuts and thickness of husk showed significant positive correlation with nut yield. Similar correlations were observed in coconut by Nampoothiri *et al.* (1975) and Sukumaran *et al.* (1981). The correlation noticed in palms imply a higher setting percentage of female flowers which leads to more number of nuts per bunch and ultimately the yield. Similar results were reported by Manju (1992). The present study revealed that number of leaves per year had significant and positive correlation with number of nuts per year, weight of nuts per year, weight of husked nuts per year and weight of copra per year contradictory to this, Manju (1992) reported that number of leaves per palm did not have significant correlation with yield.

The correlation of number of leaves per year with number of bunches was significant and positive. This is in agreement with the findings of Manju (1992) and Mathew and Gopimony (1991). This correlation revealed that almost every leaf axil has a bunch in it and when the number of leaves are more in a palm there will be a corresponding increase in number of bunches also which ultimately leads to increase in nut yield (Nambiar and Govindan, 1989; Balakishnan *et al.*, 1991; Narayanankutty and Gopalakirishnan, 1991; Manju, 1992). Significant positive correlation was noticed for number of bunches per year with number of nuts per bunch, number of number of female flowers per bunch, number of nuts per palm per year, weight of nuts per year, weight of husked nuts per year and weight of copra per year. This is in conformity with the findings of Nampoothiri *et al.* (1975), Kalathiya and Sen (1991) and Manju (1992).

Nut polar length and nut polar circumference were positively correlated with weight of nuts, weight of husked nut, weight of nuts per year and weight of husked nuts per year. However, these showed negative correlation with number of nuts per palm per year. Similar results were reported by Geethanjali *et al.* (2014). The copra content per nut and copra content per year were positively correlated with endosperm thickness. Similar correlations were observed in coconut by Kasturi (1993).

Oil content was found to be either uncorrelated or negatively correlated with majority of seednut characters. Thickness of husk, weight of husked nut, weight of nuts per year and weight of copra per year showed very high positive correlation among themselves. Similar correlation among characters were reported earlier by Mathew (1983) and Manju (1992). Sindhumole and Ibrahim (2000) reported that oil content of coconut was mostly affected by indirect effect through other characters. (Manju *et al.* 1992).

Length of leaf and length of peduncle were negatively correlated with weight of nuts, weight of husked nuts, weight of nuts per year and weight of husked nuts per year; but length of peduncle had positive correlation with weight of copra per year. This is contradictory the findings of Natarajan *et al.* (2010) and Namboothiri *et al.* (2007). Sindhumole and Ibrahim (2001) reported that nut yield was significantly correlated with vegetative and reproductive characters. In this study also yield had significant positive correlation with both vegetative and reproductive characters included in the study.

5.1.3 Generalised Linear Model for Number of Nuts per Palm per Year

Palms which were included in the category of high number of leaves per year showed the more number of nuts per palm per year. They were significantly superior to medium and low number of leaf per year. Palms with low and medium leaf per year were on par with each other (Table 6). This is in agreement with the findings of Liyanage (1964). Length of leaves, number of leaflets per leaf, girth of trunk and length of peduncle did not show any significant difference among all categories.

5.1.4 Principle Component Analysis

The principal component analysis is a technique which identifies palm quantitative characters that contribute most of the observed variations within 50 Komadan coconut palms. In this study, the criterion used by Clifford and Stephenson (1975) and corroborated by Guei *et al.* (2005), was followed which suggested that the first three principal components are often the most important in reflecting the variation patterns among palms, and the characters associated with these are more useful in differentiating palms. According to this criterion first four principle components with Eigen value of greater than 0.79 contributed about 92.08 per cent of the total variability in 50 palms (Fig 4) involving 12 quantitative traits. The cumulative variance of 96.4 per cent (Fig 5) by the first five PC axes with Eigen value of > 0.52 indicates that the identified traits within the axes exhibited great influence on variation within the palms (Table 7). However, the criterion of Raji (2002) was chosen to determine the cut off limit for the coefficients of the proper vectors in the present study. This criterion treated coefficients greater than 0.3, as having a large effect enough to be considered as important, while traits having a coefficient less than 0.3 were considered not to have important effects on the overall variation observed (Table 8).

The distribution of palms based on first and second principal components (Fig 6), second and third principal components (Fig 7), first and third principal components (Fig 8) and first, second and third principal components (Fig 9) exhibited the phenotypic variation among the 50 palms and explains how they are widely dispersed along both the axes with respect to value of coefficient of the vectors. On scattered plots, closely related palms were located adjacent to each other. On the other hand diverse palms were located at different places on the plot. The first principle component contributed for 50.22 per cent of total variation, where by weight of nuts per year, number of nuts per palm per year, weight of

Fig 4. Eigen value and 12 principle components on plot

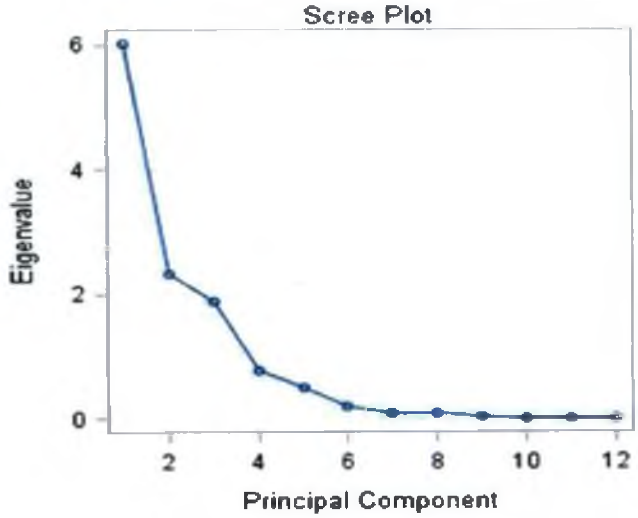


Fig 5. Variance and its cumulative proportion with 12 principle components on plot

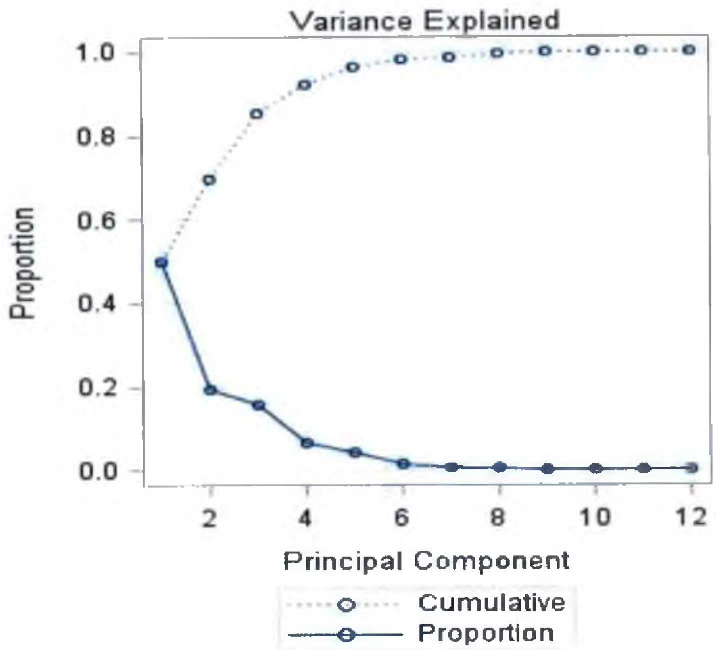


Fig 6. Scatter plot of the 50 Komadan coconut palms based on measured traits of principle component I and II

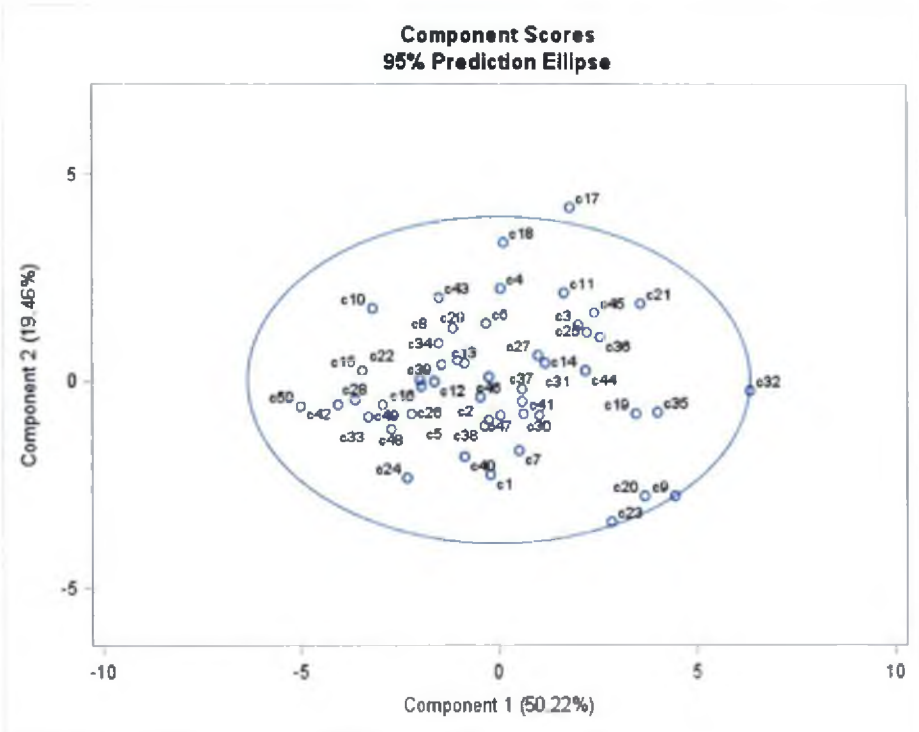


Fig 7. Scatter plot of the 50 Komadan coconut palms based on measured traits of principle component II and III

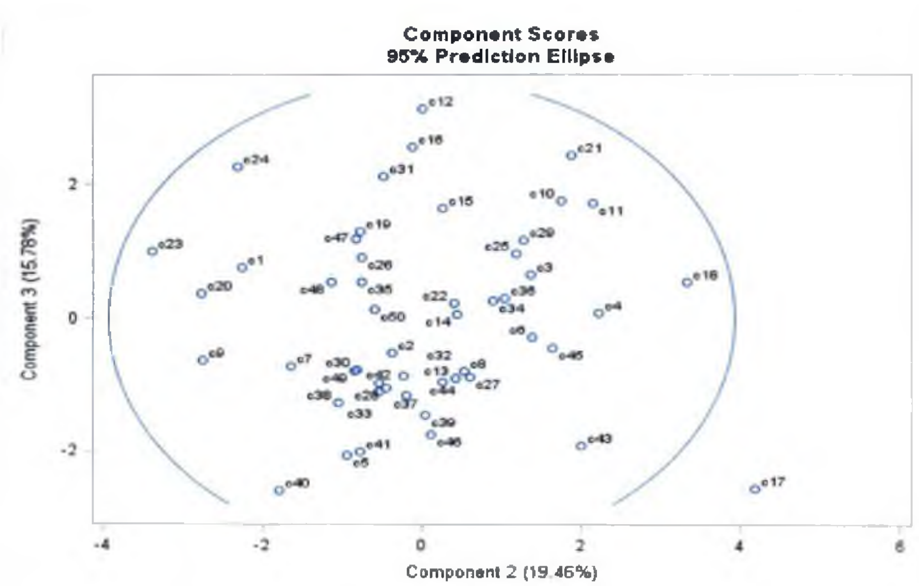


Fig 8. Scatter plot of the 50 Komadan coconut palms based on measured traits of principle component I and III

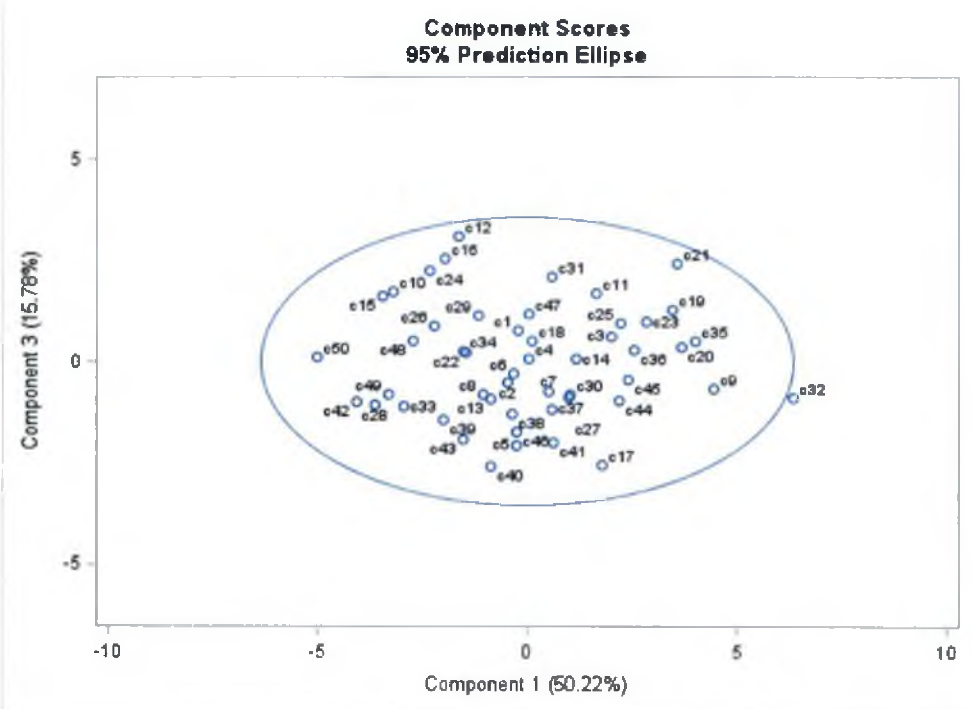
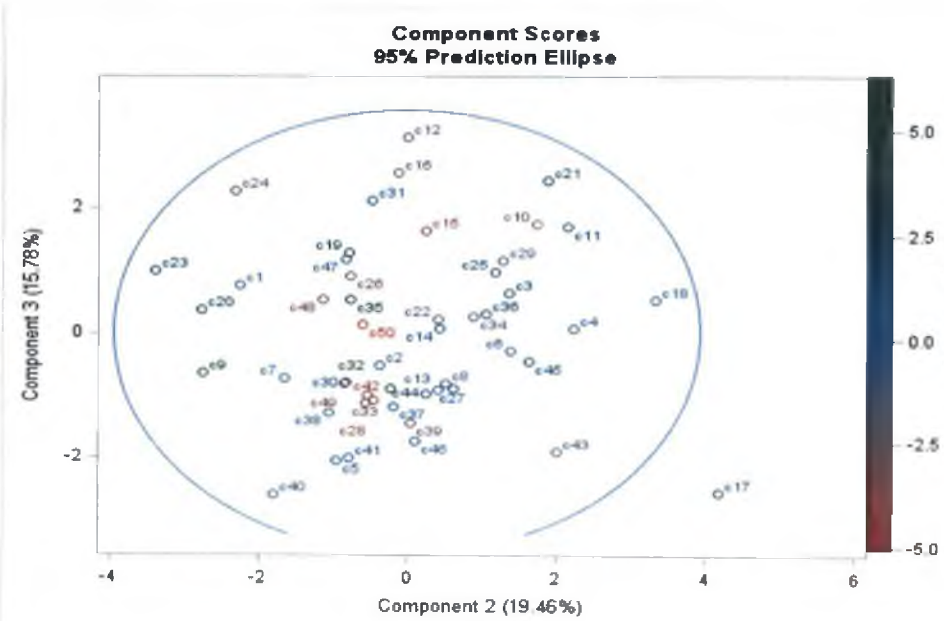


Fig 9. Scatter plot of the 50 Komadan coconut palms based on measured traits of principle component I, II and III



husked nuts per year, number of nuts per bunch, number of leaves per year, number of spadices per year and weight of nuts were positively contributed.

The second principal component accounted 19.46 per cent of the total variability. The variable contributing most positively were copra content per nut, endosperm thickness and weight of copra per year. The third principle component contributed for 15.78 per cent of the total variation, in which the variables are number of leaves per year, number of spadices per year, endosperm thickness and copra content per nut. The fourth principle component accounted 6.62 of variation in the total variability by length of peduncle and weight of nuts. Thus, the prominent characters are coming together in different principal components and contributing towards variability and have the tendency to remain together. This may be kept into consideration during utilization of these characters in breeding programmes.

The phenotypic value of each trait measures the importance and contribution of each component to the total variance, whereas each coefficient of proper vectors indicates the degree of contribution of every original variable with which each principal component is associated. The first four components accounted for 92.08 per cent of the total variation. Characters with high variability are expected to provide high level of gene transfer during breeding programmes (Zizumbo *et al.* 2006).

5.2 EXPERIMENT II

5.2.1 Patterns of Variability for Eight Quantitative Characters

The 100 Komadan seedlings showed considerable amount of variation in eight morphological characters (Table 9).

In the present study, the Komadan seedlings have shown remarkable amount of variation in number of days for germination and ranged between 97 days and 134 days. Similar observation was reported by Anilkumar and Pillai (1989). High copra content was found to have an advantage over seedling sprouting (Charles, 1968). Early germination of seednuts in coconut was associated with early bearing and increased nut yield (Harries, 1960).

The effectiveness of selection based on seedling characters for genetic improvement of coconut was reported by Fremod *et al.* (1966), Silva and George (1970) and Manju (1992). In present study, characters such as number of days for splitting of leaflets, height, number of leaves and collar girth were observed both at nine and twelve months old. The observations at nine months were done based on the reported efficiency of early selection by Satyabalan and Mathew (1977). The salient features of these results (Table 10) are discussed below.

The number of leaves at nine months age varied from 3 to 5 and twelve months age showed a range between 5 and 8. Mathes *et al.* (1989) have reported the importance of total number of leaves as the character which determines the total biological productivity through photosynthesis.

The collar girth at nine months age ranged from 11.23 cm to 13.32 cm and at twelve months age it varied between 12.27 cm and 14.3 cm. Maximum collar girth was obtained from over ripe nuts with large size (Silva and George, 1970). Menon and Pandalai (1958) revealed that girth at collar was the most important character for selection. The height of seedling showed considerable variation at nine (102.2 cm to 129.6 cm) and twelve months age (110.4 cm to 139.1 cm). The number of days for splitting of leaflets of 100 seedlings ranged from 350 days to 429 days. Menon and Pandalai (1958) reported that early splitting of leaves was a sign of precocity since the seedlings which commenced to produce leaves that tend to split into leaflets, when the seedlings had eight to ten leaves showed early flowering.

The usefulness of selecting seedlings based on height, leaf number, collar girth and early splitting of leaves for the genetic upgrading of coconuts has been emphasised by many workers like Menon and Pandalai (1958), Marar (1960), Srinivasa and Ramu (1971), Mathew *et al.* (1984) and Manju (1992). The Komadan mother palms which produce a minimum of 65 per cent quality seedlings are prepotent ones. In the present study of Komadan seedlings, the coefficient of variation was the lowest for height, collar girth and number of days for splitting of leaflets. Similar findings were reported by Manju (1992) and it was revealed that heritability and genetic advance were high for number of days for germination indicating the predominance of additive genes, while number of days for splitting of leaflets in Komadan seedling to have the low heritability and high genetic advance. This shows that the effect of environment is comparatively less on number of days for germination and that selection on the basis of this character in Komadan will result in seedling with better height, girth and number of leaves.

5.2.2 Correlation Studies on Seedling Characters

A perusal of Table 11 showed that number of days for germination had significant negative correlation at phenotypic level with most of the seedling characters in 100 Komadan seedlings indicating that early germinating seednuts produced taller seedlings with more number of leaves and increased girth at collar. This is in conformity with the findings of Valsala and Kannan (1990). The nuts which germinated early produced seedlings where splitting of leaflets occurred earlier. Hence, number of days for germination had significant and positive correlation with number of days for splitting of leaflets. Similar correlations were observed by Srinivasa and Ramu (1971).

The height of seedlings (nine and twelve months age), number of leaves (nine and twelve months age), collar girth (nine and twelve months age) were found to be significantly and positively correlated among themselves. Similar correlation was reported by Pankajakshan and George (1961), Sreerangasamy and Sridharan (1991) and Manju (1992). Collar girth (nine and twelve months age) which is an important criterion in seedling selection was found to be positively correlated with all other characters indicating its relevance in seedling selection. This is in conformity with the results of Valsala and Kannan (1990) and Manju (1992). Satyabalan and Mathew (1977) revealed that it was possible to identify palms of superior genetic value based on collar girth and leaf production of progenies from the fifth month after germination.

In the present research programme, seedling characters maintained their identity in the recovery of quality seedlings which in turn reflects on the prepotent nature of the mother palm. This fact very important from the farmer's point of view, since quality seedlings are being recommended for cultivation to increase productivity in Komadan coconut. However, regarding Komadan palms, the yield related economically important parameters like weight of nuts per year, number of nuts per palm per year, weight of husked nuts per year, number of nuts per bunch, number of leaves per year, number of spadices per year, weight of nuts, endosperm thickness, weight of copra per year, number of spadices per year, and copra content per nut were expressed towards intra-varietal variability in Komadan palms. This variation will provide opportunities to the breeder for utilization, conservation and further genetic improvement by selection of palms with promising yield related characters.

Summary

6. SUMMARY

The present project entitled "Intra-varietal variability in Komadan coconut (*Cocos nucifera* L.) palms" was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram during 2014-2016 with an objective to assess the intra-varietal variability in Komadan coconut palms for yield and other attributes. The study was carried out and data collected were from the two field experiments.

Fifty Komadan palms in the Instructional Farm, Vellayani were utilized as the materials for the study in the experiment I. Observations were recorded on 28 characters viz., number of leaves per year, length of leaves, number of leaflets per leaf, girth of trunk, number of spadices per year, number of female flower per inflorescence, number of female flower per spikelet, setting percentage, number of spikelets per spadix, length of peduncle, number of nuts per palm per year, nut polar length, nut polar circumference, nut equatorial length, nut equatorial circumference, weight of nuts, weight of husked nuts, thickness of husk, husk : nut ratio, endosperm thickness, colour of the midrib, colour of the tender coconut, number of nuts per bunch, copra content per nut and oil content per nut.

The important findings from the experiment I are summarized below.

The highest number of leaves and spadices per year were observed in palms C9, C19, C20, C21, C23, C31, C32, and C35. The maximum number of nuts per bunch, weight of copra per year, length of leaf and number of leaflets per leaf as well as the lowest thickness of husk and husk: nut ratio were recorded in palm C17. The maximum number of nus per palm per year, weight of nuts per year and weight of husked nuts per year were noticed in C32.The highest girth of trunk and length of peduncle were observed in palm C43. The maximum number of female flowers per inflorescence and number of female flowers per spikelet were recorded in palm C40. The highest weight of husked nut and nut equatorial circumference were observed in palm C19. The maximum copra content per nut and endosperm thickness were found in palm C18. The maximum coefficient of variation was recorded for number of female flowers per inflorescence. The colour of midrib was found in four different shades from moderate olive green to moderate brown and colour of tender coconut fell into five different groups from brownish orange to greyish olive green.

High positive correlation was recorded for number of nuts per palm per year, with number of leaves per year, number of spadices per year, number of female flowers per inflorescence, number of female flowers per spikelet and number of spikelets per spadix. Nut polar length and nut polar circumference were highly and positively correlated with weight of nuts, weight of husked nut, weight of nuts per year and weight of husked nuts per year.

The principle component analysis revealed that the first four components with Eigen value greater than 0.79, contributed about 92.08 per cent of the total variability. The characters such as weight of nuts per year, number of nuts per palm per year, weight of husked nuts per year, number of nuts per bunch, weight of nut, copra content per nut and weight of copra per year were the most important ones contributing to the overall variability. Thus, the prominent characters coming together in different principal components are contributing towards explaining the variability have the tendency to remain together. This may be kept into consideration during utilization of these characters in breeding programmes.

In experiment II, seedling variability among the 100 Komadan seedlings raised in the coconut nursery of Instructional Farm, Vellayani was studied.

The Komadan seedlings recorded considerable amount of variation in eight morphological characters viz., number of days for germination, number of leaves at nine months age, collar girth at nine months age, height of seedling at nine months age, number of days for splitting of leaflets, number of leaves at 12 months age, collar girth at 12 months age and height of seedling at 12 months age.

The seedling S71 showed the maximum values for collar girth at nine months age, number of leaves at nine and twelve months age. The seedling S68 had maximum height and collar girth at nine months age and number of leaves at nine and twelve months age. The seedling S100 was found to have the highest collar girth at twelve months age, number of leaves at nine months and twelve months age. The early splitting of leaves was observed in seedling S4. The maximum coefficient of variation was recorded for number of leaves at twelve months age.

Highly significant correlation was noticed among the eight morphological characters. Number of days for germination was positively correlated with number of days for splitting of leaflets and height of seedlings was positively correlated with collar girth. Number of days for splitting was negatively correlated with collar girth, number of leaves and height of seedlings. The number of leaves was positively correlated with height of seedlings and collar girth. In the present research programme, the yield related phenotypic variation of Komadan palms provides opportunities to the breeder for utilization, conservation and future genetic improvement by selection of palms with promising yield related characters.

References

7. REFERENCES

Adkins, S., Foale, M. and Harries, H. 2010. *Growth and production of coconut. In: Verheye WH, ed. Soils, plant growth and crop production*. In: Encyclopedia of Life Support Systems (EOLSS), Eolss Publishers, developed under the auspices of UNESCO, Oxford, UK. 56p.

Alexander, D. F., Silvela, L. S., Collins, F. and Land, R. C. 2001. Analysis of oil content of maize by wide-line NMR. *J. Am. Oil Chem. Soc.* 44: 555-562.

Allard, R. W. 1960. *Principle of plant Breeding.* Wiley International, New York, 79p.

Anilkumar, A. S. and Pillai, S. J. 1989. Nursery observations on the production of WCT and Komadan quality coconut seedling. *Indian Coconut. J.* 20 (2): 8-11.

Anonymous. 1986. Indian Standard Methods of sampling and test for oils and fats. Part-1 Sampling, Physical & Chemical tests (Rev.), 56p.

Arunachalam, V., Jerard, B. A., Damodaran, V., Ratnamball, M. J. and Kumaranl, P. M. 2005. Phenotypic diversity of foliar traits in coconut germplasm. *Genet. Resour. Crop Evol.* 52: 1031-1037.

Ashburner, G. R., Tompson, W. K., Halloran, G. M. and Foale, M. A. 2000. Fruit component analysis of South Pacific coconut palm populations. *Genet. Resour. Crop Evol.* 44: 327–336.

Balachandran, C. and Arumughan, C. 2000. Biochemical and cytochemical transformations in germinating coconut (*Cocos nucifera* Linn.). *J. of the Am. Oil Chem. Soc.* 72: 1385–1391.

Balakrishna, P. C. and Vijayakumar, N. K. 1988. Performance of Indigenous and Exotic cultivars of coconut in the Northern Region of Kerala. *Indian Coconut. J.* 19 (1): 3-7.

Balakrishnan, P. C. and Namboodiri, K. M. N. 1987. Genetic divergence in coconut. *Indian Coconut. J.* 18 (7):13-19.

Balakrishnan, P. C., Devadas, V. S. and Unnithan, V. K. G. 1991. Phenotypic stability of coconut (*Cocos nucifera* L.) cultivars for annual yield of nuts. *Coconut breeding and management. Proceedings of the National Symposium on coconut breeding and management* held at the Kerala Agricultural University, Thrissur, India from 23rd to 26th November 1988: 55-59.

Bourdeix, R. 1988. Effectiveness of mass selection based on yield components in coconut. *Oleagineux.* 43 (7): 291-295.

Bourdeix, R. 2005. *Coconut. A guide to traditional and improved varieties.* (12th Ed.). Diversiflora, Montpellier, pp. 221-228.

Bourdeix, R., Meunier, J. and N'Cho, Y. P. 1991. Coconut (*Cocos nucifera* L.) selection strategy II – Improvement of Tall x Tall hybrids. *Oleagineux.* 46 (7):267-281.

Charles, A. E. 1959. Nursery selection of coconut seedlings. *Pap. Newgui. Agri. J.* 12: 119-121.

Charles, A. E. 1968. Report on coconut establishment trials in New Guinea. *Paper Third session, FAO Technical Working Party on Coconut Production, Protection and Processing*. Kingston, Jamaica, 558p.

Chattopadhyay, N. and Hore, J. K. 2012. Influence of nut weight and method of planting on germination and seedling growth of coconut. *J. of Crop and Weed.* 8(1): 98-100.

Clifford, H. T. and Stephenson, W. 1975. *An Introduction to Numerical Classification*. Academic Press, London, pp. 229.

Cook, O. F. 1910. History of the coconut palm in America. *Contr. U.S. natn. Herb.* 14 (2): 271-342.

Corley, R. H. V. 2001. Potential productivity of tropical perennial crops. *Exp. Agric.* 19: 217-237.

Corner, E. J. H. 1966. *The natural history of palms*. University of California press, Berkeley, California, 122p.

Daniel, Z. and Daniel, P. E. 2000. Pattern of Morphological Variation and Diversity of *Cocos Nucifera* (Arecaceae) In Mexico. *Am. J. of Bot.* 85(6): 855–865.

Dash, D. K., Mahanama, T., Sahoo, S. C. and Dash, J. N. 1995. Local and exotic coconut cultivars in Orissa. Coconut in Orissa - Advances in cultivars. *Indian Coconut J.* 6(3) 95-106.

Davis, T. A. and Anandan, A. P. 1957. The first root of the coconut. *Indian Coconut. J.* 10 (2): 9-14.

Davis, T. A. and Gosh, S. S. 1982. Effect of rainfall on production of coconut. *Indian Coconut. J.* 13 (5): 3-7.

Donald, C. M. and Hamblian, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron.* 28: 261-405.

Dutta, A. C. 1974. *Botany for Degree students.* Oxford University press, Ely House, London, 63p.

Evgenidis, L., Daniel, V. B and Daniel, H. J. 2001. Correlation among yield characteristics in tomato. *Trop. Agric. j.* 46: 353-57.

Fernando, W. M., Pieris, T. and Wickramaratne, M. 1993. Variation in seedlings characters of three different coconut cultivars and their use in identification in the nursery. *Cocos.* 9: 23-29.

Foale, M. A. 1968. The growth of the young coconut palm (*Cocos nucifera* L.) II. The influence of nut size on seedling growth in three cultivars. *Aust. J. Agric. Res.* 19: 927-937.

Foale, M. A. 1987. Coconut germplasm in the South Pacific Islands. *ACIAR Tech. Rep. Ser*. 4 (1): 23-24.

Foale, M. A. 2004. Growth of the young coconut palm (*Cocos nucifera* L) 2. The influence of nut size on seedling growth in three cultivars. *Aust. J. of Agric. Res*. 19: 927–937.

Foale, M. A. and Ashburner, V. M. 2003. Independent origins of cultivated coconut (*Cocos nucifera* L.) in the Old World Tropics. *Adv. in coconut Res. and Dev*. 12: 56-59.

Fremond, Y., Ziller, R. and Lamothe, M. 1966. *Le cocotier*. Mai Sonneeuve and Lavoise press, Paris, 632p.

Friend, D. and Corley, R. H. V. 1994. Measuring coconut palm dry matter Production. *Exp. Agric*. 30: 223-235.

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. Plant. Crops*. 30 (2): 23-25.

Gangolly, S. R., Satyabalan, K. and Pandalai, K. M. 1957. Varieties of the coconut. *Indian Coconut. J*. 10 (4): 3-25.

Geethanjali, S., Rajkumar, D. and Shoba, N. 2014. Correlation and path coefficient analysis in coconut (*Cocos nucifera* L.). *Electr. J. of Plant Breed*. 5 (4): 702-707.

Gopimony, R. 1982. Coconut germplasm in the South Pacific Islands. *J. Plant. Crops*. 4: 23.

Gopimony, R. 1984. Preliminary observations on a local coconut type Komadan. *Proc. PIACROSYM V*, CPCRI, Kasargod, pp.177-179.

Green, A. H. and Foale, M. A. 1961. The improvement of the coconut palm production of the high islands of the Tropical Pacific. *Exp. Agric*. 5 (9): 65-69.

Guei, R. G., Sanni, K. A. and Fawole, A. F. J. 2005. Genetic diversity of rice (*Oryza sativa*, L.). *Agron. Afr.* 5: 17–28.

Guppy, H. B. 1906. *Observation of a naturalist in the Pacific between 1896 and 1899.* London, Macmillan, 112p.

Harland, S. C. 1957. *The improvement of the coconut palm by breeding and selection.* Bull press, Coconut Research Institute, Ceylon, 89p.

Harries H. C. 1960. *Malesian origin for a domestic Cocos nucifera.* In: The Plant Diversity of Malesia. Proceedings of the Flora Malesiana Symposium, (Baas, P., Kalkman, K. and Geesink, R. Ed.). Kluwer, Dordrecht, The Netherlands. pp. 351–357.

Harries, H. C. 1976. Coconut hybridisation by the policaps and Mascopol systems. *Principes*, 20 (4): 136-147.

Harries, H. C. 1978. The evolution, dissemination and classification of *Cocos nucifera* L. *Bot. Rev.* 44: 265–320.

Harries, H. C. 1990. Coconut varieties. *Indian Coconut. J.* 12 (11): 3-9.

Harries, H. C. 2000. The evolution, dissemination and classification of *Cocos nucifera* L. *The Bot. Revi.* 44: 265–319.

Heyerdhal, T. 1950. *The Kon-Tiki expedition. Londan*, Allen and Unwin.

Houman, H. 2011. Study of Some Morphological Traits of Corn Hybrids. *J. Agric. & Environ. Sci.* 10 (5): 810-813.

IBPGR, 1992. Descriptors for coconut. International Board for Plant Genetic Resources, Rome, 85p.

Jack, H. W. and Sands, W. N. 1929. Observation on the dwarf coconut palms in Malaya. *Malay. Agric. J.* 17: 140-170.

Jacob, M., Amaranath, C. H., Vijayakumar, K., Mohammed, Y. and Balakrishnan, T. K. 1988. Variations in the yield of coconuts as influenced by the pattern of rainfall and duration of dry spell. *Indian J. Hortc.* 5 (2): 48-55.

Jacob, O. P., Oluwakemi, A. B. and Olawole, O. 2016. Phenotypic Intraspecific Variability among some accessions of Drumstick (*Moringa Oleifera* Lam.). *Can. J. of Pure and Appl. Sci.* 10:3681-3693.

Jayalekshmy, V. G. and Rangasamy, S. R. 2002(a). Morphological variability in coconut cultivars. *Madras Agric. j.* 89 (1-3): 154.

Jayalekshmy, V. G. and Rangasamy, S. R. 2002(b). Cluster analysis in coconut (*Cocos nucifera*). *J. of plant. crops*. 30 (2): 18-22.

John, C. M. and Narayana, G. V. 1949. Varieties and forms of the coconut (*Cocos nucifera* L.). *Indian Coconut. J.* 2 (4): 209-226.

Kalathiya, K. V. and Sen, N. L. 1991. Correlation among floral and yield characteristics in coconut, variety Dwarf Green. *Coconut breeding and management. Proceedings of the National Symposium on coconut breeding and management* held at the Kerala Agricultural University, Trichur, India from 23rd to 26th November, 1988: 116-117.

Kasturi, B. K. V. 1993. Evaluation of coconut gemplasm for drought tolerance. Ph.D. Thesis, Mangalore University, Mangalore, India, 257p.

Kenman, E. T. 1973. Effect of seednut trimming on the germination and growth of coconuts. *Pap. NewGui. Agric. J.* 24 (1): 26-29.

Kumaran, P. M., Koshy, V., Arunachalam, V., Niral, V., and Parathasarathy, V. A. 2000. Biometric clustering of coconut populations of three Indian Ocean Islands. *Recent Adv. in Plant. Crops Res.* 34: 73-81.

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

Lamothe, M. and Rognon, F. 1977. Les cocotiers nains a Port-Bouet. 1 Nain, Jaune Ghana, Nain Rouge Malais, Nain Vert Guinee Equatoriale, Nain Rouge Cameroun. *Oleagineux*, 32 (11): 462-466.

Liyanage, D. V. 1955. Hedge planting for coconuts. *Ceylon Coconut. J.* 6 (2): 24-28.

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

Liyanage, D. V. 1964. Mass selection and progeny testing in coconut. *Ceylon Coconut Plant. Rev,* 4(4): 27-29.

Liyanage, D. V. 1966. Planting material for coconuts. *Ceylon Coconut Plant. Rev.* 4 (2): 27-29.

Liyanage, D. V. 1991. Coconut breeding in Sri Lanka. *Abstract of papers of International Symposium on coconut research and development-II* held during 26-29 November 1991 at CPCRI, Kasaragod, India: pp. 22-23.

Liyanage, D. V. and Abeywardena, V. 1957. Correlations between seednut, seedling and adult palm characters in coconut. *Trop. Agric. Ceylon.* 113: 325-340.

Liyanage, D. V. and Abeywardena, V. 1987. Correlation between seednuts, seedlings and adult palm characters in coconut. *Trop. Agric.* 113: 1- 16.

Liyanage, D. V. and Sakai, K. I. 1961. Heritability of certain yield characters of the coconut palm. *J. Genet.* 57: 245-252.

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

Louis, I. H. and Annanpan, R. S. 1985. Observation on the seedling vigour in relation to the size and shape of seednut in Tall Variety of coconut palm. *Indian Coconut. J.* 16: 5-11.

Louis, I. H. and Chopra, V. L. 1989. Selection Index in coconut palm. *The Pillippine J. of coconut Stud.* 14: 10-12.

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

Maceda, F. S. 1933. A study of coconut seedlings in relation to shape of the nuts. *Philipp. Agric.* 22: 430-431.

Manju, P and Gopimony, R. 1998. Genetic divergence in coconut types. *Proc. 10th Kerala Science Congress*, Thrissur, India, 45: 207-208.

Manju, P. 1992. Fruit component and seedling progeny analysis of Komadan coconut types. Ph.D. Thesis, Kerala Agricultural University, Thrissur, p.139.

Manju, P. and Gopimany, R. 2001. Variability and genetic parameters of mother palm characters in coconut palm. *J. of Trop. Agric.* 39: 159-161.

Manju, P., Gopimony, R. and Saraswathy, P. 1992. Evolutionary status of the coconut type Komadan. *Abstract of papers presented in Gregor Johan Mendel Birthday Lecture Series and Symposium International - 1992.* July 22-23. Dept. of Bot. University of Calicut, 34-35.

Mao, Z. and Lai, Y. 2000. The coconut germplasm of Hainan Island, China. *Plant Genet. Resour.* 91 (92): 53-57.

Marar, M. M. K. 1960. Setting up elite coconut seed farms. *Coconut. Bull.* 14 (1): 3-6.

Marar, M. M. K. and Pandalai, K. M. 1957. Influence of weather factors on the coconut crops. *Indian J. Meteorol. Geophys.* 8: 1- 1 1.

Marijana, T., Svetislav, P., Tihomir, C., Gordana, S., Ranko, G. and Vladimir, M. 2009. Evaluation of alfalfa germplasm collection by multivariate analysis based on phenotypic trait. *Romanian Agric. Res.*11:51-55.

Mathes, D. T., Liyanage, L. V. K. and Randeni, C. 1989. A method for determining leaf area of one, two and three year old coconut seedlings (var. CRIC 60). *Cocos*. 7: 21-25.

Mathew, T. 1983. Evaluation of super mother palms of coconut by seedling progeny analysis. M. Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, pp. 56-59.

Mathew, T. and Gopimony, R. 1991. Influence of seednut characters on seedling vigour in coconut. Coconut breeding and management. *Proceedings of the National Symposium on coconut breeding and management* held at the Kerala Agricultural University, Thrissur, India from 23rd to 26th November, 1988: 103-105.

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

Meerow, A. W., Wisser, R. J., Brown, J. S., Kuhn, D. N., Schnell, R. J. and Broschat T. K. 2003. Analysis of genetic diversity and population structure within Florida coconutgermplasm using microsatellite DNA with special emphasis on the Fiji Dwarf cultivar. *Theor. and appl. Genet*. 106: 715-726.

Menon, K. P. V. and Pandalai, K. M. 1958. *The Coconut Palm-A Monograph*. The Indian Coconut Committee Ernakulam, Kerala, India, pp.58-59.

Meunier, J., Rognon, P. and Nucc, M. .D. 1992. Analysis of nut components in the coconut sampling. Study of sampling. *Oleagineux*. 32 (1): 13- 14.

Meunier, J., Sangare, A., Le Saint, J. P. and Bonnot, F. 1984. Genetic analysis of yield characters in some hybrids of coconut. *Oleagineux*. 39: 581-586.

Mubarak, A. 2012. A study on coconut production and marketing in tamil nadu with special reference to pollachi south block. Ph.D. Thesis, Bharathidasan University, Coimbatore, Tamil Nadu, 55p.

Murthy, B. R. and Arunachalam, V. 1966. The nature of genetic divergence in relation to breeding system in crop plants. *Indian J. genet.* 26: 188-198.

N'cho, Y. P., Sangare, A., Bonnot, F. and Baudoin, L. 1993. Assessment of a few coconut ecotypes a biometric approach. *Oleagineux.* 48: 122-132.

Nambiar, M. C. and Nambiar, K. P. P. 1970. Genetic analysis of yield attributes in *cocos nucifera* L. var. West Coast Tall. *Euphytica.* 19: 543-551.

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

Namboothiri, C. G. N, Niral, V. and Parthasarathy, V. A. 2007. Correlation and path analysis in the F2 populations in coconut. *Indian J. Hortic.* 64 (4): 56-69.

Nampoothiri, K. U. K. 1999. Impact of prepotency in coconut productivity. *Cord.* 7(2): 1-7.

Nampoothiri, K. U. K. and Singh, H. P. 2000. *Trends in coconut Research and Development in India.* Comp. George, V.T., Markose, V.T., Sivarama Reddy, L. and Remany Gopalakrishnan. Pub. CDB. pp. 1- 102.

Nampoothiri, K. U. K., Satyabalan, K. and Mathew, J. 1975. Phenotypic and genotypic correlation of certain characters with yield in coconut. *Fourth FAO Tech. Wkg. Party Cocon. Prod. and Processg.* Kingston, Jamaica, 121p.

Nandi, A. K. and Sugata, G. 2000. Unusual early flowering in Komadan- a natural cross hybrid of coconut *(Cocos nucifera* L.*). Int. J. of Agric. Sci.* 70 (50): 336-337.

Narayanankutty, M. C. and Gopalakrishnan, P. K. 1991. Yield components in coconut palms. *Coconut breeding and management. Proceedings of the*

National Symposium held at the Kerala Agricultural University, Thrissur, India from 23rd to 26th November 1988: 94-98.

Natarajan, K., Ganesamurthy, C. and Kavitha, M. 2010. Genetic variability in coconut (*Cocos nucifera*). *Electr. J. of Plant Breed.* 1 (5): 1367-1370.

Nedunchezhiyan, M., Byju, G. and Mukherjee, A. 2008. Performance of cassava varieties intercropped in coconut plantation. *Indian J. Hortic.* 65 (1): 122-125.

Nelliat, E. V. 1978. Indian. Survey of overaged, diseased and poor yielding coconut areas in selected growing countries in Asis and the Pacific regions. Consultant report to FAO.

Nickerson Color Fan. 1957. Maximum Chroma 40 hues. Published by Munsell color Co. incorporated 2441 N. Calvert street, Baltimore, Maryland 21218.

Ninan, C. A. and Pankajakshan, A. S. 1961. Progeny studies in coconut. Relationship between parent yield and seedling characters of progeny with special reference to open pollinated and hybrid progenies of WCT and its bearing on the concept of prepotency in coconut. *Indian Coconut J.* 14: 100-109.

Odewale, J. O., Ataga, C. D., Agho, C., Odiowaya, G., Okoye, M. N. and Okolo, E. C. 2012. Genotype evaluation of coconut (*Cocos nucifera* L.) and mega environment investigation based on additive main effects and multiplicative interaction (AMMI) analysis. *Res. J. of Agric. and Environ. Manag.* 2 (1): 1-10.

Ohler, J. H. 1999. *Modem coconut management - Palm cultivation and products*, Allen and Unwin press, Londan, pp. 1 -19.

Omena, B. O., Morufat, O. B., Sikirat, R. A., Sam, K. and Taiwo, O. 2015. Intraspecific Variability in Agro-Morphological Traits of African Yam Bean *Sphenostylis stenocarpa* (Hochst ex. A. Rich) Harms. *J. Crop Sci. Biotechnol.* 18 (2): 53 – 62.

Ouvrier, M. and Ochs, R. 1980. Nutrient removal by the hybrid coconut Port Bouet 121 (MAWA). In: *Proc. Int. Conf. Cocoa and Coconuts,* Incorporated Society of Planters, Kuala Lumpur, pp. 595-605.

Ovasuru, T., Tan, G. Y. and Bridgland, L. A. 1991. Coconut germplasm collection in Papua New Guinea. *Abstract of papers of International Symposium on coconut research and development-II* held from 26th to 29th November 1991 at CPCRI, Kasaragod, India: 16p.

Pankajakshan, A. S. and George, M. 1961. Character association studies in coconut seedlings. *Indian Coconut J.* 14: 67-70.

Panse, V. G. 1957. Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet.* 17: 318-328.

Panse, V. G. and Sukhatme, P. V. 1967. *Statistical Methods for Agricultural Workers*. Indian Khavari Khorasani S, Mostafavi KH, Zandipour E,

Patel, J. S. 1938. *The Coconut- A monograph,* Government Press, Madras, India, 23p.

Patil, J. L., Hadankar, P. M., Jamadangni, B. M. and Salvi, M. J. 1993. Variability and correlation studies for nut characters in coconut. *J. Maharastra Agric. Univ,* 18 (3): 361-364

Paul, V. J. 1990. An improved smoke-free copra drier. *Indian Coconut J.* 20(8): 3-6.

Perera, K. N. S. and Perera, S. A. C. N. 2015. Multivariate discrimination of exotic coconut varieties for stem and inflorescence morphology. *Sri Lanka Assoc. for the Advmt. of Sci.* 201(1):10-13.

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

Pillai, P. K. T., Pillai, R. V., Iyer, R. D., Viraktamath, B. C. and Yadukumar, N. 2002. Economic life span of coconut hybrids. *Indian Coconut J.* 21 (10): 2-6.

Pillai, R. V., Rao, E. V. V. B. and Kumaran, P. M. 1991. Characterisation of coconut cultivars. Coconut breeding and management. *Proceedings of the National Symposium on coconut breeding and management* held at the Kerala Agricultural University, Thrissur, India from 23rd to 26th November, 1988: 75-82.

Piyasundara, J. H. N., Gunasekare, M. T. K. and Wickramasinghe. 2008. Identification of Discriminating Morphological Descriptors for Characterization of Tea (*Camellia sinensis* L.). *Germplasm in Sri Lanka. Trop. Agric. Res.* 20: 193-199.

Praduman, Y. and Murthy, I. Y. L. N. 2016. Calibration of NMR spectroscopy for accurate estimation of oil content in sunflower, safflower and castor seeds. *Curr. Sci.* 110: 55-69.

Purseglove, J. W. 1968. The origin and distribution of the coconut. *Trop. Sci.* 10 (4): 191-199.

Rajagopal, V. 2001. Coconut Research in India - Newer Perspectives. *XXXVIII APCC Session 2001*, Bangalore, India, Souvenir. pp. 97- 105.

Rajagopal, V. and Arul, R. S. 2002. Coconut cultivation in India – A SWOT analysis. *Indian Coconut J.* 33 (4): 1-2.

Rajagopal, V., Kasturibai, K. V. and Voleti, S. R. 1990. Screening of coconut genotypes for drought tolerence. *Oleagineux.* 45 (5): 215 -223.

Raji, A. A. 2002. Assessment of genetic diversity and heterotic relationships in African improved and local cassava germplasm. Ph. D. Thesis. University of Ibadan, Nigeria.

Ramadasan, A. and Mathew, J. 2003. Leaf area and dry matter production in adult coconut palms. *J. Plant. Crops.* 15(1): 59-63.

Ramadasan, A., Kasturibai, K. V., Shivashankar, S. and Vijayakumar, K. 1985. Heritability of seedling vigour in coconut palm. *J. Plant. Crops.* 13 (2): 136-138.

Ramadasan, A., Satheesan, K. V., Shivashankar, S. and Vijayakumar, K. 1980. Leaf area and shoot dry weight in coconut seedling selection. *Indian J. Agric. Sci.* 50: 553-554.

Ramanathan, T. 1984. Character association in coconut. *Madras Agric. J.* 18 (4): 3-4.

Rao, E. V. V. B. and Koyamu, K. 1955. The dwarf coconut. *Indian Coconut J.* 8: 106-112.

Rao, E. V. V. B. and Pillai, R. V. 1982. Characterisation of coconut germplasm based on fruit component analysis. ***Proceedings of the Fifth Annual Symposium on Plantation Crops***. Kasargod 15th to 18th December: 112-123.

Rao, E. V. V. B., Pillai, R. V., Vijayakumar, K., Viraktamath, B. C. and Moorthy, K. 1983. Study of variability of indigenous Tall cultivars. *Annual Report.* CPCRI, Kasaragod, 84p.

Rao, T. V. 1964. Multivariate analysis of agronomic traits of new corn hybrids (*Zea maize* L.). *Int. J. Agric. Sci.* 1(6): 314-322.

Ratnam, T. C. 1968. Coconut improvement: indigenous types show promise. *Indian Farming.* 17 (12): 21-23.

Ratnambal, M. J., Muralidharan, K., Krishnan, M. and Amarnath, C. H. 2005. Diversity of coconut accessions for fruit components. *J. Plant. Crops.* 33 (1): 1-8.

Ratnambal, M. J., Muralidharan, N. K., Nair, P. M., Kumaran, E. V. V., Bhaskara, R. and Pillai, R. V. 1995. *Coconut descriptors —part I.* CPCRI, Kasaragod, pp.56-68.

Reddy, D. V. S., Kumaran, P. M. and Reddy, L. S. 2001. Guidelines for establishing coconut seed garden and raising coconut seedlings. *Indian Coconut J.* 32: 10–12.

Ridley, H. N. 1930. *The dispersal of plants throughout the world.* Reeves, .London, 98p.

Rognon, F. 1976. Xenia and combining ability in coconut. *Oleagineux*, 31 (12): 533-537.

Rolletschek, H., Johannes, F., Svetlana, F., Andreas, B., Harald, T., Peter, M. and Ljudmilla, B. 2015. A novel noninvasive procedure for high-throughput screening of major seed traits. *Plant Biotechnol. J.* 13: 188–199.

Sankaran, M., Damodaran, V., Singh, D. R., Sankar, I. and Jerard, B. A. 2015. Genetic analysis in Pacific and Nicobar Islands coconut collections conserved at Andaman Islands, India. *Indian J. of Hortic.* 72: 117-120.

Sarkar, M. D., Choudhury, S. Islam, N. and Islam, M. N. 2012. Morphometric Characterization of Coconut Germplasm Conserved at Bari. *Int. J. of Sustain. Agric.* 4 (3): 52-56.

SAS Institute Inc. 2004. SAS Online Doc 9.1.3. SAS Institute, Cary, North Carolina.

Satyabalan, K. 1984. Life history of the coconut palm on the West Coast of India: A study. *Indian Coconut. J.* 14 (6): 3-11.

Satyabalan, K. 1993. The coconut palm Botany and Breeding, *Pub. APCC*, Jakarta, Indonesia. pp. 2 -14.

Satyabalan, K. and Mathew, J. 1977. Identification of prepotent palms in West Coast Tall variety based on growth of progeny in the nursery. *International Symposium on Coconut Research and Development*, Kasaragod, India.

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

Satyabalan, K. and Rajagopal, V. 1990. Genetic improvement of coconut palms. Combining ability of palms in Dwarf x Tall hybrids. *J. Plant. Crops*. 15: 23-30.

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

Selvaraju, S. and Jayalekshmy, V. G. 2011. Morphometric Diversity of Popular Coconut Cultivars of South Travancore. *Madras Agric. J.* 98 (3): 10-14.

Sento, T. 1974. Studies on the seed germination of palms. VI. on *Cocos nucifera* L., Phoenix humilis var. hanceana and Phoenix sylvestris. *J. Japan Soc. Hortic. Sci.* 42 (4): 380-388.

Sento, T. 1976. Studies on germination of palm seeds. *Mem. Coll. Agric. Ehime Univ.* 21: 1-78.

Shortt, D. 1885. An *Eriophyes guerreronis*: an important pest of African and American coconut groves. *Oléagineux* 32: 101-109.

Shylaraj, K. S. 1982. Identification of prepotent mother palms in coconut (*Cocons nucifera* L.)-variety Komandan. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 100p.

Shylaraj, K. S., Bindu, M., Gopakumar, K. and Gopimoney, R. 1991. Comparing Komadan coconut type with West Coast Tall. *Coconut breeding and management. Proceedings of the National Symposium on coconut breeding* *and management* held at the Kerala Agricultural University, Thrissur, India from 23rd to 26th November, 1988: 106-108.

Silva, M. A. T. and George, G. D. 1970. Influence of size and maturity of coconut seednuts on the rate of germination and subsequent growth of seedlings. *Ceylon Coconut J.* 22 (3): 114-119.

Sindhumole, P. and Ibrahim, K. K. 2000. Path analysis of nut yield in cultivars of coconut (*Cocos nucifera* L.). *South Indian Hortic.* 48 (1): 160-162.

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

Singh, V. 2001. Yield variation in coconut. *Ceylon Coconut J.* 22:97-103.

Smith, A. C. 1933. Practical seed selection of coconuts. *Malaya agric. J.* 21: 265-271.

Sreerangasamy, S. R. and Sridharan, C. S. 1991. Multistage selection in coconut palm for genetic improvement. *Abstract of papers of paper of International Symposium on coconut Research and Development-II* held during 26th to 29th November 1991 at CPCRI, Kasaragod, India: 24-25.

Srinivasa, M. V. and Ramu, P. M. 1971. Selection of coconut seedlings for planting. *Lal Baug.* 16 (1): 3-8.

Sukumaran, C. K., Narasimhayya, C. and Vijayakumar, G. 1981. Path coefficient analysis in coconut. *Proceedings of the fourth annual Symposium on plantation crops –Genetics*. Plant Breeding and horticulture. Placrosym IV: 191-199.

Thampan, P. K. 1999. *Enhancing the income and employment in the coconut sector through conservation and use of special coconut ecotypes in India.* Agrihortica Publications, Junagadh, 235p.

Thampan, P. K. 2000. *Farmer's assessment of coconut varieties in Kerala*. Pub. Peekay Tree Crops Development Foundation. pp. 1-24.

Thomas, K. M. 2003. Influence of certain physical and chemical treatments on the germination and subsequent growth of coconut *Cocos nucifera* L seedlings: a preliminary study. *East Afr. Agric. and For. J.* 40: 152–156.

Ugbah, M. M. and Akpan, E. E. J. 2003. Effect of nut positioning and husk slashing of nut germination and growth of two coconut varieties. *Nigerian J. of Palms and Oil Seeds.* 15: 11–21.

Ulaganathan, V. and Nirmalakumari, A. 2015. Finger millet germplasm characterization and evaluation using principal component analysis. *SABRAO J. of breed. and Genet.* 47 (2): 79-88.

Umali, D. L. 1940. A study on coconut seed selection for germination. *Philipp. Agric.* 29: 296-312.

Valsala, P. A. and Kannan, K. 1990. Influence of seednut characters on seedling vigour. *Indian Coconut J.* 21 (4): 11-13

Vanaja.T. and. Amma, J.S. 2002. Seasonal variation in palm characters of WCT and Komadan coconut types. *Indian Coconut J.* 33: 13-15.

Vigli, J. F. B., Lavery, J. R. and Lal, M. 2003. Oil estimation of tropical nuts. *Int. J. of Climatol.* 15: 873-892.

Vijayaraghavan, H. and Ramachandran, T. K. 1989. Seasonal variation in barren nut production. *Indian Coconut J.* 19 (9): 7.

Whitehead, R. A. 1966. *Sample survey and collection of coconut germplasm in the Pacific islands.* Ministry of Overseas Development and HMSO, London, 59p.

Zdenek, K. and Karol, M. 2012. Multivariate morphometric analysis of the *Potamogeton compressus* group (Potamogetonaceae). *Bot. J. of the Linnean Soc.* 140: 112-130.

Zizumbo, D., Colunga, E. Payroz, P., Delgado, V., and Gepts, P. 2006. Population structure and evolutionary dynamics of wild weedy domesticated complexes of common bean in a Mesomerican region. *Crop. Sci.* 45: 1073–1083.

Zizumbo, D., Fernandez, M., Hernandez, N. and Colunga, P. 2005. Morphological variation of fruit in Mexican populations of *Cocos nucifera* L. (Arecaceae) under in situ and ex situ conditions. *Genet. Resour. Crop. Evol.* 52: 419–432.

INTRA-VARIETAL VARIABILITY IN KOMADAN COCONUT (*Cocos nucifera* L.) PALMS

by

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ABSTRACT

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ABSTRACT

The project entitled "Intra-varietal variability in Komadan coconut (*Cocos nucifera* L.), palms" was under taken with an objective to assess the intra-varietal variability in Komadan coconut palms for yield and other attributes. The data for the investigation were collected from two field experiments during the period 2014-16.

In experiment I, 50 Komadan palms in the Instructional Farm, Vellayani, were utilized as the material for the study. The highest number of leaves and spadices per year were observed in palms C9, C19, C20, C21, C23, C31, C32, and C35. The maximum number of nuts per bunch, weight of copra per year, length of leaf and number of leaflets per leaf were recorded in palm C17. The maximum number of nus per palm per year, weight of nuts per year and weight of husked nuts per year were noticed in C32. The highest weight of husked nut and nut equatorial circumference were observed in palm C19. The maximum copra content per nut and endosperm thickness were found in palm C18. The maximum coefficient of variation was recorded for number of female flowers per inflorescence. The colour of midrib was found in four different ranges from moderate olive green to moderate brown and colour of tender coconut fell into five different group.

High positive correlation was recorded for number of nuts per palm per year, with number of leaves per year, number of spadices per year, number of female flowers per inflorescence, number of female flowers per spikelet and number of spikelets per spadix. The principle component analysis revealed that the first four components with Eigen value greater than 0.79 contributed about 92.08 per cent of the total variability. The characters such as weight of nuts per year, number of nuts per palm per year, weight of husked nuts per year, number of nuts per bunch, weight of nut, copra content per nut and weight of copra per year were the most important ones contributing to the overall variability.

In experiment II, seedling variability among the 100 Komadan seedlings raised in the coconut nursery of Instructional Farm, Vellayani were studied. The seedling S71 showed maximum values for collar girth at nine months age, number

of leaves at nine months age and twelve months after sowing. The seedling S68 was found to have maximum height and collar girth at nine months age and number of leaves at nine and twelve months age. The seedling S100 was observed to have the highest collar girth at twelve months age, number of leaves at nine months and twelve months age. The maximum coefficient of variation was recorded for number of leaves at twelve months age.

High significant correlation was noted among eight morphological characters. Number of days for germination was positively correlated with number of days for splitting of leaflets and height of seedlings was positively correlated with collar girth. Number of days for splitting was negatively correlated with collar girth and height of seedlings.

In the present research, the yield related parameters such as number of female flowers per inflorescence, number of female flowers per spikelet, setting percentage, number of nuts per palm per year, number of nuts per bunch, weight of nuts per year, weight of husked nuts per year and weight of copra per year of Komadan palms and number of leaves of seedlings expressed high variability. Hence, selection based on these traits is important in the crop improvement programmes of Komadan. The intra-varietal variability existing among these palms will provide opportunities to the breeder for utilization, conservation and further genetic improvement.

Appendices

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Intra-varietal Variability in Komadan Coconut (*Cocos nucifera* L.) Palms

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ABSTRACT

Fourteen morphological characters recorded from fifty Komadan coconut palms were analysed statistically to assess intra-varietal variability. The highest number of leaves and spadices per year was observed in palms C9, C19, C20, C21, C23, C31, C32, and C35. The maximum number of nuts per bunch, length of leaf and number of leaflets per leaf were recorded in palm C17. The maximum coefficient of variation was recorded for number of female flowers per inflorescence. The colour of midrib was found in four different ranges from moderate olive green to moderate brown and colour of tender coconut fell into five different groups. High positive correlation was recorded for number of nuts per palm per year, with number of leaves per year, number of spadices per year, number of female flowers per inflorescence, number of female flowers per spikelet and number of spikelets per spadix. The variability existing in the Komadan variety provide opportunities for future coconut improvement programmes.

Key words *Coconut, Komadan, intra-varietal, correlation*

Coconut palm (*Cocos nucifera* L.) is one of the valuable gifts of nature to mankind. It is considered as the tree of life and is eulogised as 'Kalpavriksha', the all giving tree or the Tree of Heaven. Coconut fruit is considered as 'Lakshmi Phal', the fruit of wealth. Coconut is a highly cross pollinated crop, showing great variation in its yield potential. Desirable variations can be utilized for better yield, which may be achieved through hybridization as well as selection. A knowledge of the associations among floral or reproductive characters, vegetative characters and yield of nuts is a prerequisite for any selection programme. Since coconut is a cross pollinated crop, the variability studies play an important role in crop improvement programme. A range of germplasm with 241 accessions, comprising of 101 exotic and 140 indigenous, is now available in the country and the accessions are being utilized for varietal improvement through intra-varietal and inter-varietal crossing (Rajagopal *et al.* 2001). Considering these facts, the present study is undertaken to find the intra-varietal variability in coconut ecotype Komadan.

MATERIALS AND METHODS

Fifty Komadan coconut palms with in the Instructional Farm, College of Agriculture, Vellayani, Thriruvanathapuram, Kerala, India was utilized as the materials for the study. The palms of similar age group was selected and its two qualitative traits and twelve quantitative traits were studied.

Qualitative traits

The two qualitative traits recorded include colour of midrib of leaf and colour of tender coconut. The pigmentation was scored as per standards fixed in the "Nickerson Colour Fan (1957)".

Quantitative traits

Data were recorded on twelve quantitative traits of fifty Komadan palms. These characters are listed below.

1. Number of leaves per year: Number of leaves on the crown were counted for one year.
2. Length of leaves (m): Each individual leaf was measured by measuring tape from the tip of the leaflet to bottom of the petiole.
3. Number of leaflets per leaf: Number of leaflets were counted from three fully opened leaves and mean value was is calculated.
4. Girth of trunk (cm): Trunk girth or circumference was measured by measuring tape at five feet above from the base of trunk of all palms. (Nedunchezhiyan, 2008).
5. Number of spadices per year: Number of spadices or bunches were counted throughout the year.
6. Number of female flowers per inflorescence: Female flowers on the youngest three inflorescences in which male flowers were in anthesis were counted at random. Then the mean number of female flowers per inflorescence was computed.
7. Number of female flowers per spikelet: Female flowers on the spikelet were counted and the mean was calculated.

Table 1. Colour of the midrib in Komadan palms

Sl. No.	Colour index	Colour	Number of palms
1.	5 GY 4/3	Moderate olive green	C4. C8. C13. C17. C21. C25. C28. C35. C38. C42. C45. C49
2.	5 Y 5/6	Light olive	C1. C3. C6. C9. C12. C15. C16. C18. C20. C22. C24. C29. C30. C33. C37. C39. C40. C43. C46. C47. C48. C50
3.	7.5 Y 4/3	Moderated olive	C5. C11, C14, C26, C27. C31. C32. C36, C41. C44
4.	5 YR 3/3	Moderate brown	C2. C7. C10. C19. C23. C34

8. Setting percentage: Number of nuts per bunch and number of female flowers per bunch were counted from three bunches at random and the mean percentage was calculated.
9. Number of spikelets per spadix: The number of spikelets per inflorescence in each accession was counted and the average was worked out.
10. Length of peduncle (cm): Length was measured from the bottom of the fully opened mature leaf to the first leaflet by using measuring tape.
11. Number of nuts per palm per year: The total number of nuts in a palm was counted from the oldest bunch to the youngest bunch where the nuts were in button stage.
12. Number of nuts per bunch: Nuts, up to button stage, were counted on all bunches of each palm and the mean number of nuts per bunch was obtained.

Data analysis

Statistical analysis of data was performed using Microsoft Excel. This included the calculation of standard deviations, mean, coefficient of variations (CVs), and Pearson correlation coefficients. Standard deviations were calculated using the STDEV function, CVs were calculated by dividing the standard deviation of a set of values by the mean of those values and then expressed as percentage.

RESULTS AND DISCUSSION

The eco-type Komadan coconut is a robust palm, with tall, slender and thick stem. Variability exists among Komadan coconut on a number of morphological traits.

Qualitative traits

Among the 50 palms evaluated, 12 palms produced moderate olive green, 22 palms had light olive colour, 10 palms expressed moderate olive and 6 palms exhibited moderate brown colour of midrib (Table 1). About 88 per cent of the Komadan palms exhibited olive shade for the midrib. The colour of the tender coconut is presented in Table 2. The 50 palms had different shades of brown and olive for tender coconuts. The 40 per cent of palms had two different shades of brown colour viz., brownish orange and moderate olive brown. Brown colour was reported to be the product of hybridisation between green and red or orange palms which are homozygous for these colours. Similar results were obtained by Lamothe and Rognon (1977). Remaining 60 per cent of palms had different shades of olive colour which may be the result of segregation of genes for tender coconut colour.

Quantitative traits

Data on 12 morphological traits were recorded on fifty palms belonging to same eco-type, Komadan. The magnitude of variation is represented by standard

Table 2. Colour of the tender coconut in Komadan palms

Sl. No.	Colour index	Colour	Number of palms
1.	2.5 YR 5/9	Brownish orange	C2, C6, C9, C12, C16, C20, C24, C27, C30, C32, C36, C41, C47
2.	2.5 Y 4/4	Moderate olive brown	C3, C10, C15, C22, C29, C38, C43
3.	10 Y 4/3	Moderate olive	C4, C7, C17, C18, C19, C28, C34, C42, C46
4.	2.5 GY 4/3	Moderate olive green	C1, C5, C8, C11, C14, C23, C31, C35, C39, C44, C45, C48, C49, C50
5.	2.5 GY 3/1	Greyish olive green	C13, C21, C25, C26, C33, C37, C40

Table 3. Mean, Standard Deviation (SD), Minimum, Maximum, Range and coefficient of variation for 12 characters in Komadan palms

Characters	Mean	Standard Deviation	Minimum	Maximum	Range	CV
Number of leaves per year	13.4	0.992	11.00	15.00	4.00	7.39
Length of leaves (m)	4.2	0.632	2.30	5.46	3.16	15.21
Number of leaflets per leaf	208.4	18.649	160.00	240.00	80.00	8.95
Girth of trunk (cm)	83.5	8.071	71.20	103.20	32.00	9.66
Number of spadices per year	13.4	0.992	11.00	15.00	4.00	7.39
Number of female flower per inflorescence	35.0	24.946	3.00	123.00	120.00	71.32
Number of female flower per spikelet	34.9	14.224	6.50	66.67	60.16	40.77
Setting percentage	34.9	14.224	6.50	66.67	60.16	40.77
Number of spikelets per spadix	34.7	10.949	21.00	63.00	42.00	31.55
Length of peduncle (cm)	112.8	20.333	59.20	150.20	91.00	18.03
Number of nuts per palm per year	88.7	33.591	25.00	154.00	129.00	37.87
Number of nuts per bunch	10.7	5.682	1.00	24.00	23.00	53.01

CV-Coefficient of variation

deviation, coefficient of variation and range (Table 3). The number of leaves per year varied from 11 to 15. Increase in number of leaves is advantageous in assessing the future yields (Liyanage, 1966). Average length of leaves of 50 palms was 4.2 m. Palm C50 produced the lowest mean length of leaf (2.30 m) and palm C17 showed the highest mean length of leaf (5.46 m). The palm C17 had the highest number of leaflets per leaf (240) and C50 showed the lowest number of leaflets per leaf with mean value of 208.4. The girth of trunk for 50 palms varied from 71.2 cm to 103.2 cm. The palm C50 produced the lowest number spadices

Table 4. Correlation Matrix of quantitative morphometric characters.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.000											
X2	-0.306*	1.000										
X3	-0.284*	0.709**	1.000									
X4	-0.084	0.389**	0.423**	1.000								
X5	1.000**	-0.306*	-0.284*	-0.084	1.000							
X6	0.179	0.099	0.197	0.381**	0.179	1.000						
X7	0.020	0.199	0.156	0.400**	0.020	0.912**	1.000					
X8	0.280*	-0.128	-0.185	-0.276	0.280*	-0.427**	-0.391**	1.000				
X9	0.495**	-0.233	0.072	0.006	0.495**	0.396**	0.038	-0.005	1.000			
X10	-0.275	0.831	0.635**	0.367**	-0.275	0.140	0.246	-0.101	-0.224	1.000		
X11	0.481**	-0.059	-0.004	0.042	0.481**	0.591**	0.522**	0.254	0.494**	0.046	1.000	
X12	0.402**	0.038	0.044	0.105	0.402**	0.615**	0.564**	0.248	0.451**	0.142	0.961**	1.000

* significant at 5% level ** significant at 1% level

X1 Number of leaves per year, X2 Length of leaves, X3 Number of leaflets per leaf, X4 Girth of trunk, X5 Number of spadices per year, X6 Number of female flower per inflorescence, X7 Number of female flower per spikelets, X8 Setting percentage, X9 Number of spikelets per spadix, X10 Length of peduncle, X11 Number of nuts per palm per year, X12 Number of nuts per bunch

(11) and palms C9, C19, C20. C21. C23, C31, C32, and C35 exhibited the highest number of spadices per year (15). The palm C40 produced maximum number of female flower per inflorescence (123) and palm C24 exhibited minimum number of female flower (3). The Number of female flowers varied with the season and the season had no effect on the average nut production per bunch (Vanaja and Amma. 2002). The average number of female flowers per spikelet was observed as one.

The palm C24 produced the highest setting percentage (66.67) and palm C40 exhibited the lowest setting percentage (6.5). The yield is a function of number of female flower production and setting percentage. Factors affecting any one of these characteristics will influence the final yield (Marar and Pandalai, 1957). Number of spikelets per spadix varied from 21 to 63. The palm C43 showed the highest length (150.2 cm) and palm C50 exhibited the lowest length of peduncle (59.2 cm) followed by C25 (73.9 cm). Significant variation was noticed for number of nuts per palm per year, which ranged between 25 (C15) and 154 (C32). The palm C32 produced maximum number of nuts per year (154) followed by C17 (140) and C9 (139). Palm C15 recorded the lowest number of nuts per year (21) followed by C10 (26) and C50 (29). Number of nuts per bunch varied from 1 (C15 and C50) to 17 (C17). The maximum coefficient of variation was found in number of female flowers per inflorescence (71.32 %) followed by weight of nuts per year (54.94) and number of nuts per bunch (53.01). Hence, there is scope for selecting high yielding palms.

Correlation provides information on the nature and extent of relationship among the various characters (Table 4). In Komadan coconut palms, number of leaves per year was found significantly and positively correlated with number of spadices per year (1.00), setting percentage (0.280), number of spikelets per spadix (0.495), and number of nuts per palm per year (0.481). This is in agreement with the findings of Manju (1992) and Mathew and Gopimony (1991). Length of leaves had highly significant and positive correlation with number of leaflets per leaf (0.709), girth of trunk (0.389) and length of peduncle (0.831). It showed negative correlation with number of spadices per year (-0.306) and number of spikelets per spadix (-0.233). Girth of trunk had highly significant and positive correlation with number of female flowers per inflorescence (0.381), number of female flower per spikelet (0.400) and length of peduncle (0.367). Number of spadices per year was found significantly and positively correlated with setting percentage (0.280), number of spikelets per spadix (0.495), number of nuts per palm per year (0.481) and number of nuts per bunch (0.402). This correlation reveals that almost every leaf axil has a bunch in it and when the number of leaves are more in a palm there will be a corresponding increase in number of bunches also, which ultimately leads to increase in nut yield. Similar findings were obtained by Nambiar and Govindan (1989).

Strong positive correlation of number of female flowers per inflorescence was obtained with number of female flower per spikelet (0.912), number of spikelets per spadix (0.396), number of nuts per palm per year (0.591) and number of nuts per bunch (0.615). It was highly significant and negatively correlated with setting percentage (-0.427). Number of spikelets per spadix had significant and positive correlation with number of nuts per palm per year (0.494) and number of nuts per bunch (0.451). The number of nuts per palm per year was significantly and positively correlated with number of nuts per bunch (0.961). The correlation noticed in palms implies that a higher setting percentage of female flower which leads to more number of nuts per bunch and ultimately results in higher yield. Similar result was obtained by Manju (1992).

However, regarding Komadan palms, the yield related economically important parameters like number of female flower per inflorescence, number of female flower per spikelet, setting percentage, number of spikelets per spadix, number of nuts per palm per year and number of nuts per bunch expressed high range and coefficient of variation. This variation will provide opportunities to the breeder for utilization, conservation and further genetic improvement by selection of palms with promising yield related characters.

LITERATURE CITED

Lamothe, M. and Rognon, F. 1977. Les cocotiers nains a Port-Bouet. 1 Nain, Jaune Ghana, Nain Rouge Malais, Nain Vert Guinee Equatoriale, Nain Rouge Cameroun. *Oleagineux*, 32 (11): 462-466.

Liyanage, D. V. 1966. Planting material for coconuts. *Ceylon Coconut Planters Review*. 4(2):27-29.

Manju, P. 1992. Fruit component and seedling progeny analysis of Komadan coconut types. Ph.D. Thesis, Kerala Agricultural University, Thrissur, pp.139.

Marar, M. M. K. and Pandalai, K. M. 1957. Influence of weather factors on the coconut crops. *Indian J. Meteorol. Geophys.* **8**: 1-1 1.

Mathew, T. and Gopimony, R. 1991. Influence of seednut characters on seedling vigour in coconut. Coconut breeding and management. *Proceedings of the National Symposium on coconut breeding and management* held at the Kerala Agricultural University, Thrissur, India from 23rd to 26th November, 1988: 103-105.

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

Nedunchezhiyan. M., Byju. G. and Mukherjee. A. 2008. Performance of cassava varieties intercropped in coconut plantation. *Indian J. Hort.* **65**(1): 122-125.

Nickerson Color Fan. 1957. Maximum Chroma 40 hues. Published by Munsell color Co. incorporated 2441 N. Calvert street. Baltimore, Maryland 21218.

Rajagopal, V. and Kasturi Bai, K. V. 2001. Performance of coconut cultivars under different soil types. *India Coconut J.* **31** (10): pp. 2-3.

Vanaja.T. and. Amma, J.S. 2002. Seasonal variation in palm characters of WCT and Komadan coconut types. *Indian Cocon. J.* **33**:13-15.

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