

**TRENDS IN PRODUCTION AND BIENNIALITY  
OF COCONUT (*Cocos nucifera* L.) VAR. WCT.**

*by*

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**(2016-19-003)**

**THESIS**

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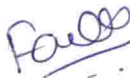
**KERALA, INDIA**

**2018**

**DECLARATION**

I, hereby declare that this thesis entitled “**TRENDS IN PRODUCTION AND BIENNIALITY OF COCONUT (*Cocos nucifera* L.) VAR. WCT.**” 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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Certified that this thesis entitled “**TRENDS IN PRODUCTION AND BIENNIALITY OF COCONUT (*Cocos nucifera* L.) VAR. WCT**” is a record of research work done independently by Mr. **FALLULLA, V.K.** (2016-19-003) 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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### LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
<i>et al</i>	Co –workers/co-authors
CDB	Coconut Development Board
CRS	Coconut Research Station
CD	Critical difference
°C	Degree Celsius
E	East
etc	et cetera
KAU	Kerala Agricultural University
MSS	Mean sum of squares
<i>viz.</i>	Namely
N	North
No.	Number
ppm	Parts per million
%	Per cent
RARS	Regional Agricultural Research Station
Sl	Serial
<i>i.e.</i>	That is
on	Trees with above average yield in an year
off	Trees with below average yield in an year
var.	Variety
WCT	West Coast Tall

# *INTRODUCTION*

## 1. INTRODUCTION

Coconut is extensively useful to the mankind as every part of the tree is utilized in one form or in the other and thus the palm is delightfully called as '*Kalpavriksha*', the tree of heaven. According to Harries (1977), coconut originated in South east Asian countries like Indonesia, Malaysia and Philippines. Coconut is admired to be a small-holders crop in India even though the cultivation is practised by the large and marginal farmers. It act as a source of food, beverage, drug, fuel, wood, and natural fibre, and provides various raw materials to the industrial society producing a variety of commodities. India has a recognized history of about 3000 years in coconut cultivation which is greatly connected with the socio-economic livelihood of a huge number of small and marginal farmers (Lathika and Kumar, 2005).

About 12 million of population in India depends on the coconut farming, processing and trading activities. The four southern states of India contribute for more than 90 per cent of the total production in the country viz. Kerala, 31.1 per cent, Karnataka, 28.33 per cent, Tamil Nadu, 27.48 per cent, Andhra Pradesh, 5.76 per cent and other states, 7.25 per cent. Kerala has the largest area under coconut with 37 per cent of national area and the total area under coconut cultivation increased from 409400 Ha to 770790 Ha from the period 1950-51 to 2015-16. Production of coconut during this period increased to 7448.65 million nuts from 2026 million nuts. An annual increase of 2.43 per cent is observed in growth of production of coconut during 1980-81 while for 2015-16 it was 0.56 per cent showing that the rise in production was due to increase in yield rather than in the area (CDB, 2017).

One special problem accompanying perennial crops is the presence of biennial rhythm. Coconut being a perennial crop need to be studied for its biennial bearing tendency. The term bienniality pertains to the affinity of a fruit tree to produce an above average yield, called an 'on' crop for a particular year and a below

average yield in the next year called 'off' crop. Coconut exhibit biennial bearing tendency but intensity of biennial rhythm is not so high as trees like apple, mango *etc.* The degree and extent of bienniality in coconut was reported by many workers. An awareness concerning intensity of biennial rhythm will be of much importance while designing experiments on palms possessing significant bienniality. One cannot rely on the production data for more than two years for their treatment effects, if the palms are possessing a significant biennial rhythm as the treatment effects might be masked by the bienniality. In this background the present study tried to quantify biennial tendency through appropriate statistical tools in respect of graphical, parametric and non parametric approaches.

There is a 44 months of reproductive phase from primodium initiation to the harvest of nuts for coconut palm and unlike other perennial crops variations in climate during the initial developmental phases have a greater effect on the final nut size, yield and oil content. Several workers have studied effect of various climatic factors on coconut production and reported that among the weather parameters, maximum and minimum temperatures, rainfall, rainy days, relative humidity, vapour pressure deficit, wind velocity and sunshine hours are found to have direct influence on the crop growth and yield (Kumar, 2011). In this context, effect of climatic factors on production of nuts is performed in this study with the help of meteorological data for 25 years *viz.* 1993-2017 .

Repeatability is a measure of degree to which the variations between individuals under study depends on the genetic and permanent effects rather than the temporary effects (Turner and Young, 1969). According to Lush (1954), repeatability is an important genetic parameter which is to be popularized among the biometricians working with the perennial crops. Statistically repeatability is nothing but an intraclass correlation coefficient over the years or over some aspect of time. Repeatability studies are important for perennial crops breeders, since they represent the maximum value that the heritability of a character in a wide sense can reach. They

are also used to find the number of phenotypic observations to be made in each individual so that the discrimination or phenotypic selection among genotypes is efficiently carried out with low costs. In this context, repeatability coefficients have been estimated in variety of fruit crops by many research workers and the present study tried to estimate repeatability coefficient and its variation for coconut.

In this context the present study seeks to examine the growth trends in coconut yield for the past twenty five years and is intended at the following objectives.

1. To study the trends in yield of coconut variety West Coast Tall (WCT) for its yielding period
2. To identify the extent of bienniality and type of yield fluctuations from year to year among coconut palms
3. To estimate the repeatability coefficient and its variance
4. To study variations in crop yield and bienniality from year to year due to climatic factors under standard cultivation practices.

*REVIEW OF LITERATURE*

## 2. REVIEW OF LITERATURE

This chapter puts forward the critical reviews of literature related to the current study. The research works done by many research workers based on the particular statistical problem under study has been critically reviewed under the subheadings given below.

- 3.1 Importance of coconut cultivation
- 3.2 Effect of climatic factors on production
- 3.3 Biennial bearing tendency and its importance
- 3.4 Repeatability coefficient and its importance

### 2.1 IMPORTANCE OF COCONUT CULTIVATION

Coconut palm is known as '*Kalpavriksha*' (meaning tree of heaven) as every part of it is useful to the mankind for some purpose or the other. According to Harries (1977), origin of coconut is the South east Asian countries like Indonesia, Malaysia and Philippines. Coconut is acclaimed to be a small-holder's crop in India and has a recognized history of about three thousand years. Coconut serve as a supply of food, medicine, beverages, fuel, timber, natural fiber and raw materials for industries producing a varying range of commodities and is connected with the socio economic life of a number of small and marginal farmers in India (Lathika and Kumar, 2005).

Shashikumar and Chandrashekhar (2014) reported that 65 to 70 per cent vegetable oil is present in the copra which is prepared by drying the kernel of coconut. On a productive land a tall variety of coconut will produce 75 nuts per year but more frequently production is not more than 30 because of the inappropriate cultural practices adopted.

About 12 million of population in India depends on the coconut farming, processing and trading activities. The four southern states of India contribute for

more than 90 per cent of the total production in the country viz. Kerala, 31.1 per cent, Karnataka, 28.33 per cent, Tamil Nadu, 27.48 per cent, Andhra Pradesh, 5.76 per cent and other states, 7.25 per cent. Kerala has the largest area under coconut with 37 per cent of national area and the total area under coconut cultivation increased from 409400 Ha to 770790 Ha from the period 1950-51 to 2015-16. Production of coconut during this period increased to 7448.65 million nuts from 2026 million nuts. An annual increase of 2.43 per cent is observed in growth of production of coconut during 1980-81 while for 2015-16 it was 0.56 per cent showing that the rise in production was due to increase in yield rather than in the area (CDB, 2017).

## 2.2 EFFECT OF CLIMATIC FACTORS ON PRODUCTION

Copeland (1931) studied the effect of wind velocity on production of coconut and reported that wind velocity does not have an independent effect on production instead it influences the soil moisture conditions. According to him, strong wind make a significant damage to coconut plantation thus are not desirable for production.

Patel and Anandan (1936) remarked that a particular year's production will be affected by the rainfall during the January to April for the current year of harvest and that of preceding two years.

According to Abeywardena (1955), same degree of association between production of current year and the climatic factors of previous successive year cannot be obtained as in the cycle of development of bunches, there may have some certain periods or phases which are enormously vulnerable to climatic factors.

Marar and Pandalai (1957) observed a non significant correlation coefficient between production of nuts and individual climatic factors and thus, could not explain the effect of seasonal changes in the production of nuts for coconut in terms of the individual climatic factors.

Abeywardena (1966) studied the effect of rainfall in coconut palms. According to him, the production of nuts will increase as the effective rainfall increases up to a certain level then law of diminishing return will act and for further increase, the production will decrease. The study attempted to predict production of nuts using the rainfall data. Study reported that palms in an area can vary with a broad range of as much as 40 per cent of the average yield solely as the effect of the variations in the prevalence of rainfall.

Smith (1966) studied the effect of rainfall on the copra yield of coconut from the 19 years production data from a coconut estate of 800 palms. In the study a regression equation was estimated by taking yield in a particular year as dependent variable and soil water deficit over the 29 months before the start of crop year as independent variable and observed a correlation coefficient of  $-0.81$  indicating that yield is more related with the soil water deficit than the rainfall.

Three phases of fruit development were identified and documented by Nambiar *et al.* (1969) and observed that growth rate in the second phase of development is largely correlated with the final volume, unhusked nut and the copra content. The three phases of development were first phase of slow growth (about 3 months after fertilization), the second phase of fast growth (next 4 months) and the third phase of fast decline in growth (about 2 months). Study also observed that any detrimental climatic effect in the lively period of development will harmfully affect the rate of growth of nuts and final size of copra.

Abeywardena (1971) reported that there is a prominent yield variation against the climatic factors for the production of coconut than in other crops, the reason would be that for coconut palms the lengthy reproductive cycle obviate from inexplicable change of weather in its external illustrations.

Thampan (1981) studied the effect of minimum temperature on production of coconut and observed that average minimum temperature below  $21^{\circ}\text{C}$  will be

detrimental to the total production in coconut. Thampan (1982) reported that heavy rainfall interferes with the pollination process and thus adversely affects the nut yield.

Rao (1982) studied twenty five year's coconut production of Pilicode region of northern Kerala. In the study a relation between annual coconut production and rainfall was tried with the help of moving averages and reported that subsequent years coconut production is negatively affected by the absence of pre and post monsoons as well as heavy rainfall during monsoon. According to him, increase in rainfall beyond a specific maximum limit would not help to increase production instead have negative effects.

A negative correlation between the heat units which is a function of temperature during 4 to 7 months after fertilization with the husked nut weight were obtained in the study of Rao and Nair (1986). The study also observed that there was a decrease in size of nut during July to December as a result of increase in the heat units. According to them, total heat units above 2100 day °C will adversely affect the nut development for this period.

Effect of seasonal weather factors on coconut production in different lag periods were studied by Nair and Unnithan (1988) and observed that the sunshine hours, relative humidity and evaporation have a significant effect on annual production while rainfall and number of rainy days does not have a significant effect. From their study obtained a negative correlation between relative humidity and annual production while sunshine hours and evaporation showed a positive correlation.

Babu *et al.* (1993) observed a positive correlation between the yield and March to May rainfall of three years before the actual harvest and a negative correlation with January to November rainfall. No significant influence on the production was observed with change in monthly rainfall during the rest of the periods.

Peiris and Peries (1993) observed a low and non significant correlation coefficient between yield and climatic factors during the harvesting year or preceding year or two years prior to harvest.

Onkar *et al.* (1998) tried to forecast wheat production based on a multiple linear regression model using the data collected from Junagarh Research Station of Cropping Systems and observed that the explanatory variables *viz.* height of plants, number of tillers, and length of ear head were able to explain the variation in yield up to 62 per cent and no significant correlation were obtained for the climatic factors.

According to Hansen (2002), production of coconut can be predicted 15 months in advance from the observed rainfall. He observed that models based on the seasonal rainfall and with the help of available seasonal climatic factors the prediction-lead-time can potentially be extend from 15 months to 24 months.

There is 44 months of reproductive phase from primodium initiation to the harvest of nuts for coconut palm unlike other perennial crops. Variations in climate during the initial developmental phases have a greater effect on the final nut size, yield and oil content. Several workers outside and inside India have studied the effect of various climatic factors on coconut production and reported that among the weather parameters, maximum and minimum temperatures, rainfall, rainy days, relative humidity, vapour pressure, wind velocity and sunshine hours are found to have direct influence on the crop growth and yield (Kumar, 2011).

Sunil *et al.* (2011) studied arecanut yield for its effects on climatic factors through a field experimentation during the period 1991 to 2006 at Regional Agricultural Research Station (RARS), Ambalavayal, Wayanad, Kerala and observed that an annual rainfall of 2000 mm and a temperature below 21°C would be detrimental to the production and reported that a high rainfall during the nut development stage will cause infestation of pest and diseases and thus reduces the yield considerably.

Many agricultural production systems are susceptible to the climatic changes and thus could significantly influence the total production. Effect of climatic factors on plantation crops are of much importance as they are grown in the ecologically susceptible areas like coastal belts, hills and areas with high rainfall and humidity and are contributing considerably to the agricultural exports of the country (Kumar and Aggarwal, 2009).

### 2.3 BIENNIAL BEARING TENDENCY AND ITS IMPORTANCE

Alternate bearing (also known as biennial bearing or irregular bearing) is a prevalent incident in many evergreen fruit and nut tree species. The term pertains to the affinity of a fruit tree to produce an above average yield, called an 'on' crop (on-crop year or 'on' phase), succeeded by a below average yield in the next year, called an 'off' crop (off-crop year, 'off' phase) for a series of several years (Monselise and Goldschmidt, 1982). According to them, the 'on' year fruits are generally of poor quality and in a large number whereas 'off' year fruits are of good quality but are few in number. The alternation of too much and too little crop in the 'on' and 'off' years respectively, may endure with immense accuracy, even if it might be affected by some unknown factors. Study also reported and documented biennial bearing tendency in a variety of perennial crops

Hoblyn *et al.* (1936) introduced two factors 'B' and 'I' to measure the alternate bearing behavior and intensity of crop fluctuations from year to year and was the first to formulate a method to estimate biennial bearing tendency among orchard crops. The 'B' factor was based on different pairs of successive signs positive or negative indicating fall or rise in yield over continuous years for each of the palms and 'I' factor was based on production of different years.

Satyabalan *et al.* (1936) applied correlation studies to identify bearing pattern of coconut palms and observed that biennial bearing tendency is significant among coconut palms. Study reported that low yielding palms (producing below 40 nuts per

year ) are exhibiting high extent to bienniality (73 to 93 per cent) and among high yielding palms (producing above 80 nuts per year) percentage of biennial palms were 17 to 40.

Webster (1939) studied biennial bearing tendency in oil palms, a species closely related with coconut and reported 40 per cent bienniality in them.

The alternate bearing behavior is widely identified to be a universal characteristic of fruit trees in both tropical and sub tropical regions (Singh, 1948). According to him, perennial plants and fruit trees are far different from other crops in general. One particular problem that desires attention in perennial species is that of their biennial or alternate fruit bearing tendency. In biennial rhythm when the trees are in a heavy or above average yield in one year , the next year poor or below average yield is obtained and in third year again it proceeds to the heavy yield and so on.

According to Pearce (1953), most perennial palms are exhibiting an alternate pattern at least to some degree in their bearing and growth. Singh (1948) reported that trees exhibiting biennial bearing cycle will carry a high yield in one year, called the 'on' year and a very poor yield in the subsequent year, called the 'off' year. This distinguishing cycle of high and low yields in the 'on' and 'off' years endure with great reliability and occasionally it may exaggerated by the climatic factors.

Haldane (1958) mentioned about alternate bearing tendency. According to him, it is essential to recognize if this is a sharply defined character, how it is persisting for years and whether it can be conquer with the help of any chemical mixtures.

Shrikande (1958) and Pankajakshan (1960) reported biennial bearing tendency in coconut palms through graphical approach however their magnitude was not specified.

Singh (1961) studied the alternate bearing tendency in the mango trees and observed that alternate bearing habit of mango is controlled by the timely production of new vegetative shoots and it does not affected by resorting to fertilizers, irrigation, pruning and pest control and it could not be controlled by the use of different varieties. According to him, major meteorological factors like rainfall and temperatures do not affect biennial bearing tendency.

According to Abeywardena (1962a), a reorientation of conventional methods of experimentation and its evaluation would be required if bienniality were recognized as a sharply distinct character and thus could not be considered simply as an academic curiosity to research personnel. The biennial or alternate bearing tendency of perennials thus necessitates a special concern in their design and analysis. An information on the degree or intensity of bienniality will be helpful to design experiments on them and also in analyzing several years yield data. According to him, the results of experiments based on individual year's yield data would be valid only if the magnitude of biennial tendency is irrelevant.

Abeywardena (1962b) applied 'B' factor proposed by Hoblyn *et al.* (1936) to 300 coconut palms to estimate biennial bearing index and observed that 38.5 per cent of the palms are showing significant biennial bearing tendency. He tried a modified approach to 'B' factor. According to him, 'B' factor cannot be directly applied to the coconut palms as these palms are highly influenced by the rainfall so he modified the yield data by regressing the effect of rainfall and the corrected yield is then used for analysing 'B' factor but he observed the same 38.5 per cent of palms with significant biennial bearing thus he concluded that rainfall does not have a significant effect on biennial bearing tendency

Northwood (1967) estimated correlation coefficient between production in subsequent years of cashew and according to him, low correlation among years put forward an affinity towards alternate bearing.

Pearce and Urbanc (1967) estimated biennial and irregular bearing phenomenon in apple trees by considering various methods.

Biennial bearing tendency in apple is influenced by the tendency to initiate flower buds and the tendency to set fruit, in which growth potential of the tree, growth of short spurs, the ratio between carbohydrate and nitrogen quantities and the hormonal activity all have a role. This emphasize the complex behavior of the biennial bearing rhythm. Attempts to neutralize biennial bearing rhythm by simple managerial measures were resulted in disappointment (Williams and Edgerton, 1974).

Friedrich (1977) in a study on apple and pear in the Western Europe reported that biennial bearing tendency and its adverse effects can be avoided by the use of modern rootstocks and tree-forms and with a proper maintenance of orchards with incorporation of modern cultivation practices.

Das and Sahoo (1981) treated the 'off' years with Gibberlic acid and urea in Langra mango. GA<sub>3</sub> at 50ppm + urea at 1 per cent, applied to trees in the 'on' year induced vegetative shoot growth and simulated the number of leaves and leaf area. These effects in the 'on' year further provided better production in the next 'off' year.

Saraswathi (1983) experimented on coconut palms and derived some orthogonal contrasts especially suited to test the significance of biennial and time trend effects in coconut. Study reported that biennial bearing tendency is an established characteristic of coconut palms and used some non parametric approaches to confirm the occurrence of alternate bearing behaviour. In the study 53 per cent of the west coast tall palms was biennial in production for the pre-experimental stage, 52.5 per cent in the experimental and 23.2 per cent in the post-experimental phase.

In the study the degree of crop fluctuations using the 'I' factor were estimated and found that 72 per cent palms are having an intensity of 30 per cent for the pre-experimental phase, and less than 20 per cent 'I' is showed by 72 per cent palms both

in experimental and post-experimental period indicating chances of treatment effect in dropping bienniality. The tests of significance confirmed presence of bienniality in pre-experimental and experimental period and its absence in post experimental period. Application of magnesium at 0.5 kg per palm per year found to increase the biennial bearing tendency.

Pal *et al.* (1984) studied alternate bearing tendency in mango by applying various treatments on mango to encourage normal bearing pattern but none of the applied treatments improved towards regular bearing. A treatment with ethephon at 200 ppm + 0.1 per cent urea in one trial or at 400 ppm + 1 per cent urea in another trial introduced five times a day at 30 (first trial) or 15 (second trial) days interval induced bearing in the 'off' years.

Lathy (1989) studied alternate bearing tendency among different coconut varieties. Study estimated magnitude of bienniality for different varieties and observed a 100 per cent, 52.26 per cent, 84.34 per cent bienniality for the palms taken from RARS, Pilicode, RARS, Kumarakom and CRS, Balaramapuram respectively. In estimated intensity of crop fluctuations for these palms and observed that all palms from three centres were found to be having an intensity less than 50 per cent. In the study the method developed by Saraswathi (1983) to test biennial effect and time-trend using the orthogonal contrasts were applied by considering 169 WCT palms maintained under a uniform system of management in the Regional Agricultural Research Station, Pilicode for a period of 8 years. Significant  $F_1$  ratio along with a non significant  $F_2$  ratio were obtained for the 8 year period viz.1969-1984 indicating presence of biennial tendency in the absence of time-trend effect for all the 8 year period.

Wahi (1994) estimated the bienniality in guava and orange using the biennial bearing index 'I' proposed by Hoblyn *et al.* (1936). And observed that 40 per cent of orange trees under study were with an 'I' factor 75 per cent compared to the mean 'I'

factor value of 55 to 75 per cent. For guava trees 74 per cent of total trees were showing significant bienniality with 'I' factor ranging from 30 to 40 per cent.

Even if Hoblyn's statistic were accepted as a universal standard to estimate the bienniality, According to Huff (2001), usage of biennial bearing index 'I' to quantify the degree of biennial bearing tendency will be misleading as it is highly sensitive to the variations in the total production of the palm, yet he could not propose any alternative to the biennial bearing index 'I'.

Five genotypes of pistachio were studied for their biennial bearing effect in the early phases by Kallsen *et al.* (2007) and found that the genotypes 'Golden Hills' and 'Lost Hills' show poor alternate bearing behaviour while the genotypes 'B19-1' and 'B5-8' showed a high alternate bearing behaviour for the first 5 to 6 years of production.

Effect of environmental and endogenous factors along with their combined effect on the biennial bearing rhythm were studied by Lavee (2007) in olive and he pointed some cultural practices viz. pruning, thinning, girdling and irrigation which have some control effect on bienniality but have temporary effects towards it.

Rosenstock *et al.* (2010) studied 4288 pistachio trees for their bienniality and observed 58 per cent of them with significant biennial rhythm. Rest of the 42 per cent palms showed a indistinguishable pattern of fluctuations in the production. The numerical measure of bienniality, the 'I' factor were estimated and found to be ranging from 0.04 to 0.83 for the 4288 trees. Maximum trees were possessing 'I' factor of 0.48. According to them, study performed over a few years with few number of replications on young trees may not capture the true biennial behaviour of the species studied.

Biennial bearing behavior affects the estimation of production and genetic parameters like heritability, repeatability *etc.* and also results in surplus and deficit in

yield. Many factors viz. marketing, pricing and demands for labor affected by the biennial tendency. Main disadvantage of biennial tendency is the effect on fruit size, large number of ugly fruits in 'on' year and few number of good quality fruits in 'off' year (Rosenstock *et al.*, 2010).

According to Guitton *et al.* (2011), flowering genes are less likely to be responsible for alternate bearing tendency than the hormone associated genes for apple trees.

Krishnamurthy *et al.* (2013) reported biennial bearing rhythm in black pepper (*Piper nigrum L.*) and found that bienniality is influenced by carbohydrates, hormones (IAA and zeatin riboside) and minerals. He observed more concentration of mineral nutrients during the 'on' phase compared to the 'off' phase for leaves and for stem cells more concentration of mineral nutrients were in the 'off' phase than in the 'on' phase and leaf and stem metabolite levels at harvest were more in the 'off' phase than in the 'on' phase telling that remobilization of nutrients to the mounting berries must have been affected throughout 'off' year, thus leading to the accumulation of more nutrients at harvest in 'off' year than in the 'on' year.

According to Rodrigues *et al.* (2013), plants possess biennial bearing tendency in their genetic material itself and expresses it with a greater magnitude due to the stress caused by various factors and also when the adverse climatic conditions occur.

Chao (2014) reported that excessive abscission of reproductive structures during fruit set period due to the failure of floral development due to heavy rainfall like adverse climatic conditions are the main cause of introduction of an 'off' year followed by an 'on' year. According to him, all unfavorable climatic conditions like high or low temperatures, heavy rain, water deficiency, strong wind can cause the destruction of reproductive structures and initiation of biennial cycle and once a cycle of alternate bearing is initiated, it will perpetuate by the effect of total number of fruit

on endogenous tree factors that eventually create an impact on floral intensity in the subsequent year.

A predominant factor controlling the intensity of yield fluctuations from year to year for coconut palm is identified by Ranasinghe *et al.* (2015). According to him, the fruit setting and abortion rates of an inflorescence in the first three months after opening of the inflorescence will affect variations in yield considerably.

Biennial bearing tendency can be confirmed by plotting the annual yield against the years. If the trend line exhibit troughs and peaks for the alternate years then it reveals the presence of bienniality for that particular palm. Graphical method will only be able to detect and confirm the biennial bearing tendency and a quantitative estimate cannot be obtained. (Wolstenholme, 2015).

Extend and intensity of biennial bearing behavior in mango were studied by Choudary *et al.* (2016) with graphical as well as quantitative approaches. The study analysed mango varieties in 4 locations over different years and calculated the B factor, tested for its significance using binomial distribution and concluded that there exist a moderate to strong bienniality in mango crop from all the four locations.

## 2.4 REPEATABILITY COEFFICIENT AND ITS IMPORTANCE

Repeatability is a measure of degree to which the variations between individuals under study depends on the genetic and permanent effects rather than the temporary effects. (Turner and Young, 1969). According to Lush (1954), repeatability is an important genetic parameter which is to be popularized among the biometricians working with the perennial crops. Statistically repeatability is nothing but an intraclass correlation coefficient over the years or over some aspect of time. The estimate of repeatability, repeatability coefficient ( $\rho$ ) is broadly used by the biometricians and geneticists as an index of the upper limit of heritability and as a measure of the efficiency of phenotypic selection. It tells us the total variation proportion which is explained by the variations provided by the genotype and by the permanent alterations associated with the common environment

Abeywardena and Fernando (1963) estimated repeatability coefficient for the number of nuts per palm with the data for the 972 palms of the N.P.K. trial conducted at Bandirippuwa Estate by the Soil Chemist's Division of the Coconut Research Institute of Ceylon and the coefficient estimated was found to be low, i.e. 0.1826.

Repeatability studies are important for perennial crops breeders, since they represent the maximum value that the heritability of a character in a wide sense can reach. They are also used to find the number of phenotypic observations to be made in each individual so that the discrimination or phenotypic selection among genotypes is efficiently carried out with low costs. In this context, repeatability coefficients have been estimated in variety of fruit crops.

According to Wahi (1994), repeatability can also be used as an index of gain in accuracy which is to be expected from the continual measurements on the same entity. Breeders are using the repeatability coefficient as the most important genetic parameter during rising of a progeny as an index of its reliability. Repeatability coefficient ranges from zero to one, one indicating the perfectly consistent

measurements with no observer error and no change in trait size between observations.

Aguiar *et al.* (2006) estimated repeatability coefficient by the analyses of variance, principal components and multivariable methods. According to them, principal component analysis with the help of correlation matrix is the most appropriate method to estimate the repeatability coefficient in various rubber varieties. In the study repeatability coefficient for perennial crops viz. cacao, coffee, mango, coconut and peach palm were documented.

Choudhary *et al.* (2016) estimated repeatability coefficient for the number of fruits per tree with the help of Analysis of Variance (ANOVA) for four locations Rewa, Sangareddy, Sabour, and Vengurla and reported a moderate estimate of repeatability at three canters viz. Rewa, Sangareddy, and Vengurla. A very low repeatability coefficient of 0.013 with standard error 0.023 observed for the third location Sabour.

## *MATERIALS AND METHODS*

### 3. MATERIALS AND METHODS

The experiment on the “Trends in production and bienniality of coconut (*Cocos nucifera* L.) var. WCT ” was carried out during the period from 2016-2018 in College of Agriculture, Vellayani, Thiruvananthapuram based on the data recorded at Coconut Research Station, Balaramapuram (8°24'0.32''N, 77°1'46.739''E) to study the trends in production of coconut variety WCT (West Coast Tall) and its variations in crop yield from year to year due to climatic factors. Study also aims to estimate the repeatability coefficient and its variations. The details of the materials used and methods followed for the analysis are presented in this chapter in the upcoming subheadings.

- 3.1 Materials used
- 3.2 Initial data analysis
- 3.3 Estimation and testing of Bienniality
- 3.4 Estimation of Repeatability
- 3.5 Effect of climatic factors on bienniality

#### 3.1 MATERIALS USED

The present study is based on the data recorded at Coconut Research Station, Balaramapuram for the past 25 years *viz.* 1993-2017. The WCT palms were planted in the year 1966 and were grown under rainfed conditions with recommended management practices. The details of the data collected are presented below.

##### **3.1.1 Biometric Data**

###### **3.1.1.1 *Number of Nuts per Palm per Harvest***

The number of nuts harvested from a palm in each harvest for the period 1993-2017 were collected for 525 palms along with the tree numbers.

### **3.1.1.2 *Number of Harvest per Year and Period of Harvest***

Total number of harvests in an year and period of each harvest were collected for the 25 years.

### **3.1.2 *Meteorological Data***

Meteorological observations recorded at Coconut Research Station, Balaramapuram was collected for the 25 year period (1993-2017) on daily basis.

#### **3.1.2.1 *Rainfall***

The amount of precipitation measured by depth in millimeters (mm) were collected for each days for the period 1993-2017. The average rainfall for each harvesting period and average annual rainfall were estimated for the said period.

#### **3.1.2.2 *Number of Rainy Days***

Number of rainy days with rainfall exceeding 2.5 mm per day were counted for each harvesting period and for each year. Number of days without rain in summer season *viz.* January to May (Dry spell) were separately counted for each years.

#### **3.1.2.3 *Wind Velocity***

Velocity of wind in kilometer per hour were collected for each days for the period 1993-2017 and averaged for each harvesting period and for each year.

#### **3.1.2.4 *Maximum and Minimum Temperature***

Highest temperature recoded in a day is the maximum temperature of that day and the lowest temperature recorded is the minimum temperature. Maximum and minimum temperatures were collected in degree Celsius unit for 1993-2017 on daily basis and averaged for each harvesting period.

## 3.2 INITIAL DATA ANALYSIS

### 3.2.1 Descriptive Statistics

Descriptive statistics are brief descriptive coefficients that summarize a given data set, which can be used to describe the basic features of the data under study. Descriptive statistics *viz.* mean, standard deviation, coefficient of variation, quartiles, were estimated for the period 1993-2017.

### 3.2.2 Elimination of Outliers

The data consist of production of 525 palms in terms of number of nuts per palm for 25 year period. As these data were recorded manually and also the sample size is huge, possibility of errors is more. There may be outliers in the data set and if they are present, results won't be reliable. Removal of outliers and extreme values is necessary before the actual analysis. There are many criteria for identifying outliers. One among them is that outliers will be greater than  $Q_3+1.5\times(Q_3-Q_1)$  and less than  $Q_1-1.5\times(Q_3-Q_1)$  where  $Q_1$ ,  $Q_2$ , and  $Q_3$  be the first, second and third quartiles. Box plot technique was used to identify the outliers present in the data.

### 3.2.3 Analysis of Variance

Analysis of variance have done to test the significant differences among the production of palms for different years and also among different harvests. Analysis of variance is a statistical method in which the variation in a set of observations is divided into distinct components and it can be used for testing the homogeneity of a given set of observations with respect to a single character. The model for testing the significant differences among years and among different harvests is;

$$Y_{ij} = \mu + \alpha_i + \varepsilon$$

where  $i = 0, 1, 2, \dots, n$  and  $j = 0, 1, 2, \dots, m$ .

$Y_{ij}$  – Production of  $j^{\text{th}}$  palm in  $i^{\text{th}}$  year

$\mu$  - General mean effect

$\alpha_i$  - Effect of  $i^{\text{th}}$  year

$\varepsilon_{ij}$  - Random error component  $\sim N(0, \sigma)$

The total dispersion is split up into various components as given in Table 1.

Table 1. Analysis of variance (ANOVA) table –Testing significance among years or harvests

Source of variation	D.f.	Sum of squares
Between years	(n-1)	
Within years	(n×(m-1))	
<b>Total</b>	<b>(mn-1)</b>	

Where  $n$  is the number of years and  $m$  is the number of palms. In case of testing significance among different harvests  $n$  being number of harvests instead of number of years. Significance of  $F$  will indicate that there is significant difference among production of nuts among different harvests or different years (Rangaswamy, 2010).

### 3.2.4 Correlation Studies

Time series analysis used to understand what are the fundamental forces, leading to a particular trend in the time series data points (production of nuts in different years). Relationship between yield and climatic factors are identified using Pearson's correlation coefficient. Correlation coefficient provides a measure of intensity or degree of linear association between two variables.

Correlation coefficient between two variables x and y is given by;

$$r = \frac{\text{Cov}(x,y)}{\sigma_x \sigma_y}$$

Where Cov (x,y) is the covariance between the two variables x and y,  $\sigma_x$  and  $\sigma_y$  be the standard deviations of x and y respectively,  $n$  is the number of observations in each set.

or,

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}}$$

Where  $\bar{x}$  and  $\bar{y}$  is the mean for x and y variables respectively. Correlation coefficient ranges between -1 to +1, -1 indicates perfect negative correlation and +1 indicates perfect positive correlation.

Significance of correlation coefficient is tested using  $t$  test. Test statistic is;

$$t = r \sqrt{\frac{n-2}{1-r^2}} \sim t_{n-2} \quad (\text{Rangaswamy, 2010}).$$

### 3.3 ESTIMATION AND TESTING OF BIENNIALITY

Biennial or alternate bearing is a common characteristic of perennials and coconut being a perennial crop exhibit alternate bearing tendency. Coconut palms which exhibit biennial rhythm will produce an above average yield in one year called 'on' year and a below average yield in the alternate year called 'off' year. While experimenting on coconut palms information about biennial tendency will be of

much importance and thus necessitates special considerations in their design and analysis.

Biennial bearing behavior is estimated using three different approaches *viz.* Graphical approach, Parametric approach and Non parametric approach.

### 3.3.1 Graphical Approach

A plot of average number of nuts per year against the years will provide a confirmation of biennial tendency, if the trend line shows troughs and peaks in the alternate years (Lathy, 1989).

### 3.3.2 Parametric Approach

Parametric approach assumes that the sample data comes from a population that follows a probability distribution based on a fixed number of parameters. Test of significance of biennial tendency are derived on the basis of several orthogonal contrasts (Saraswathi, 1983). Biennial effect, time trend and random error are the terms involved in each contrast. Biennial effect is the change in yield due to biennial bearing tendency and time trend is the pattern of gradual change in the average yield over years. If  $Y_{i1}$ ,  $Y_{i2}$ ,  $Y_{i3}$ , and  $Y_{i4}$  are the yield of  $i^{\text{th}}$  palm in the first, second, third and fourth years respectively;

$$Y_{i1} = Y_i - \frac{3}{2}\lambda - \frac{1}{2}\delta + e_{i1}$$

$$Y_{i2} = Y_i - \frac{1}{2}\lambda + \frac{1}{2}\delta + e_{i2}$$

$$Y_{i3} = Y_i + \frac{1}{2}\lambda - \frac{1}{2}\delta + e_{i3}$$

$$Y_{i4} = Y_i + \frac{3}{2}\lambda + \frac{1}{2}\delta + e_{i4}$$

Where  $Y_i$  is the expected yield of  $i^{\text{th}}$  palm,  $\lambda$  is the time-trend effect,  $\delta$  is the difference between the on and off year effect and  $e_{ij}$  is a random variable which is normally and independently distributed with  $N(0, \sigma_e^2)$ . The contrasts are defined as;

$$X_{i1} = \frac{1}{\sqrt{4}}(Y_{i1} - Y_{i2} - Y_{i3} + Y_{i4})$$

$$X_{i2} = \frac{1}{\sqrt{20}}(-Y_{i1} + 3Y_{i2} - 3Y_{i3} + Y_{i4})$$

$$X_{i3} = \frac{1}{\sqrt{20}}(-3Y_{i1} - Y_{i2} + Y_{i3} + 3Y_{i4})$$

$$X_{i4} = \frac{1}{\sqrt{4}}(-Y_{i1} - Y_{i2} + Y_{i3} + Y_{i4})$$

$$X_{i5} = \frac{1}{\sqrt{4}}(-Y_{i1} + Y_{i2} - Y_{i3} + Y_{i4})$$

The contrasts  $X_{i1}$ ,  $X_{i2}$ , and  $X_{i3}$  are mutually orthogonal.  $X_{i4}$  and  $X_{i5}$  are not orthogonal to either  $X_{i2}$  and  $X_{i3}$ . The contrast  $X_{i3}$  is orthogonal to  $X_{i1}$  and  $X_{i2}$  but not orthogonal to  $X_{i4}$  and  $X_{i5}$ . Substituting the values of  $Y_{i1}$ ,  $Y_{i2}$ ,  $Y_{i3}$ , and  $Y_{i4}$ ,

$$X_{i1} = \frac{1}{\sqrt{4}}(e_{i1} - e_{i2} - e_{i3} + e_{i4})$$

$$X_{i2} = \frac{1}{\sqrt{20}}(4\delta - e_{i1} + 3e_{i2} - 3e_{i3} + e_{i4})$$

$$X_{i3} = \frac{1}{\sqrt{20}}(10\lambda + 2\delta - 3e_{i1} - e_{i2} + e_{i3} + 3e_{i4})$$

$$X_{i4} = \frac{1}{\sqrt{4}}(4\lambda - e_{i1} - e_{i2} + e_{i3} + e_{i4})$$

$$X_{i5} = \frac{1}{\sqrt{4}}(2\lambda + 2\delta - e_{i1} + e_{i2} - e_{i3} + e_{i4})$$

The contrast  $X_{i1}$  is independent of both time trend and biennial effect but have random error component.  $X_{i2}$  is influenced by biennial effect but independent of time trend ;  $X_{i4}$  is affected by time trend but free from biennial effect ;  $X_{i3}$  and  $X_{i5}$  are influenced by both time trend and biennial effect. Biennial effect will be positive or negative based on the year of starting being off or on year.

### 3.3.2.1 Testing Significance of Biennial Tendency in Absence of Time Trend

The contrasts  $X_{i1}$  and  $X_{i2}$  are orthogonal.

$$E\left(\frac{1}{n} \sum_i X_{i1}\right) = 0 \text{ and}$$

$$E\left(\frac{1}{n} \sum_i X_{i2}\right) = \frac{4}{20} \delta$$

The expectation of  $\frac{1}{n} \sum_i X_{i2}^2$  involves biennial effect and random error component and free from time-trend effect.

To test the significance of biennial tendency, the null hypothesis and alternate hypothesis can be stated that

$$H_0 : \delta = 0$$

$$\text{v/s } H_1 : \delta \neq 0$$

F test is given by,

$$F_1(n, n) = \frac{\sum_i \frac{X_{i2}^2}{n}}{\sum_i \frac{X_{i1}^2}{n}} \sim F_{(n, n)}$$

This  $F_1$  ratio is distributed as the conventional  $F$  with  $n_1 = n$  and  $n_2 = n$  degrees of freedom where  $n$  is the sample size. This offers a test of significance of biennial effect when the time-trend effect is absent .

### 3.3.2.2 Testing Significance of Time Trend Effect in Presence of Biennial Tendency

The contrasts  $X_{i3}$  is orthogonal to contrasts  $X_{i1}$  and  $X_{i2}$  and involves both  $\lambda$  and  $\delta$ . A test for time-trend  $\lambda$  in presence of biennial tendency  $\delta$  can be derived by considering the contrasts  $X_{i3}$ ,  $X_{i1}$  and  $X_{i2}$ .

The null hypothesis and alternate hypothesis can be stated that

$$H_0 : \lambda = 0 \text{ v/s } H_1 : \lambda \neq 0$$

The ratio,

$$F_2(n, 2n) = \frac{\sum_i \frac{X_{i3}^2}{n}}{\left( \frac{1}{2} \sum_i X_{i2}^2 + \frac{3}{2} \sum_i X_{i1}^2 \right) / 2n} \sim F_{(n, 2n)}$$

Is distributed as the conventional  $F$  with  $n_1 = n$  and  $n_2 = 2n$  degrees of freedom where  $n$  is the sample size. This offers a test of significance of time-trend  $\lambda$  in presence of biennial tendency  $\delta$ .

### 3.3.2.3 Testing Significance of Time Trend in Absence of Biennial Tendency

The contrasts  $X_{i4}$  and  $X_{i5}$  are orthogonal to  $X_{i1}$  But not orthogonal to  $X_{i2}$  and  $X_{i3}$ . Test of significance of time-trend effect independent of biennial effect can be derived by using the contrasts  $X_{i4}$ ,

The null hypothesis can be stated that

$$H_0 : \lambda = 0$$

Against the alternate hypothesis

$$H_1 : \lambda \neq 0$$

Then ratio given by ;

$$F_3(n, n) = \frac{\sum_i \frac{X_{i4}^2}{n}}{\sum_i \frac{X_{i1}^2}{n}} \sim F_{(n,n)}$$

Is distributed as the conventional  $F$  with  $n_1 = n$  and  $n_2 = n$  degrees of freedom. This provides a test of significance of time-trend effect independent of the biennial effect.

#### 3.3.2.4 Testing Significance of Biennial Tendency in Presence of Time Trend

Let the contrasts  $X_{i5}$  is orthogonal to contrasts  $X_{i1}$  and  $X_{i4}$  and involves both  $\lambda$  and  $\delta$ . A test for biennial tendency  $\delta$  in presence of time-trend  $\lambda$  can be derived by considering the contrasts  $X_{i5}$ ,  $X_{i1}$  and  $X_{i4}$ .

The null hypothesis and alternate hypothesis be,

$$H_0 : \delta = 0$$

$$v/s H_1 : \delta \neq 0$$

The  $F$  ratio is given by,

$$F_4(n, 2n) = \frac{\sum_i \frac{X_{i5}^2}{n}}{\left( \frac{1}{2} \sum_i X_{i4}^2 + \frac{3}{2} \sum_i X_{i1}^2 \right) / 2n} \sim F_{(n, 2n)}$$

Is distributed as the conventional  $F$  with  $n_1 = n$  and  $n_2 = 2n$  degrees of freedom where  $n$  is the sample size. This ratio provides the test of significance of biennial tendency  $\delta$  in presence of time-trend  $\lambda$ .

Significance of biennial tendency and time trend can be tested using the above  $F$  ratios viz.  $F_1, F_2, F_3$  and  $F_4$ . Biennial tendency of palms can be first tested by  $F_1$  criteria on the hypothesis of absence of time trend effect, If palms exhibit biennial tendency by this test then effect of time trend was tested by  $F_2$  criterion. If palms not influenced by time trend effect so  $F_1$  test itself gives evidence of biennial tendency. If palms influenced by time trend so proper test for testing significance of biennial tendency is  $F_4$ . If palms do not exhibit biennial tendency by  $F_1$  then  $F_3$  will provide effect of time-trend in the absence of bienniality. The above tests developed by Saraswathi (1983) were utilized to test for the significance of biennial tendency and time-trend.

### 3.3.3 Non Parametric Approach

The biennial effect can be examined by non parametric methods. Non parametric methods makes no assumptions and could be employed on observed data despite of the superimposition of fluctuations due to weather. The two alternate bearing indices 'B' and 'I' proposed by Hoblyn *et al.* (1936) and measurement of biennial tendency using spearman's rank correlation are the non parametric methods for estimating bienniality

#### 3.3.2.1 Hoblyn's 'B' Factor

The cropping performance of a tree viz., regularly annual, biennial or irregular can be explained using Hoblyn's 'B' factor (Hoblyn *et al.*, 1936). At least three years of crop records is needed for determining 'B' factor. If the next year yield exceeds the previous year's yield, a plus (+) sign is given for the difference

otherwise, a minus sign (-). Similarly, a series of signs for each consecutive pairs of years is calculated.

From this series, the 'B' factor is computed by determining the percentage of consecutive pairs of unlike signs over the whole period. A complete bienniality in yield is indicated by the value of 'B'=100 whereas 'B' = 0 indicates either regular increase or regular decrease in yield.

If  $n$  is the number of years, 'B' factor can be obtained for  $(n-2)$  pairs of dissimilar signs. The probability of getting  $0, 1, 2, \dots, n$  unlike signs is distributed as binomial.

$$P_n(x) = \binom{n}{x} p^x q^{n-x}$$

$$x = 0, 1, 2, \dots, n.$$

Where  $p$  is the probability of getting  $x$  unlike signs in  $n$  pairs of consecutive years and  $q = 1-p$ .

Based on equiprobable hypothesis, *i.e.*, the probability of unlike signs in any pair of consecutive years is 0.50, a test of significance for bienniality were developed by Saraswathi (1983) using binomial probabilities given by:

$$P(x) = \binom{n}{x} \left(\frac{1}{2}\right)^x \left(\frac{1}{2}\right)^{n-x}$$

Where,  $x$  is the number of pairs of unlike signs ( $x = 0, 1, 2, \dots, n$ ).

Chi square test is applied in order to test the significant departure from the equiprobable hypothesis and is given by;

$$\chi^2 = \frac{(p - p')^2}{\frac{pq}{n}} \sim \chi^2_{(N-1)}$$

Where  $n$  is the number of years and  $p' = P(X \geq x)$ , is the observed proportion of palms showing like signs for  $x$  and above.

### 3.3.2.2 Hoblyn's 'I' Factor

Yield in a year is affected by the previous year's yield in the case of alternate bearing mechanism. Alternate bearing index ('I') suggested by Hoblyn *et al.* (1936) quantifies the extent to which this serial dependence takes place.

$$I = \frac{\text{Difference between two successive yields}}{\text{Sum of the two successive yields}}$$

For  $n$  years 'I' obtained as the sum of the absolute value of the difference in yields between two successive years  $t$  and  $t-1$ , scaled by the sum of the yields over these two years; and then standardized over the total number of years.

$$I = \frac{\sum_{t=2}^n (|Y_t - Y_{t-1}|) / (|Y_t + Y_{t-1}|)}{n-1}$$

The 'I' factor gives a measure of intensity or degree of crop fluctuations from year to year and it varies between 0 and 1, with 'I' = 0 represent no alternate bearing behaviour and 'I' = 1 correspond to strict alternate bearing behaviour.

### 3.3.2.3 Measurement of Biennial Tendency by Using Spearman's Rank Correlation Coefficient

This method makes no assumptions whatsoever and could be employed on observed data despite of the superimposition of fluctuations due to weather.

Ranks are given to individual tree yield either in descending or ascending order, but in the same order for all the years. This is based on the fact that the Spearman's rank correlation coefficients for the alternate years should be high compared to that for the adjacent years (Choudhary *et al.*, 2016). Spearman's rank correlation coefficients are calculated for every pair of adjacent years and every pair of alternate years.

If the ranks are observed to be more in alternate years than in adjacent years, it is said that biennial tendency is present because a tree that is in the 'on' phase in a particular year will be in the 'off' phase in the adjacent year and again in the 'on' phase in the subsequent year. A palm if in a particular year produce an above average yield then it is said to be in the 'on' phase and if it produce a below average yield then in the 'off' phase.

Two sets of measurements are ranked separately and then Spearman's rank correlation is calculated by;

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n-1)}$$

Where  $d_i$ 's are the differences between the ranks of each pairs and  $n$  is the number of observations (Rangaswamy, 2010).

Rank sum test or Wilcoxon's test provides a test of significance of whether the correlation coefficient is higher for the alternate years than adjacent years. Let there are  $m$  coefficients ( $r_1, r_2, \dots, r_m$ ) for alternate years and  $n$  coefficients ( $r_1, r_2, \dots, r_n$ ) for

adjacent years. Then the null hypothesis is that there is no difference in  $m$  coefficients  $(r_1, r_2, \dots, r_m)$  for alternate years and  $n$  coefficients  $(r_1, r_2, \dots, r_n)$  for adjacent years.

These coefficients are combined together into a single ordered series and ranked from 1 (the lowest) to  $m + n$  (the highest). All the ranks of the first set of  $m$  correlation coefficients are added and let it be  $T$ , the total score. For large values of  $n$  and  $m$ ,  $T$  is distributed with mean and variance given by;

$$E(T) = \frac{1}{2} m (m + n + 1)$$

$$V(T) = \frac{1}{12} mn (m + n + 1)$$

For large samples, test statistic is;

$$Z = \frac{|T - E(T)|}{\sqrt{V(T)}} \sim N(0,1) \quad (\text{Abeywardena, 1962}).$$

### 3.4 ESTIMATION OF REPEATABILITY

Repeatability is actually a measure of the degree to which differences between individuals depend on genetic and permanent environmental effects rather than temporary effects. In statistical terms repeatability is considered as the intra class correlation over the years / or over some aspect of time (Wahi, 1994). Estimation of gain in accuracy to be expected from repeated measurements on the same individual can also be determined from repeatability.

#### 3.4.1. Estimation of Repeatability by ANOVA

The estimate of repeatability is regarded as a measure of the upper limit of heritability and as a measure of the efficiency of phenotypic selection. It is the most

suitable genetic parameter for assessing the genetic improvement widely used by the breeders.

Analysis of Variance (ANOVA) can be used for estimating the repeatability. Consider a linear model;

$$Y_{ij} = \mu + g_i + t_j + e_{ij}$$

where  $i = 1, 2, \dots, n$  and  $j = 1, 2, \dots, k$ .

$n$  is the number of palms under study and  $k$  is the number of years.

And  $Y_{ij}$  is the response (say yield) of  $i^{\text{th}}$  tree at  $j^{\text{th}}$  time period,  $\mu$  is the general mean,  $g_i$  is the  $i^{\text{th}}$  tree effect,  $t_j$  is the  $j^{\text{th}}$  period effect and  $e_{ij}$  random error distributed normally with  $N(0, \sigma_e^2)$ .

After suppressing the fixed time effect, the model reduces to,

$$Y_{ij} = \mu + g_i + e_{ij}$$

where  $i = 1, 2, \dots, n$  and  $j = 1, 2, \dots, k$ .

On the basis of this model, the between trees mean sum of square (MSG) and within tree mean sum of square (MSE) respectively are computed. The estimators of  $\sigma_e^2$  and  $\sigma_g^2$  are obtained by equating the mean squares of each source of variation to its expectation.

The estimators are ;

$$\hat{\sigma}_e^2 = MSE ;$$
$$\sigma_g^2 = \frac{MSG - MSE}{k}$$

Repeatability ( $\rho$ ) was estimated as ;

$$\hat{\rho} = \frac{\hat{\sigma}_g^2}{\hat{\sigma}_g^2 + \hat{\sigma}_e^2}$$

with variance,

$$V(\hat{\rho}) = \frac{2[1 + (k - 1)\rho]^2(1 - \rho)^2}{k(k - 1)(n - 1)}$$

Analysis of variance table for estimating the repeatability coefficient is presented in Table 2.

Table 2. ANOVA table for estimating repeatability coefficient.

Source	D.f.	Mean sum of Squares (MSS)	Expectation of Mean Square- E(MS)
Individuals	n-1	$\frac{K \sum_{i=1}^n (\bar{Y}_i - \bar{Y}_{..})^2}{n - 1}$	$\sigma_e^2 + k\sigma_g^2$
Time	k-1	$\frac{n \sum_{j=1}^k (\bar{Y}_j - \bar{Y}_{..})^2}{k - 1}$	$\sigma_e^2 + \frac{n}{k-1} \sum_{j=1}^k t_j^2$
Error	(n-1)(k-1)	$\frac{\sum_{i=1}^n \sum_{j=1}^k (Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{Y})^2}{(n-1)(k-1)}$	$\sigma_e^2$

### 3.5 EFFECT OF CLIMATIC FACTORS ON BIENNIALITY

Biennial bearing index 'B' proposed by Hoblyn *et al.* (1936) is obtained for each individual palm on account of production data for 25 years. As the climatic factors are available on yearly basis, while considering an year, the number of trees in the 'on' phase or number of trees in the 'off' phase will act as index of bienniality. Effect of climatic factors on the number of trees in 'on' phase and number of trees in 'off' phase in an year is identified using correlation coefficient. Linear regression models are tried to fit using step wise multiple regression method with the help of statistical package SPSS.

## *RESULTS AND DISCUSSION*

## 4. RESULTS AND DISCUSSION

The results on application of statistical techniques on the data collected from the Coconut Research Station, Balaramapuram are described in this chapter. Number of nuts produced by five hundred and twenty five WCT palms for the twenty five years period each coming under six harvests in an year were evaluated for the study along with the meteorological observations. Results obtained from the study in accordance with the objectives specified are discussed under the upcoming subheadings.

- 4.1 Elimination of outliers
- 4.2 Descriptive statistics
- 4.3 Analysis of variance
- 4.4 Correlation studies
- 4.5 Estimation and testing of bienniality
- 4.6 Estimation of repeatability
- 4.7 Effect of climatic factors on yield and bienniality

### 4.1 ELIMINATION OF OUTLIERS

Initial data analysis was carried out to identify and remove the outliers present in the total production of individual palms for the twenty five year period using box plot. Box plot was drawn using SPSS package and outliers (if any) present in the samples were removed from the analysis. The figures are given in Figure 1. Palms without having continues production data for all the 25 years were also eliminated from the remaining analysis.

First, second and third quartiles were obtained for total yield per palm from box plot as 1347, 1612 and 1877. Box plot identified 14 palms having the total production for 25 years, less than 552 nuts per palm and greater than 2672 nuts per palm as outliers and are eliminated from the remaining analysis. 110 palms were not

having data for the production of nuts for all the harvests for the period 1993-2017 and such palms were also eliminated. Thus a total of 124 palms excluded from the remaining analysis and 401 palms are retained for further study.

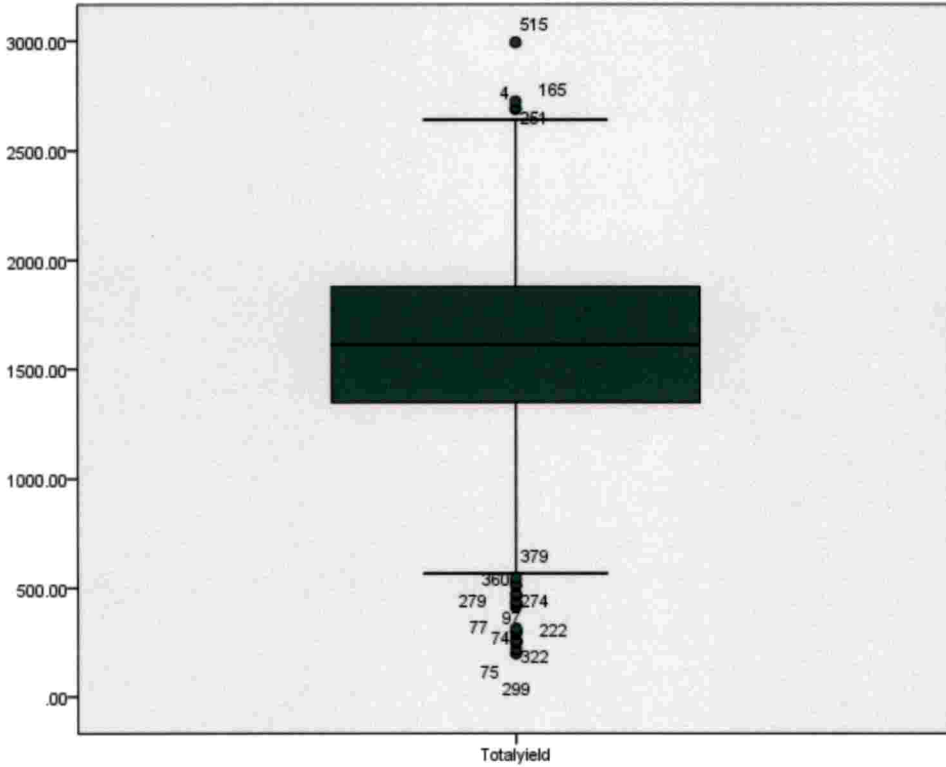


Figure 1. Box plot for total number of nuts produced from 1993 to 2017

#### 4.2 DESCRIPTIVE STATISTICS

Descriptive statistics for the number of nuts produced in an year and for each harvest are estimated and presented in the Table 3 and Table 4. It is observed from the table that a coconut palm produces an average of 68.52 nuts in an year with an overall standard deviation of 37.83 with standard error 1.89. Maximum number of

nuts produced in an year per palm was found to be 205 and the minimum number of nuts produced is zero. Year wise descriptive statistics are presented in Appendix I.

Table 3. Descriptive statistics for the number of nuts produced per palm per year

Mean	68.52
Median	63.00
Standard deviation	37.83
Max	205
Min	0
Q1	41.00
Q3	90.00
Coefficient of variation	55.21

Table 4. Descriptive statistics for the number of nuts produced for each harvest

	1 <sup>st</sup> Harvest	2 <sup>nd</sup> Harvest	3 <sup>rd</sup> Harvest	4 <sup>th</sup> Harvest	5 <sup>th</sup> Harvest	6 <sup>th</sup> Harvest
Mean	12.2	16	14.1	9.04	8.68	12.6
Median	10	13	12	7	6	10
Standard deviation	10.7	14.1	13.2	8.82	8.9	11.8
Q1	5	6	5	3	3	5
Q3	16	22	20	13	12	17
Coefficient of variation	87.7	88	93.5	97.5	102	93.4

Maximum number of nuts was recorded during 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> harvest , while the predominance of nuts was low in 5<sup>th</sup> and 6<sup>th</sup> harvest.

Average number of nuts produced by the 401 palms for each harvests for different years are presented in the Table 7. The maximum number of nuts *i.e.* 28.98 was observed for the third harvest for the year 1994. Average number of nuts produced in each harvests against the years were plotted from these data and are presented in the Figure 2. From this graph it can be see that there is an alternate increase and decrease in production for each harvests and thus there is alternate trends in production among different harvests. Average number of nuts produced by the 401 palms for each year are then estimated and presented in the Table 5. A plot based on this data is given in the Figure 3. The average yield of WCT palms during the period 1993 to 1995 showed an increasing trend while for the period 1995 to 1999 decreasing trend was noticed. In the year 1996 to 2011, alternate troughs and peaks in production was observed in two year interval. A steady decrease in production was observed from 2012 onwards and as these palms were planted in the year 1966, a steady decrease in yield after about 50 years of planting can be acknowledged from these results.

Table 5. Average number of nuts produced by the 401 palms for each year.

Year	Average Production	Standard deviation	Coefficient of variation (per cent)
1993	86.63	40.14	46.34
1994	96.93	41.33	42.63
1995	110.47	37.47	33.92
1996	90.32	39.25	43.46
1997	89.55	37.58	41.97
1998	72.28	34.07	47.14
1999	69.63	32.57	46.77
2000	78.27	34.07	43.52
2001	81.46	32.87	40.34
2002	56.05	28.67	51.16
2003	64.07	36.98	57.71
2004	69.12	35.99	52.07
2005	53.17	41.56	78.18
2006	66.95	31.86	47.58
2007	79.80	35.19	44.09
2008	72.05	35.05	48.64
2009	53.36	36.68	68.74
2010	47.67	20.14	42.24
2011	60.03	22.86	38.09
2012	84.97	31.35	36.89
2013	54.85	36.98	67.43
2014	44.79	25.45	56.83
2015	50.50	25.01	49.52
2016	42.93	22.54	52.49
2017	37.01	15.19	41.03
Overall	68.52	37.83	55.21

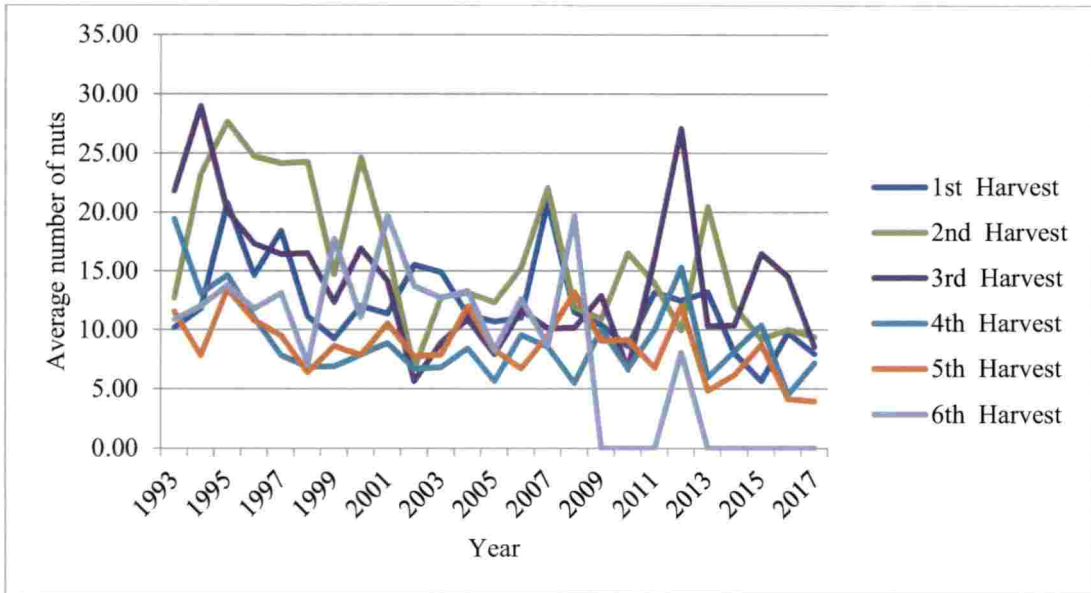


Figure 2. Plot of average number of nuts produced for each harvest over years

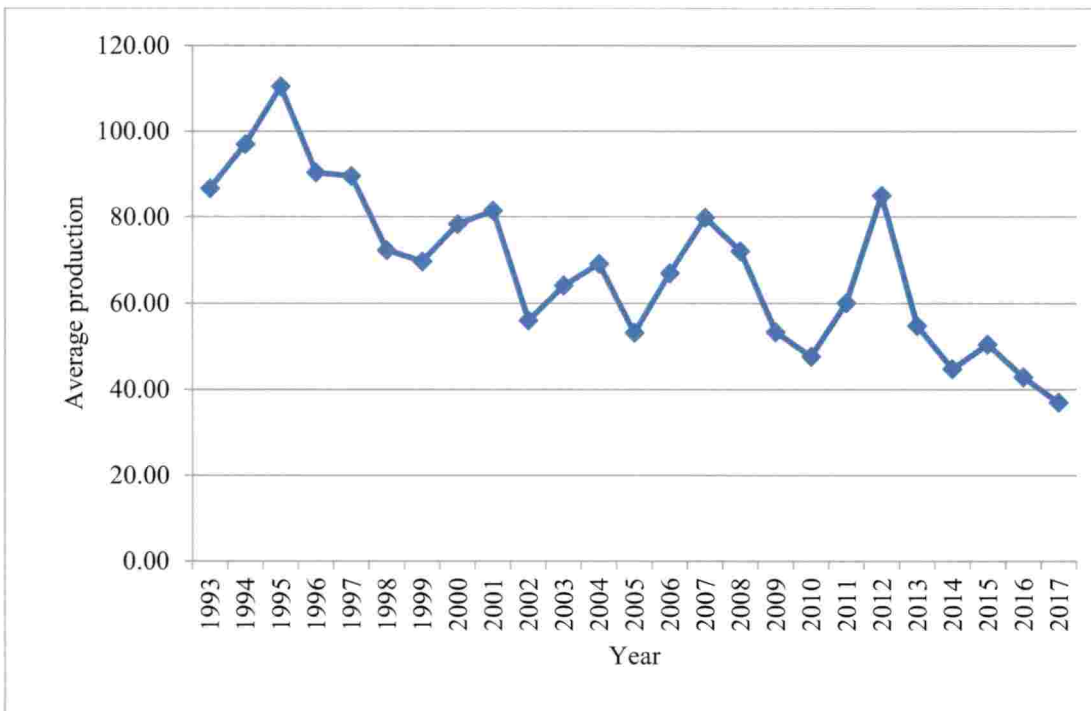


Figure 3. Plot of average number of nuts produced in an year over years

### 4.3 ANALYSIS OF VARIANCE

Analysis of variance (ANOVA) for the number of nuts produced by individual palms revealed high significant difference between different palms with respect to each harvest in all the years and the results are presented in the Table 6.

Table 6. ANOVA table to test significance among different harvests

Year	MSS-Between harvest	MSS-within harvest	F value
1993	9730.1	109.4	89.0*
1994	26386.1	179.3	147.2*
1995	12344.0	127.7	96.7*
1996	11572.3	159.2	72.7*
1997	14609.1	133.2	109.7*
1998	20339.0	111.7	182.1*
1999	6783.7	105.8	64.1*
2000	16646.3	152.3	109.3*
2001	6784.0	108.8	62.4*
2002	7030.3	86.3	81.4*
2003	4164.2	109.1	38.2*
2004	1292.0	122.6	10.5*
2005	2209.5	119.7	18.5*
2006	3360.0	82.7	40.6*
2007	16318.3	138.6	117.7*
2008	8563.2	133.1	64.3*
2009	809.1	65.8	12.3*
2010	6683.7	73.2	91.3*
2011	5376.9	95.8	56.1*
2012	18428.2	164.8	111.8*
2013	15844.0	85.7	185.0*
2014	2075.8	81.9	25.4*
2015	6359.1	73.5	86.5*
2016	7512.3	66.0	113.9*
2017	1744.6	34.8	50.1*

\*Significant at 5 per cent level of significance

Average number of nuts produced by the 401 palms for each harvest for different years are presented in Table 7. Maximum of 15.99 nuts were obtained from the second harvest. Analysis of variance have done again to test the significant differences between the production of palms for different years and the results revealed significant F value indicating significant difference between different palms with respect to each year and the results are presented in the Table 8.

Table 7. Average number of nuts produced by the 401 palms for each harvest for different years

Year	1 <sup>st</sup> Harvest	2 <sup>nd</sup> Harvest	3 <sup>rd</sup> Harvest	4 <sup>th</sup> Harvest	5 <sup>th</sup> Harvest	6 <sup>th</sup> Harvest
1993	10.17	12.73	21.83	19.43	11.59	10.89
1994	11.79	23.22	28.98	13.08	7.85	12.01
1995	20.80	27.67	20.06	14.67	13.47	13.80
1996	14.63	24.75	17.33	11.02	10.80	11.79
1997	18.44	24.16	16.42	7.85	9.54	13.14
1998	11.16	24.27	16.51	6.86	6.38	7.10
1999	9.25	14.74	12.35	6.91	8.63	17.75
2000	12.03	24.66	16.93	7.90	7.86	11.07
2001	11.39	16.78	14.16	8.87	10.54	19.73
2002	15.54	6.68	5.64	6.72	7.77	13.71
2003	14.90	12.77	8.93	6.84	7.90	12.74
2004	11.28	13.15	10.92	8.43	12.02	13.32
2005	10.71	12.35	7.91	5.65	8.28	8.27
2006	11.03	15.30	11.69	9.56	6.72	12.65
2007	20.89	22.08	10.13	8.53	9.50	8.67
2008	11.53	11.95	10.16	5.49	13.21	19.71
2009	10.43	10.93	12.90	10.02	9.07	0.00
2010	8.61	16.56	6.63	6.72	9.15	0.00
2011	13.19	13.96	16.12	10.00	6.76	0.00
2012	12.47	9.97	27.07	15.32	12.04	8.09
2013	13.20	20.48	10.33	5.96	4.87	0.00
2014	8.03	12.02	10.38	8.18	6.16	0.00
2015	5.65	9.19	16.49	10.41	8.75	0.00
2016	9.75	10.02	14.51	4.49	4.15	0.00
2017	7.94	9.38	8.54	7.18	3.96	0.00
Overall	<b>12.20</b>	<b>16.00</b>	<b>14.10</b>	<b>9.04</b>	<b>8.67</b>	<b>12.6</b>

Table 8. ANOVA table to test significance among different years

Source of Variation	SS	Df	MS	F
Between Years	3357800	24	139908.4	127.3353*
Within Years	10987398	10000	1098.74	
Total	14345198	10024		

Thus Analysis of variance (ANOVA) for the number of nuts produced by individual palms revealed significant difference between different palms with respect to each harvest and also with respect to each year.

#### 4.4 CORRELATION STUDIES

Correlation matrix showing correlation between average yield of different harvests are shown in the Table 9. Significant correlation were observed with the previous harvest of the same year. Thus number of nuts obtained from a harvest significantly influences the production of next harvest. Effect of different harvests of current and previous years of harvest were estimated using correlation coefficient between them and are presented in the Table 10. All the coefficients were not significant thus production of a particular harvests does not influenced by the production of nuts for the previous year. Correlation coefficient between current year yield and previous year yield obtained based on 25 year's yiled data and was 0.69, significant at five per cent level of significance, thus current year yield is having a significant linear relationship with the previous year's yield. Correlation matrix showing correlation coefficients based on 401 palms among 25 years are shown in Appendix II.

Table 9. Correlation matrix - Correlation coefficient between different harvests.

	1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest	6th harvest
1st harvest	1.00					
2nd harvest	0.56*	1.00				
3rd harvest	0.09	0.35*	1.00			
4th harvest	0.13	0.14	0.75*	1.00		
5th harvest	0.34	0.17	0.30	0.51*	1.00	
6th harvest	-0.10	-0.20	-0.10	-0.14	0.44*	1

\*Significant at 5 per cent level of significance

Table 10. Correlation between different harvests of successive years

	r <sub>1</sub>	r <sub>2</sub>	r <sub>3</sub>
1993-1994	0.03	0.03	-0.01
1994-1995	0.09	0.06	0.10
1995-1996	0.09	0.07	0.10
1996-1997	0.14	0.10	0.12
1997-1998	0.09	0.07	0.09
1998-1999	0.12	0.12	0.17
1999-2000	-0.04	0.05	0.07
2000-2001	0.15	0.15	0.18
2001-2002	0.21	0.04	0.04
2002-2003	0.11	0.10	0.09
2003-2004	0.13	0.16	0.00
2004-2005	-0.02	-0.02	-0.02
2005-2006	0.01	-0.08	0.04
2006-2007	0.00	0.13	0.11
2007-2008	0.02	0.10	-0.05
2008-2009	0.18	0.75*	0.34
2009-2010	0.06	-0.02	0.12
2010-2011	-0.04	-0.05	0.03
2011-2012	0.11	-0.05	0.05
2012-2013	-0.06	0.03	0.06
2013-2014	-0.07	-0.06	-0.03
2014-2015	0.03	0.02	0.10
2015-2016	-0.01	0.09	0.15
2016-2017	0.17	0.20	0.10

174493



\*Significant at 5 per cent level of significance

r<sub>1</sub> - Correlation between first harvest of current year and second harvest of next year

r<sub>2</sub> - Correlation between second harvest of current year and third harvest of next year

r<sub>3</sub> - Correlation between third harvest of current year and fourth harvest of next year

## 4.5 ESTIMATION OF BIENNIALITY

### 4.5.1 Graphical Approach

The data used for the study refers to 401 palms of WCT cultivated at the Coconut Research Station, Balaramapuram. A visual idea of alternate bearing tendency of coconut palm can be recognized from the examination of trends in annual yields over years. If the graph of annual yield against years shows an incline and decline in behavior alternatively over years, is the clear indication of alternate bearing tendency. Annual yield over years is plotted for a single palm selected at random and are presented in the Figure 4a. A plot of total yield against years for low (Tree No. 65), medium Tree No. 19) and heavy (Tree No. 518) yielding palms also showed alternate troughs and peaks for successive years and this alternation is more prevailed in the palm with medium yield. The graph is shown in Figure 4b.

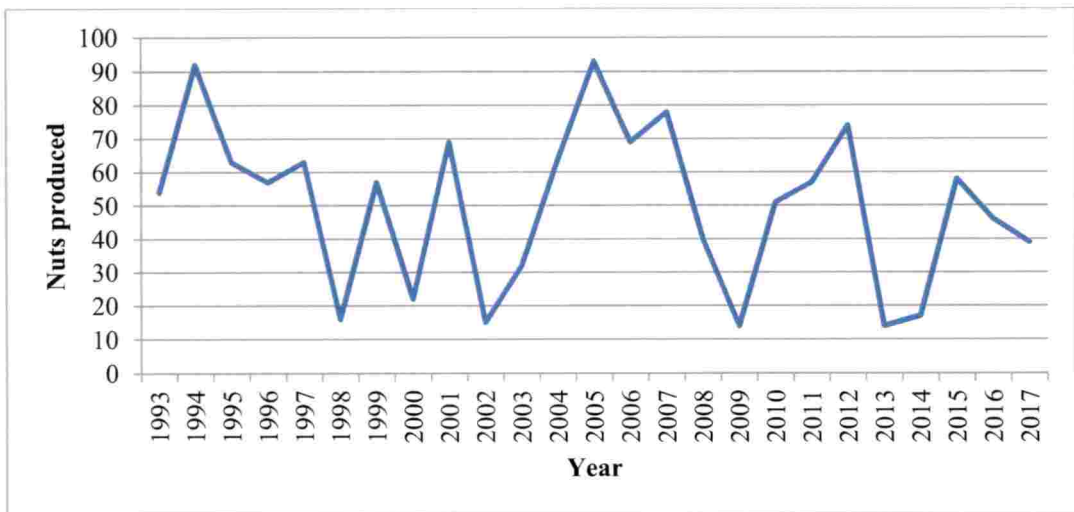


Figure 4a. Plot of average yield over years for a single tree selected at random (Tree No.100)

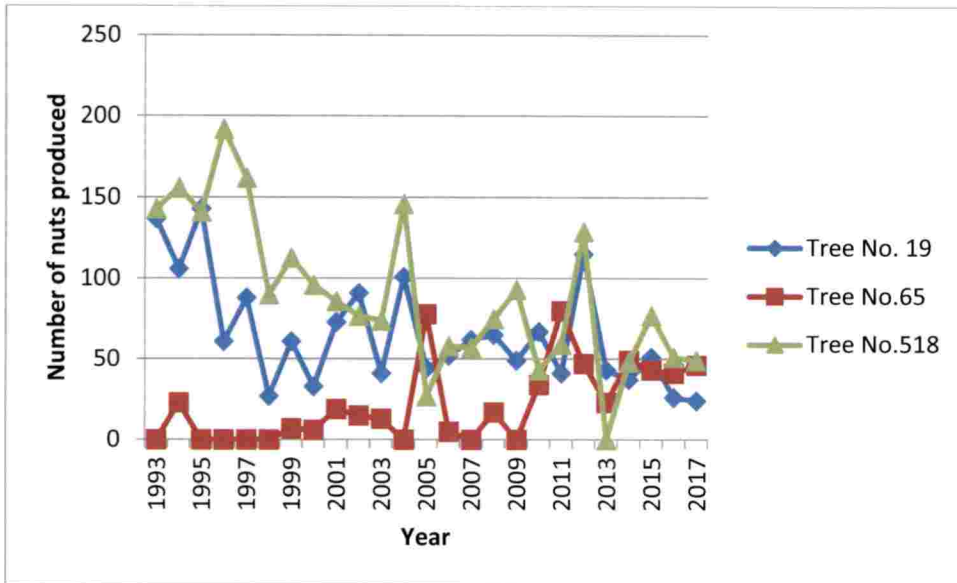


Figure 4b. Plot of average yield over years for low (Tree No. 65), Medium(Tree No. 19) and high (Tree No. 518) yielding trees

From the graph it can be seen that there is an alternate peaks and troughs in yield from 1993 to 2017 while irregularities in this pattern observed for the years 1994, 2003, 2010 and 2014. Biennial bearing tendency can be confirmed from this graph for the selected tree. Plot of average annual yield for all palms together over years will not give a clear idea of biennial bearing tendency as for a particular year if some plants are in ‘on’ phase some others would be in the ‘off’ phase. Thus an alternate graph is drawn to confirm biennial bearing tendency and is done by identifying the ‘on’ and ‘off’ phase palms for the first year and plotting average yield for ‘on’ phase palms over years and average yield for ‘off’ phase palms over years separately. These graphs are presented in the Figure 5 and Figure 6

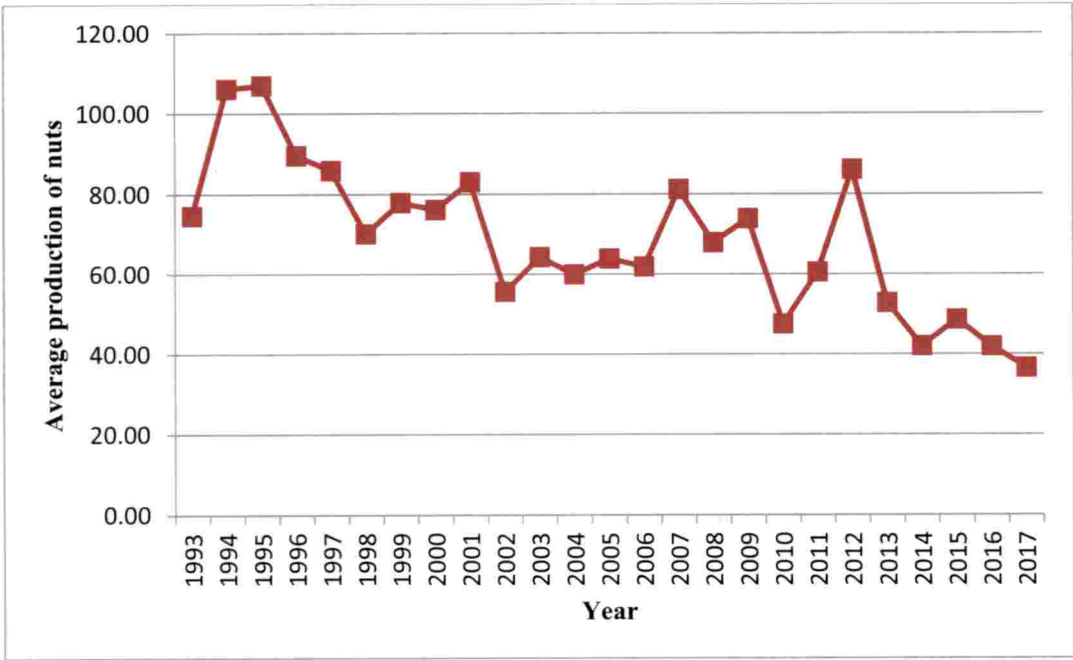


Figure 5. Plot of average production of nuts over years for 'off' phase palms

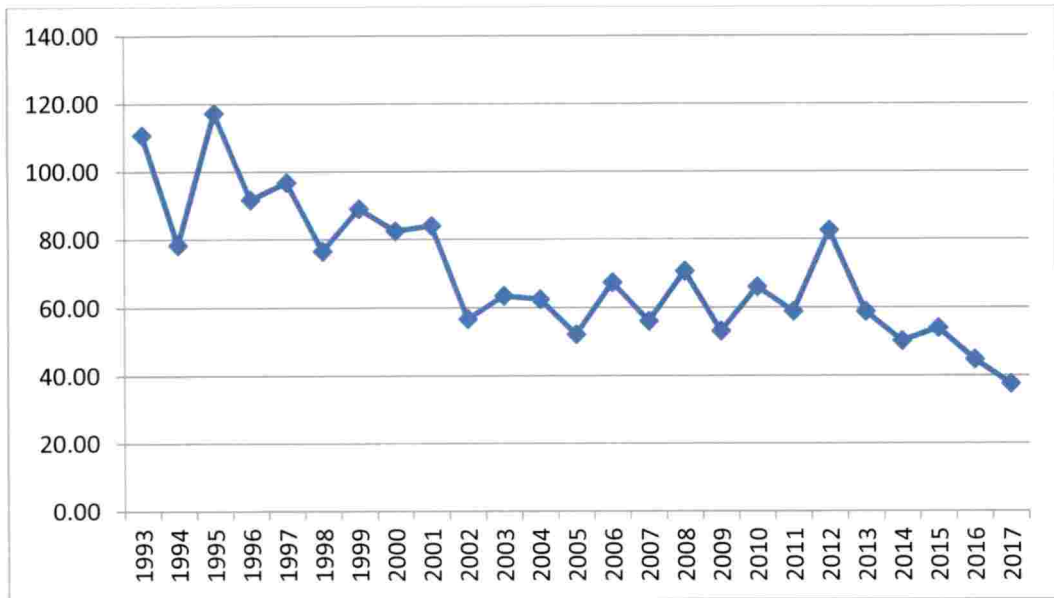


Figure 6. Plot of average production of nuts over years for 'on' phase palms

Both graphs shows troughs and peaks alternatively over years and thus graphical approach confirms biennial bearing tendency for all the 401 WCT palms. But the graphical approach do not give a quantitative estimate of biennial tendency which is further estimated using parametric and non parametric approaches.

Graphical approach was used to confirm biennial bearing tendency in coconut in study conducted by Shrikande (1958). Pankajakshan (1960) reported biennial bearing tendency in coconut palms through graphical approach however their magnitude was not specified.

#### 4.5.2 Testing of Biennial Effect Using Orthogonal Contrasts

Significance of biennial tendency and time-trend were tested by parametric approach using the orthogonal contrasts developed by Saraswathi (1983) as given in chapter 3 and the results are presented in Table 11.

The biennial tendency of the 401 WCT palms were first tested by  $F_1$  criterion. As  $F_1$  criterion is based on the assumption of absence of time-trend, this has to be tested which is done using  $F_2$  criterion.  $F_1$  ratio were found to be 1.98 for the period 1997-2000 which is significant at 5 per cent level of significance indicating significance of biennial effect for this period. Then the assumption of absence of time-trend effect is then tested using  $F_2$  ratio for this period.  $F_2$  were non significant showing WCT palms are not influenced by time-trend during this period. So the  $F_1$  ratio itself gives an evidence of biennial tendency for the period 1993-2000.

For the rest of the periods viz. 1993-1996, 2001-2004,2005-2008,2009-2012 and 2013-2016, the  $F_1$  was found to be non significant indicating the non significant biennial bearing tendency in the absence of time-trend effect. So time-trend effect for these periods were tested using the  $F_3$  criterion. For the periods 2005-2008 and 2009-2012,  $F_3$  ratios were 1.56 and 1.41 respectively which is significant at 5 per cent level of significance thus these periods are having a significant time-trend effect. As time-

trend effects were significant for these periods, it necessitates testing biennial tendency again under the assumption of presence of time-trend which is done using  $F_4$  criterion and the results revealed non significant  $F_4$  ratios thus absence of biennial effect confirmed for the periods 2005-2008 and 2009-2012. For the periods 1993-1996, 2001-2004 and 2013-2016 both  $F_1$  and  $F_3$  were non significant indicating the absence of both biennial and time-trend effect for these periods.

Testing of biennial bearing tendency using orthogonal contrasts was based on the different periods rather than considering individual palms and biennial bearing effect were found to be significant for the four year period 1997-2000.

Lathy (1989) applied the method developed by Saraswathi (1983) to test biennial effect and time-trend using the orthogonal contrasts. In this study 169 WCT palms maintained under a uniform system of management in the Regional Agricultural Research Station, Pilicode for a period of 8 years were considered. Significant  $F_1$  ratio along with a non significant  $F_2$  ratio were obtained for the 8 year period viz.1969-1984 indicating presence of biennial tendency in the absence of time-trend for all the 8 year period.

#### **4.5.3 Non Parametric Approach to Estimate Biennial Tendency**

##### **4.5.3.1 'B' Factor**

Orthogonal contrasts developed by Saraswathi (1983) were used to test the biennial effect and time-trend among four year time periods and does not consider individual palms and also do not provide quantitative estimate for biennial tendency. The 'B' Factor proposed by Hoblyn *et al.* (1936) as described in chapter 3 was applied to the data to estimate the magnitude of bienniality for the period of 1993-2017. The results are presented in the Table 12.

Table 11. Test of significance of biennial tendency and time-trend

Period	Mean square due to contrast					F Ratios			
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	F <sub>4</sub>
1993-1996	1067.1	1168.4	921.9	966.8	1123.5	1.09		0.91	
1997-2000	602.0	1193.0	753.5	482.8	1463.7	1.98 *	1.00		
2001-2004	1104.2	796.6	969.4	849.6	916.5	0.72		0.77	
2005-2008	1009.0	977.0	1754.5	1572.2	1159.3	0.97		*1.56	1.01
2009-2012	902.7	460.6	1609.3	1276.7	793.2	0.51		*1.41	0.80
2013-2016	787.7	540.5	975.5	767.6	748.4	0.69		0.97	

\*Significant at 5% level of significance

Table 12. 'B' factor values for 401 palms

Factor 'B'	'B' in per cent	No. of palms	Percentage of palms	Cumulative percentage
0/23	0	0	0.0	100.0
1/23	4.35	0	0.0	100.0
2/23	8.70	0	0.0	100.0
3/23	13.04	0	0.0	100.0
4/23	17.39	0	0.0	100.0
5/23	21.74	0	0.0	100.0
6/23	26.09	0	0.0	100.0
7/23	30.43	0	0.0	100.0
8/23	34.78	0	0.0	100.0
9/23	39.13	0	0.0	100.0
10/23	43.48	2	0.5	100.0
11/23	47.83	12	3.0	99.5
12/23	52.17	22	5.5	96.5
13/23	56.52	56	14.0	91.0
14/23	60.87	62	15.5	77.1
15/23	65.22	82	20.4	61.6
16/23	69.57	64	16.0	41.1
17/23	73.91	48	12.0	25.2
18/23	78.26	37	9.2	13.2
19/23	82.61	11	2.7	4.0
20/23	86.96	4	1.0	1.2
21/23	91.30	1	0.2	0.2
22/23	95.65	0	0.0	0.0
23/23	100.00	0	0.0	0.0
		<b>401</b>	<b>100.0</b>	

All palms showed a 'B' factor greater than 10/23 *i.e.* 43.4 per cent bienniality. Highest biennial bearing factor 15/23 *i.e.* 65 per cent is exhibited by 20.4 per cent of palms. The distribution of biennial bearing factor 'B' is shown in the Figure 7.

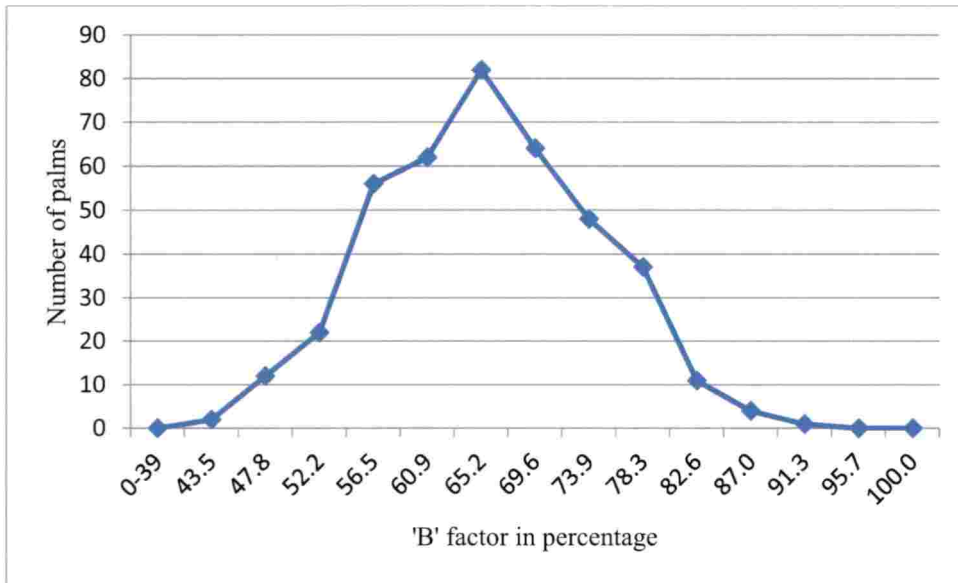


Figure 7. Distribution of 'B' factor among 401 WCT palms

From the graph it can be seen that maximum number of palms are having a biennial bearing factor ranging between 13/23 to 17/23. A zero per cent 'B' factor indicates no biennial bearing behaviour and a 100 per cent 'B' factor indicates complete bienniality. Testing of 'B' factor has to be done to identify which value of 'B' can be considered as an estimate of a significant bienniality. This is done by testing the departure from the equiprobable hypothesis using binomial probabilities.

The data analysed for the period of 25 years *viz.* 1993-2017. The 'B' factor was thus based on 23 pairs of successive signs, positive or negative indicating fall or rise in yield over continuous years for each of the palms. Probability of unlike signs in any pair of consecutive years is 0.5 on the basis of equiprobable hypothesis, *i.e.*

probability of unlike signs in any pair is  $\frac{1}{2}$  if a group of palms are considered. Therefore a test of significance of bienniality can be obtained by calculating the binomial probabilities given by ;

$$P(x) = \binom{23}{x} \left(\frac{1}{2}\right)^x \left(\frac{1}{2}\right)^{23-x}$$

Where x is number of pairs of unlike signs  $x = 0, 1, 2, \dots, 23$ .

Based on these probabilities, the expected proportion of palms for the corresponding number of unlike signs are estimated. Based on these expected proportion and actual proportion of palms showing bienniality for x unlike signs, Sarawsathi (1983) proposed a chi square value to test departure from the equiprobable hypothesis and are presented in the Table 13.

These chi square follows chi square distribution with  $n-1$  degrees of freedom *i.e.* 24 degrees of freedom. Table value of chi square at 24 degrees of freedom for 5 per cent level of significance is 36.41. Significant difference from the equiprobable hypothesis is observed for  $x=16$  and above thus any value of  $x=16$  or above is a significant departure from the equiprobable hypothesis. Therefore we can consider a palm showing a B factor equal to or higher than  $16/23$ , *i.e.* 69.56 per cent as significantly biennial in bearing; and on this basis we find that 41.1 per cent of the palms are significantly biennial in bearing.

The number of palms in on and off phase were identified for each year and the details are given in the Table 14.

Table 13. Chi square values for x unlike signs

No. of unlike signs (x)	p(x)	q=1-p	$X^2$
0	0.000	1.000	$2.1 \times 10^8$
1	0.000	1.000	$9.1 \times 10^6$
2	0.000	1.000	$8.28 \times 10^5$
3	0.000	1.000	$1.1 \times 10^5$
4	0.001	0.999	$2.3 \times 10^4$
5	0.004	0.996	6207.02
6	0.012	0.988	2052.34
7	0.029	0.971	830.38
8	0.058	0.942	402.69
9	0.097	0.903	231.61
10	0.136	0.864	158.3
11	0.161	0.839	75.45
12	0.161	0.839	56.12
13	0.136	0.864	43.21
14	0.097	0.903	40.15
15	0.058	0.942	39.20
16	0.029	0.971	25.7
17	0.012	0.988	26.36
18	0.004	0.996	20.32
19	0.001	0.999	18.51
20	0.000	1.000	17.79
21	0.000	1.000	5.03
22	0.000	1.000	0.00
23	0.000	1.000	0.00

Table 14. Number of palms showing ‘on’ and ‘off’ phase during 1993-2017

Year	Plants in on phase	Plants in off phase	percentage of on phase
1994	269	132	67.08
1995	258	143	64.34
1996	106	295	26.43
1997	205	196	51.12
1998	142	259	35.41
1999	193	208	48.13
2000	238	163	59.35
2001	222	179	55.36
2002	97	304	24.19
2003	239	162	59.60
2004	226	175	56.36
2005	145	256	36.16
2006	245	156	61.10
2007	251	150	62.59
2008	160	241	39.90
2009	92	309	22.94
2010	182	219	45.39
2011	259	142	64.59
2012	315	86	78.55
2013	88	313	21.95
2014	177	224	44.14
2015	244	157	60.85
2016	167	234	41.65
2017	173	228	43.14

During 1994, 1995, 1997, 2000, 2001, 2003, 2004, 2006, 2007, 2011, 2012 and 2015 the proportion of palms in the ‘on’ phase was high and for the remaining years it was significantly low. Number of palms in the ‘on’ phase was found to be maximum for the year 2012 *i.e.* 78.55 per cent and number of palms in the ‘off’ phase was found to be maximum for the year 2013 *i.e.* 78.05 per cent. The distribution of number of palms in the ‘on’ phase are presented in the Figure 8.

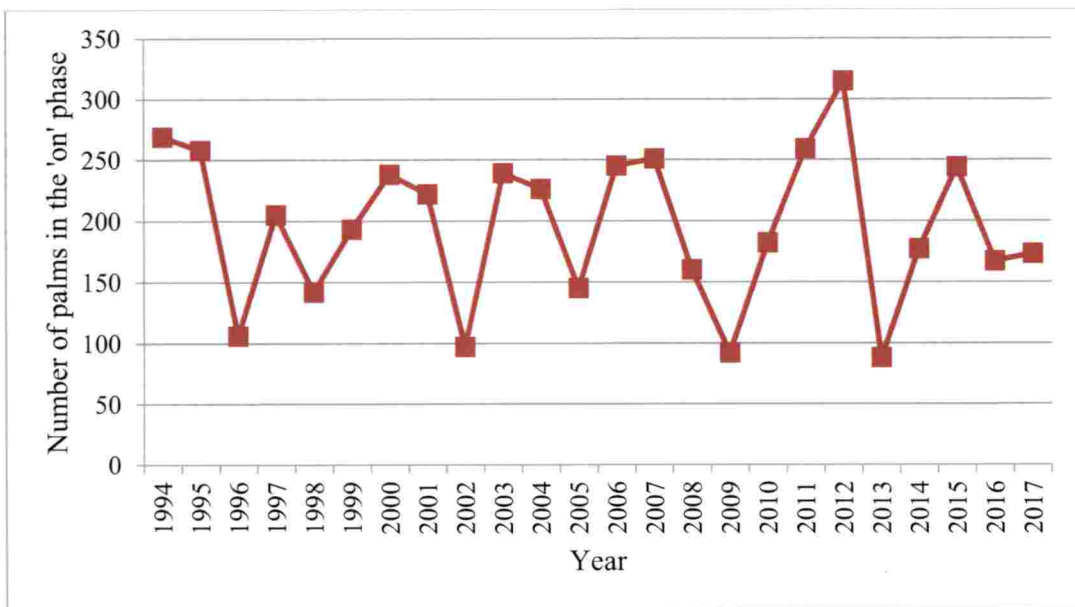


Figure 8. Distribution of number of palms in the ‘on’ phase

From the graph it can be seen that ‘on’ phase palms *i.e.* palms with above average production in an year are distributed in an alternate manner. If more number of palms are in ‘on’ phase for an year then for the next year number of palms in ‘on’ phase are less and again number increased for the next year.

The 'B' factor analysis revealed that 41.1 per cent of the palms are significantly biennial in bearing. Abeywardena (1962) studied 300 palms grown at Botanist's division of Coconut Research Institute of Ceylon for its biennial bearing tendency for the 19 year period *i.e.* 1936-1954 and observed that 38.5 per cent of palms are exhibiting significant biennial bearing tendency. Sarawsathi (1983) studied 132 WCT palms and observed 41 per cent palms for significant biennial bearing tendency.

Lathy (1989) studied 169 WCT palms maintained under a uniform system of management in the Regional Agricultural Research Station, Pilicode for a period of 8 years *viz.* 1969-1984 and observed that a 'B' factor greater than or equal to 2/8 is significantly biennial in bearing and on this basis the study considered 100 per cent of the WCT palms at RARS, Pilicode exhibiting significant biennial bearing tendency.

#### 4.5.3.2 'I' Factor

Intensity of the degree of crop fluctuations was measured by the 'I' factor (Hoblyn *et al.*, 1936). The results are presented in Table 15.

The value of 'I' can vary from 0 to 100 per cent. All WCT palms showed an intensity of crop fluctuations less than 50 per cent of which in 81.8 per cent the intensity ranged from 20 to 30 per cent. None of the palms showed an intensity greater than 50 per cent. A zero percent I indicates regular bearing or no alternate bearing behavior. Regular bearing was not observed for any palms. 100 per cent I indicates strict alternate bearing behavior. No palms were found to be strict alternate in bearing. Maximum number of palms were in a state that they are exhibiting the biennial bearing pattern but are not strict in bienniality *i.e.* 100 per cent.

A steady decrease in yield were observed from 2011 onwards therefore I factor is separately estimated by eliminating these years and the results are described in the Table 16.

Table 15. Distribution of 'I' factor among 401 WCT palms for 1993-2017

Factor 'I'	No. of palms	Percentage of palms	Cumulative percentage
<10	1	0.25	0.25
10-20	92	22.94	23.19
20-30	235	58.60	81.80
30-40	66	16.46	98.25
40-50	7	1.75	100.00
50-60	0	0.00	100.00
60-70	0	0.00	100.00
70-80	0	0.00	100.00
80-90	0	0.00	100.00
90-100	0	0.00	100.00
<b>Total</b>	<b>401</b>	<b>100.00</b>	

Table 16. Distribution of 'I' factor among 401 WCT palms for 1993-2011

Factor 'I'	No. of palms	Percentage of palms	Cumulative percentage
<10	21	5.24	5.24
10-20	202	50.37	55.61
20-30	126	31.42	87.03
30-40	35	8.73	95.76
40-50	12	2.99	98.75
50-60	4	1.00	99.75
60-70	1	0.25	100.00
70-80	0	0.00	100.00
80-90	0	0.00	100.00
90-100	0	0.00	100.00
<b>Total</b>	<b>401</b>	<b>100</b>	

The intensity of crop fluctuation, I was plotted against the number of palms for the whole period 1993-2017 and 1993-2011 and the figures are given in Figure 9. From the graph it can see that for both the periods maximum palms are possessing an 'I' factor ranging from 20 to 30. While considering the years 1993-2011 only number of palms showing 'I' factor less than 10 per cent is 21 i.e. 5.24 per cent and 100 per cent palms are showing an 'I' factor less than 70 per cent of which in 87.03 per cent the intensity ranged from 20 to 30 per cent.

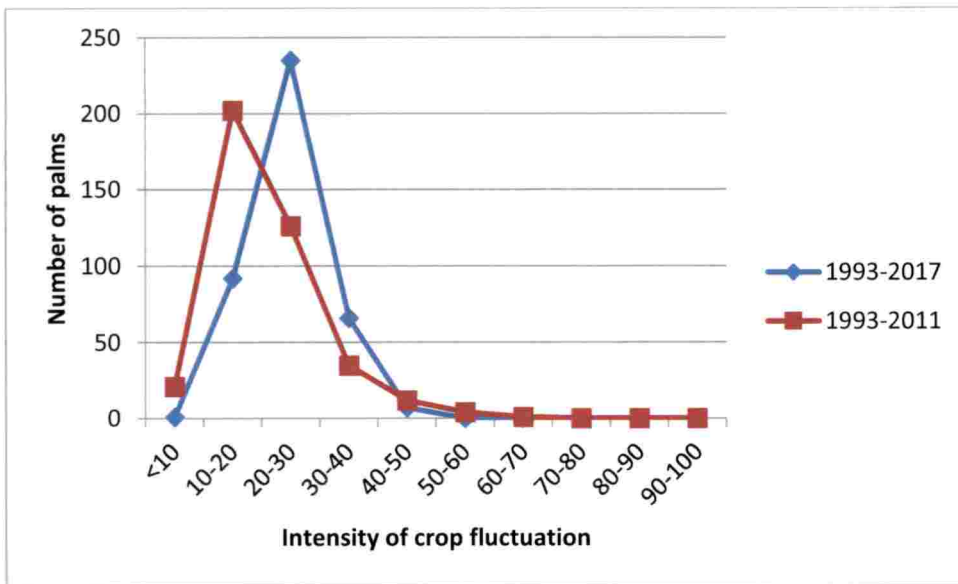


Figure 9. Distribution of 'I' factor

Abeywardena (1962) observed an 'I' factor ranging from 5 to 15 per cent for 85.4 per cent of palms of which 44.7 per cent was found between 10 and 15 per cent.

The present study is in accordance with Lathy (1989). The study reported that 83.43 per cent of the WCT palms showed an intensity less than 50 per cent of which in 79.29 per cent the intensity ranged from 20 to 50 per cent and for the remaining 16.57 palms had an intensity of crop fluctuations ranged from 50 to 90 per cent.

#### **4.5.3.3 Measurement of Bienniality by Spearman's Rank Correlation**

Spearman's rank correlation coefficient was calculated for all 23 pair of alternate years and all 24 pair of adjacent years as described in chapter III and are presented in the Table 17.

For palms possessing biennial tendency the coefficients for alternate years should be higher than that of adjacent years and this is tested by rank sum test referred to as Wilcoxon's test. For  $m$  coefficients of alternate years and  $n$  coefficients of adjacent years,  $m$  and  $n$  being reasonably large the Wilcoxon score  $T$  may be assumed to be normally distributed and can be tested using  $Z$  test.

$T$  value are estimated along with the expectation and variance as described in the chapter 3 and are presented in the Table 18.

Spearman's coefficient as well as Wilcoxon's score  $T$  were estimated for two periods, the whole period 1993-2017 and the stable yielding period 1993-2001.  $Z$  test was conducted for both the periods and was found significant for 1993-2001, indicating significant biennial tendency for this period and for the whole period, 1993-2017,  $Z$  was not significant.

Present study is in accordance with the study of Abeywardena (1962). In this study measured biennial bearing tendency using Spearman's rank correlation and reported that the value of  $T$  on the basis of 18 pairs of adjacent years and 17 pairs of alternate years was statistically significant indicating significant biennial bearing tendency for the whole period of study viz. 1936-1954.

Table 17. Spearman's rank correlation coefficients for alternate years and adjacent years

<b>Adjacent years</b>	<b>r<sub>s</sub></b>	<b>Alternate years</b>	<b>r<sub>s</sub></b>
1993-1994	0.47	1993-1995	0.55
1994-1995	0.39	1994-1996	0.50
1995-1996	0.43	1995-1997	0.36
1996-1997	0.26	1996-1998	0.41
1997-1998	0.26	1997-1999	0.27
1998-1999	0.27	1998-2000	0.98
1999-2000	0.28	1999-2001	0.99
2000-2001	0.27	2000-2002	0.09
2001-2002	0.22	2001-2003	0.22
2002-2003	0.36	2002-2004	0.25
2003-2004	0.20	2003-2005	0.05
2004-2005	-0.11	2004-2006	0.16
2005-2006	0.02	2005-2007	0.12
2006-2007	0.17	2006-2008	0.22
2007-2008	0.47	2007-2009	0.13
2008-2009	0.55	2008-2010	0.34
2009-2010	0.20	2009-2011	0.16
2010-2011	0.10	2010-2012	0.07
2011-2012	0.14	2011-2013	0.08
2012-2013	0.06	2012-2014	0.17
2013-2014	-0.04	2013-2015	-0.01
2014-2015	0.23	2014-2016	0.10
2015-2016	0.31	2015-2017	0.25
2016-2017	0.39		

Table 18. Test of significance of biennial tendency using Spearman's rank correlation

<b>period</b>	<b>T</b>	<b>E(T)</b>	<b>V(T)</b>	<b>Z</b>
1993-2017	529	552	2208	0.49
1993-2001	73	56	68	2.06*

\*Significant at 5 per cent level of significance

#### 4.6 ESTIMATION OF REPEATABILITY BY ANALYSIS OF VARIANCE

Repeatability is a statistical appraisal of the uniformity of repeated measurements. It indicates the imminence of the agreement between the results of consecutive measurements of the same measure and carried out under the same circumstances of each measurement. Analysis of variance is used to estimate the repeatability coefficient as described in the chapter 3. Four hundred and one individuals against 25 years was analyzed to estimate repeatability coefficient for the number of nuts per palm. The mean sum of squares due to individual effect and due to fixed year effect were estimated for the period 1993-2017 and the results are presented in Table 19.

Table 19. ANOVA to estimate repeatability for 1993-2017

Source	Df	SS	MSS
Individuals (palms)	400	1677399.13	4193.49
Time (years)	24	3357800.43	139908.35
Error	9600	9240106.771	962.51

From the table, mean sum of square per palm was found to be 4193.49 and mean sum of squares for the time was 139908.35 for the period 1993-2017. The estimators of  $\sigma_e^2$  and  $\sigma_g^2$  are obtained by equating the mean squares of each variation to its expectation and is given by;

$$\sigma_e^2 = \text{MSE} = 962.51$$

$$\sigma_g^2 = (\text{MSG} - \text{MSE}) / k = 129.23$$

Repeatability coefficient then estimated from these estimators and was found to be  $\rho=0.12$  with variance  $v(\rho) = 0.00095$ . Repeatability coefficient ranges from zero

to one. Repeatability of one indicates that the measurement is absolutely steady with no observer error and no change in trait size among observations.

As the repeatability estimate was very low for the whole period, repeatability estimated for a separate 15 year maximum yielding period and for each four year intervals. The results are presented in the Table 20.

Table 20. ANOVA to estimate repeatability for 1997-2011

Source	Df	SS	MSS
Individuals	400	1290143.93	3225.36
Time	14	517347717.2	36953408.37
Error	5600	5354430.98	956.15

From the table mean sum of square was found to be 3225..36 and mean sum of squares for the time was 36953408.37 for the period 1997-2011. The estimators of  $\sigma_e^2$  and  $\sigma_g^2$  are obtained by equating the mean squares of each variation to its expectation and is given by;

$$\sigma_e^2 = \text{MSE} = 956.15$$

$$\sigma_g^2 = (\text{MSG} - \text{MSE}) / k = 151.28$$

Repeatability coefficient then estimated from these estimators and was found to be  $\rho=0.131$  with variance  $v(\rho) = 0.00015$ . Repeatability coefficient estimated for different periods are presented in the Table 21.

Table 21. Repeatability coefficient estimated for different periods

Period	Repeatability coefficient ( $\rho$ )	S.E ( $\rho$ )
1993-1996	0.397	0.027
1997-2000	0.355	0.027
2001-2004	0.259	0.027
2005-2008	0.137	0.001
2009-2012	0.113	0.024
2013-2016	0.060	0.023

While considering the whole period 1993-2017 and 2013-2016 repeatability coefficient was very low 0.13 and 0.06 respectively with variances 0.00015 and 0.00052 respectively. High estimate of repeatability, 0.397, 0.355 respectively were observed for the period 1993-1996 and 1997-2000.

Abeywardena (1963) estimated repeatability coefficient for the number of nuts per palm with the data for the 972 palms at Bandirippuwa Estate by the Soil Chemist's Division of the Coconut Research Institute of Ceylon and the coefficient estimated was found to be low, *i.e.* 0.1826.

Choudhary *et al.* (2016) estimated repeatability coefficient for the number of fruits per tree using analysis of variance for different locations Rewa, Sangareddy, Sabour, and Vengurla and he observed a moderate estimate of repeatability at three centers viz. Rewa, Sangareddy, and Vengurla. A very low repeatability coefficient of 0.013 with standard error 0.023 observed for the location Sabour.

## 4.7 EFFECT OF CLIMATIC FACTORS ON YIELD AND BIENNIALITY

### 4.7.1 Trends in Climatic Factors Over Years

#### 4.7.1.1 Trends in Annual Rainfall

A plot of annual rainfall over years is presented in the figure 10. From the graph maximum annual rainfall is observed for the year 2015 with a precipitation of 2308 mm and a minimum were observed in the year 2011 (1040 mm). Annual rainfall shows an irregular trend over years. For the period 1993 to 1996 a steady decrease in rainfall is observed and a further increase for the period 1996 to 1998 later for the period 1997 to 2010 an alternate increase and decrease in rainfall observed .

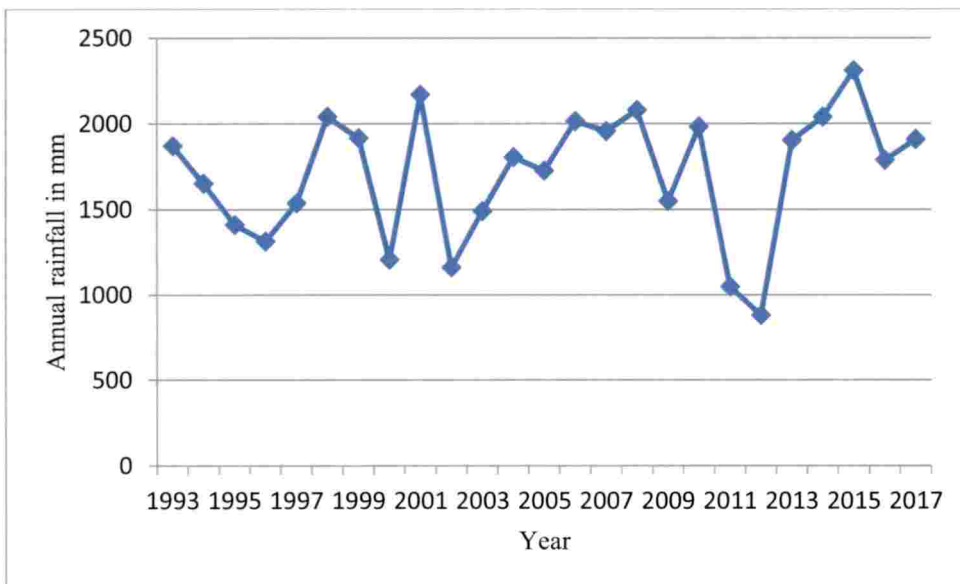


Figure 10. Trends in annual rainfall over years

#### 4.7.1.2 Trends in Number of Rainy Days

Number of rainy days showed an alternate trend over years and are shown in Figure 11. For the period 1999 to 2014 a clear alternate troughs and peaks were

observed for the trend line indicating that a high number of rainy days for a particular year there are chances of few rainy days in the next year.

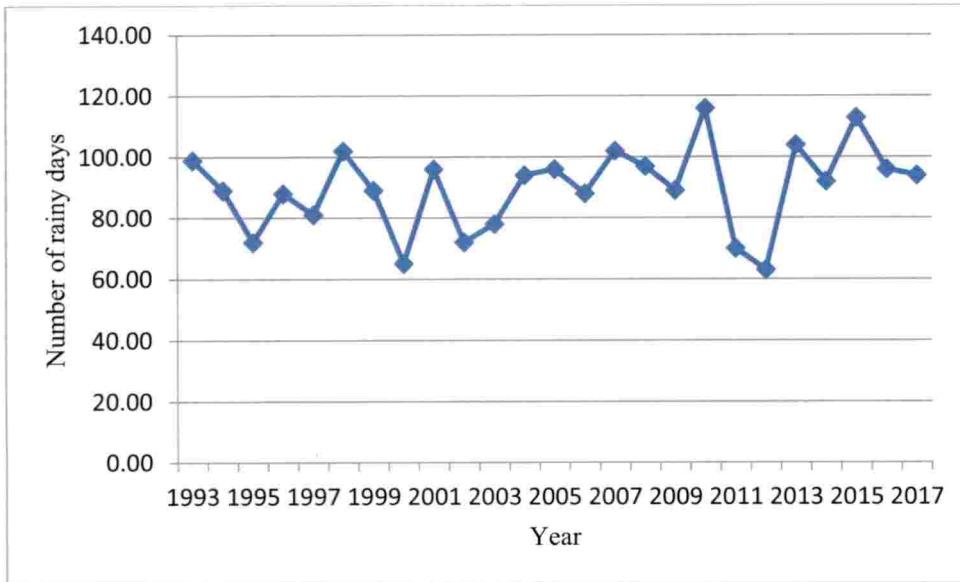


Figure 11. Trends in number of rainy days over years

#### 4.7.1.3 Trends in Maximum and Minimum Temperatures

Trends in the maximum and minimum temperatures were shown in the Figure 12. Both maximum and minimum temperatures show a small variations for the period 1993-2013. An alternate troughs and peaks were observed for the trend lines of both maximum and minimum temperatures.

#### 4.7.1.4 Trends in Wind Velocity

Plot of average annual wind velocity over years shown in Figure 13. A steady increase in average wind velocity observed for the period 1993 to 2013 following a sudden fall in the year 2006 and a further increase till the year 2015.

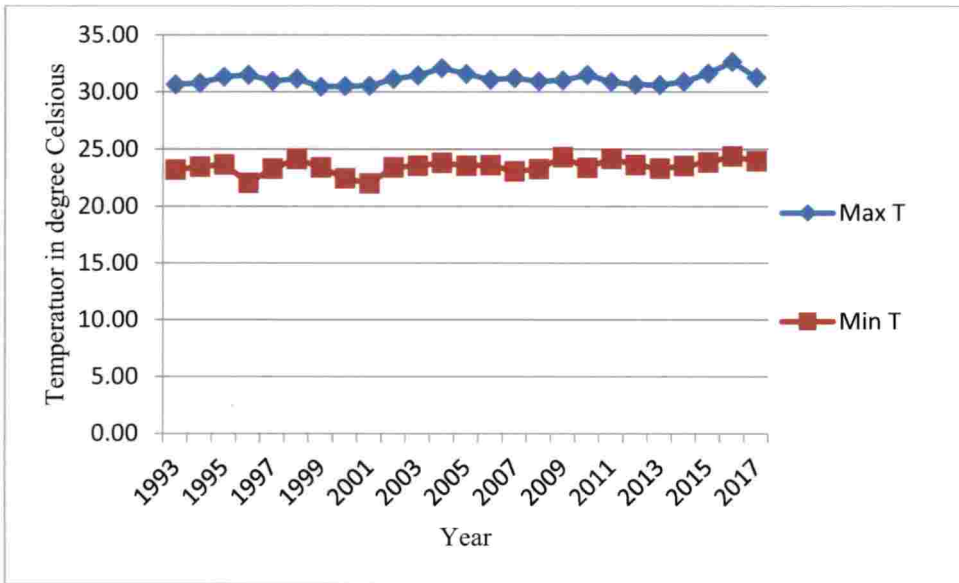


Figure 12. Trends in maximum and minimum temperatures over years

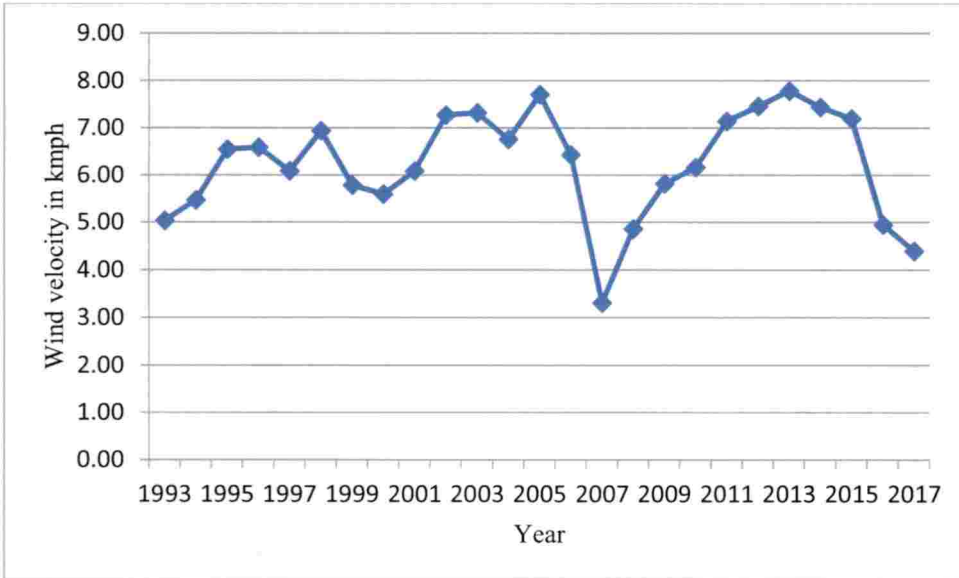


Figure 13. Trends in wind velocity over years

#### 4.7.2 Effect of Climatic Factors on Yield

Effect of climatic factors on yield are studied using correlation coefficient. Correlation between climatic factors in the current year, previous year, two years before and three years before with the production of nuts for the current year were estimated and the results are presented in the Table 22. Correlation coefficient between climatic factors of different years *viz.* harvesting year, preceding year, two years prior to harvest, with the production of nuts in an year were not significant except for the minimum temperature of the current year. It indicated that the parameters of annual climatic factors were not adequate to explain the temporal variation in yield. The graphs plotted by taking different climatic factors in the x axis and yield in the y axis also did not show a systematic correlation and these graphs are presented in the Appendix III.

Table 22. Correlation coefficient between yield and climatic factors of different years

	Correlation between production of nuts in the current year t with				
	Climatic factors of year t	Climatic factors of year t-1	Climatic factors of year t-2	Climatic factors of year t-3	Climatic factors of year t-4
Max T	-0.34	-0.25	-0.21	-0.05	-0.09
Min T	-0.47*	-0.48	-0.22	-0.18	-0.22
Wind velocity	-0.13	0.06	0.18	0.09	-0.05
Rainfall	-0.30	-0.19	-0.07	-0.01	-0.15
Rainy days	-0.19	0.02	0.08	0.34	0.09

Max T –Maximum temperature, Min T- Minimum Temperature

Present study of effect of climatic factors on yield is in accordance with the study of Abeywardena (1955). He reported that climatic factors of an year did not affect the yield of next successive years production to the same level because in the cycle of development of bunches, there are certain periods (phases) which are extremely vulnerable to climate. Marar and Pandalai (1957) in a study reported that it was not possible to explain the influence of seasonal changes in production terms of individual climatic factors. Peiris and Peries (1993) reported similar results of effect of climatic factors on coconut yield. Correlation coefficient between yield and climatic factors during the harvesting year or preceding year or two years prior to harvest were found to be low and not significant.

#### ***4.7.2.3 Effect of Dry Spell on Production***

Number of days without rain from January to May were counted for every year and its effect on production in different seasons is studied using correlation coefficient. Number of days without rain in summer called as dry spell. Significant correlation is observed for dry spell with the production in June to August of next year of harvest and the details are presented in the Table 23 and Table 24.

Correlation between number of days without rain in summer (dry spell) and yield in succeeding season of next year was found to be -0.43 which is negatively significant, showing this factor will inversely affect the yield of the next harvest.

Table 23. Number of non rainy days in summer and yield in succeeding season of next year

Year	Number of non rainy days in summer	Yield in succeeding season
1994	125	32.95
1995	126	41.93
1996	130	28.12
1997	133	27.14
1998	127	20.34
1999	106	33.29
2000	132	26.83
2001	118	39.13
2002	123	28.19
2003	124	27.48
2004	119	38.78
2005	119	39.12
2006	126	28.94
2007	127	26.70
2008	115	38.41
2009	131	24.13
2010	125	15.87
2011	121	16.77
2012	125	35.46
2013	122	30.41
2014	116	32.16
2015	127	19.16
2016	130	27.14
2017	128	28.44

Table 24. Correlation of dry spell and yield in succeeding season of next year and total yield of next year

Correlation coefficient between dry spell and yield in succeeding year	-0.27
Correlation coefficient between dry spell and yield in succeeding season of next year.	<b>-0.43*</b>

### 4.7.3 Effect of Climatic Factors On Bienniality

Biennial bearing index 'B' proposed by Hoblyn (1936) is obtained for each individual palm on an account of production data for 25 years. As the climatic factors are available on the yearly basis, while considering an year, the number of trees in the 'on' phase (above average yield in one year) or number of trees in the 'off' phase (below average yield in one year) will act as index of bienniality. Effect of climatic factors on the number of trees in 'on' phase in an year identified using correlation coefficient and are presented in the Table 25.

Table 25. Effect of climatic factors on Bienniality

	Correlation between number of trees in the 'on' phase and				
	Climatic factors of year t	Climatic factors of year t-1	Climatic factors of year t-2	Climatic factors of year t-3	Climatic factors of year t-4
Max T	-0.119	-0.084	-0.103	-0.067	-0.063
Min T	-0.002	-0.003	-0.018	-0.201	-0.197
Wind velocity	-0.106	-0.070	-0.081	-0.069	-0.067
Rainfall	-0.159	-0.157	-0.124	-0.209	-0.206
Rainy days	-0.178	-0.147	-0.086	-0.068	-0.071
Dry spell	-0.131	0.006	-0.003	0.055	0.044

Correlation coefficient between number of trees in the 'on' phase and climatic factors of current year, previous year, two years before and up to four years before the harvest are estimated and all coefficients were non significant indicating that the parameters of annual climatic factors viz. rainfall, rainy days, wind velocity, maximum and minimum temperature are not sufficient to explain the sequential

variations in bienniality. Present study is in accordance with Abeywardena (1962). He reported that rainfall don't have direct effect on bienniality.

#### 4.7.4 Linear Regression Model Fitting

Correlation studies confirmed that production in an year have a significant linear relation with the number previous years production and number of trees in the 'on' phase. A linear regression model based on stepwise forward regression were fitted with the help of statistical package SPSS by considering both the harvest data and climatic factors and details are given in Table 26. A linear regression model with high R<sup>2</sup> value, 0.98 obtained with current year yield as dependent variables and previous year yield, Number of trees in the 'on' phase, Rainy days and Wind velocity as independent variables indicating 98 per cent variation in yield can be explained by these independent variables. Standardized regression coefficients with significance are provided in Appendix IV.

$$Y_t = -27.44 + 0.98 Y_{t-1} + 0.22 n - 0.78 r_d - 1.07 w$$

Where  $Y_t$  – yield in the year  $t$ ,  $Y_{t-1}$  – yield in the year  $t-1$ ,  $n$ -number of trees in the 'on' phase,  $r_d$ - number of rainy days ,and  $w$ -wind velocity

Table 26. Model Summary – linear regression model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.696 <sup>a</sup>	.485	.461	13.71322
2	.990 <sup>b</sup>	.980	.978	2.79226
3	.992 <sup>c</sup>	.984	.982	2.52669
4	.994 <sup>d</sup>	.988	.986	2.22151

a. Predictors : (constant), Previous year yield

b. Predictors : (constant), Previous year yield, Number of 'on' trees

c. Predictors : (constant), Previous year yield, Number of 'on' trees, Rainy days

d. Predictors : (constant), Previous year yield, Number of 'on' trees, Rainy days, Wind velocity

## *SUMMARY*

## 5. SUMMARY

Coconut being a perennial crop, exhibit a special characteristic, namely biennial bearing tendency. Studying the extent of bienniality among them is of much importance as the individual palms yield data would be valid only for negligible bienniality and reorientation of conventional methods of designing experiments would be required if palms exhibit significant bienniality. Effect of climatic factors on coconut production is also important as the crop is grown in an ecologically susceptible areas like coastal belts, hills and areas with high rainfall and humidity and are contributing considerably to the agricultural exports of the country.

The experiment on the “Trends in production and bienniality of coconut (*Coccoloba nucifera* L.) var. WCT ” was carried out during the period from 2016-2018 in College of Agriculture, Vellayani, Thiruvananthapuram based on the data recorded at Coconut Research Station, Balaramapuram to study the trends in production of coconut variety WCT (West Coast Tall), extent of bienniality and variations in crop yield from year to year due to climatic factors. The present study also aims to estimate the repeatability coefficient and its variation. The data pertains to 525 WCT palms planted in the year 1966 and were grown under rainfed conditions with recommended management practices for the 25 year period viz. 1993 to 2017. Meteorological factors like rainfall, number of rainy days, maximum and minimum temperature and wind velocity of the above period also formed part of this study.

Initial data analysis was carried out to remove the outliers present. First, second and third quartiles were obtained from box plot as 1347, 1612 and 1877 for total number of nuts produced per palm per year. Box plot identified 14 palms having the total production of nuts in an year less than 552 nuts and greater than 2672 nuts for the 25 year period as outliers and are eliminated from the remaining analysis. 110 palms were not having data for the production of nuts for all the harvests for the period 1993-2017 thus such palms were also eliminated. Thus out of 525 palms a

total of 124 palms excluded from the remaining analysis and 401 palms are selected for further study.

The descriptive statistics for the data set were estimated and it is observed that a coconut palm produces an average of 68.52 nuts in an year with an overall standard deviation of 37.83. Maximum number of nuts produced in an year was found to be 305 and the minimum number of nuts produced is zero. Preliminary statistical analysis by applying Analysis of variance (ANOVA) for the number of nuts produced by individual palms revealed high significant difference between different palms with respect to each harvest and also with respect to each year.

Pearson's correlation coefficient between yield data of different harvests in an year as well as previous years were estimated. Significant correlation were observed with the previous harvest of the same year. Thus number of nuts obtained from a harvest significantly influences the production of next harvest. Statistical tools in respect of graphical, parametric and non parametric approaches were tried as an attempt to detect and quantify the biennial bearing tendency. Annual yield is plotted over years for a high yielding, moderately yielding and low yielding trees and a randomly selected tree, all showing alternate trough and peaks in the trend line. Annual average production over years for the palms which were in the 'on' phase for the starting year also showed alternation of heavy and low production. Thus graphical approach confirmed biennial bearing tendency among different years as well as among different harvests. Bienniality is then attempted by parametric and non parametric methods.

The parametric study was carried out using orthogonal contrasts developed by Saraswathi (1983). This method used four F ratios  $F_1$ ,  $F_2$ ,  $F_3$  and  $F_4$ , the significance of which provide biennial tendency and time-trend each for four year periods.  $F_1$  ratio is used to test the biennial tendency under the assumption of absence of time trend and then confirmed by  $F_2$  ratio.  $F_3$  is used to test time trend effect under the

assumption of absence of biennial effect. This assumption confirmed by  $F_4$  ratio. For the period 1997-2000,  $F_1$  was found to be significant at 5 per cent level indicating biennial tendency for this period in the absence of time trend, which was then confirmed using  $F_2$  criterion. But this method didn't confirm bienniality for other periods.

The non parametric approach using biennial bearing index 'B' (Hoblyn *et al.*, 1936) was made for the period of 1993-2017. The 'B' factor was based on 23 pairs of successive signs positive or negative indicating fall or rise in yield over continuous years for each of the palms. A test of significance of bienniality was obtained by calculating the binomial probabilities. Number of successive change in signs of 16 or above for this period indicate significant departure from the equiprobable hypothesis. Therefore a palm showing a B factor equal to or higher than 16/23 can consider as significantly biennial in bearing; and on this basis 41.1 per cent of the palms were found to be biennial in bearing.

Intensity or degree of crop fluctuations was measured by the 'I' factor (Hoblyn *et al.*, 1936). All palms showed an intensity of crop fluctuations less than 50 per cent; of which in 81.8 per cent, the intensity ranged from 20 to 30 per cent. A zero percent 'I' indicates regular bearing or no alternate bearing behavior. Regular bearing was not observed for any of the palms. 100 per cent I indicates strict alternate bearing behavior. No palms were found to be strict in alternate bearing also. Maximum number of palms were found to exhibit the biennial bearing pattern but are not strict (100 per cent) in bienniality.

Spearman's rank correlation coefficients were calculated for all 23 pair of alternate years and all 24 pair of adjacent years. For palms possessing biennial tendency the coefficients for alternate years should be higher than that of adjacent years and this is tested by rank sum test (Z). The Z value was found to be non significant for the period 1993-2017 indicating no strict alternate bearing behavior in

the selected palms. As production is found to be in a steady decrease from 2002 onwards 'Z' is separately estimated for the period 1993-2001, and found to be significant for this period indicating alternate bearing behavior for this period.

Repeatability was estimated for number of nuts per tree using ANOVA estimator for different periods. While considering the whole period 1993-2017 and 2013-2016 repeatability coefficient was very low 0.13 and 0.06 respectively with variances 0.00015 and 0.00052 respectively. High estimate of repeatability, 0.397, 0.355 respectively were observed for the period 1993-1996 and 1997-2000.

Effect of climatic factors on yield are studied using correlation coefficient. Correlation between climatic factors in the current year, previous year, two years before and three years before with the production of nuts for the current year were estimated and were not significant except for the minimum temperature of the current year. It indicated that the parameters of annual climatic factors were not adequate to explain the temporal variation in yield. Correlation between number of days without rain in summer (dry spell) and yield in succeeding season of next year was found to be -0.43 which is negatively significant, showing this factor will inversely affect the yield of the next harvest. Correlation coefficient between number of trees in the 'on' phase and climatic factors of current year, previous year, two years before and up to four years before the harvest are estimated and all coefficients were non significant indicating that these parameters are not sufficient to explain the sequential variations in bienniality. A linear regression model with high  $R^2$  value, 0.98 were fitted with current year yield as dependent variables and previous year yield, Number of trees in the 'on' phase, Rainy days and Wind velocity as independent variables.

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## *APPENDICES*

**APPENDIX - I**  
**YEAR WISE DESCRIPTIVE STATISTICS**

Year	Mean	Standard deviation	Q1	Q2	Q3	C.V
1993	86.63	40.14	59.0	79.0	105.0	46.34
1994	96.93	41.33	71.0	92.0	117.0	42.63
1995	110.47	37.47	86.0	106.5	131.0	33.92
1996	90.32	39.25	65.0	83.0	109.8	43.46
1997	89.55	37.58	62.0	89.8	113.8	41.97
1998	72.28	34.07	47.0	67.0	93.0	47.14
1999	69.63	32.57	46.0	67.0	88.8	46.77
2000	78.27	34.07	53.0	73.0	99.0	43.52
2001	81.46	32.87	58.0	78.5	100.0	40.34
2002	56.05	28.67	35.0	54.0	71.0	51.16
2003	64.07	36.98	37.0	59.0	80.8	57.71
2004	69.12	35.99	41.0	62.0	90.0	52.07
2005	53.17	41.56	21.0	48.0	76.8	78.18
2006	66.95	31.86	41.0	66.0	87.8	47.58
2007	79.80	35.19	56.0	76.0	100.0	44.09
2008	72.05	35.05	50.0	68.0	87.0	48.64
2009	53.36	36.68	29.0	49.0	69.0	68.74
2010	47.67	20.14	34.0	46.5	60.0	42.24
2011	60.03	22.86	45.0	59.0	73.0	38.09
2012	84.97	31.35	65.0	80.0	100.0	36.89
2013	54.85	36.98	27.0	46.0	70.0	67.43
2014	44.79	25.45	28.0	40.0	55.0	56.83
2015	50.50	25.01	34.0	48.0	63.8	49.52
2016	42.93	22.54	27.0	39.0	56.0	52.49
2017	37.01	15.19	27.0	36.0	45.0	41.03

APPENDIX -II

CORRELATION MATRIX SHOWING CORRELATION COEFFICIENTS BASED ON 401 PALMS AMONG 25 YEARS

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
1993	1.00																										
1994	0.37	1.00																									
1995	0.50	0.33	1.00																								
1996	0.40	0.40	0.39	1.00																							
1997	0.41	0.29	0.38	0.23	1.00																						
1998	0.32	0.15	0.35	0.39	0.22	1.00																					
1999	0.26	0.36	0.31	0.35	0.30	0.21	1.00																				
2000	0.32	0.15	0.35	0.39	0.22	1.00	0.21	1.00																			
2001	0.27	0.36	0.29	0.35	0.29	0.21	0.99	0.21	1.00																		
2002	0.25	0.22	0.19	0.20	0.19	0.12	0.28	0.12	0.28	1.00																	
2003	0.19	0.21	0.11	0.24	0.13	0.07	0.23	0.07	0.25	0.35	1.00																
2004	0.14	0.25	0.24	0.25	0.20	0.12	0.22	0.12	0.21	0.25	0.24	1.00															
2005	-0.03	0.04	-0.05	-0.05	0.00	-0.08	-0.01	-0.08	0.00	0.01	0.24	-0.01	1.00														
2006	0.17	0.19	0.12	0.20	0.00	0.16	0.21	0.16	0.23	0.17	0.14	0.18	0.04	1.00													
2007	0.10	0.18	0.08	0.18	0.07	0.11	0.13	0.11	0.14	0.12	0.14	0.14	0.11	0.15	1.00												
2008	0.20	0.20	0.19	0.21	0.15	0.13	0.19	0.13	0.21	0.28	0.22	0.18	-0.03	0.21	0.41	1.00											
2009	0.09	0.08	0.13	0.15	0.09	0.21	0.08	0.21	0.08	0.17	0.09	0.08	-0.02	0.13	0.14	0.51	1.00										
2010	0.09	0.12	0.08	0.07	-0.05	0.06	0.05	0.06	0.06	0.04	-0.10	0.07	0.03	0.18	0.32	0.37	0.20	1.00									
2011	0.03	0.11	0.05	0.17	-0.06	0.00	0.05	0.00	0.05	0.07	0.04	0.11	0.01	0.40	0.21	0.14	0.14	0.09	1.00								
2012	0.02	0.04	0.09	0.07	-0.04	0.00	0.09	0.00	0.09	-0.03	0.00	0.04	-0.01	0.06	0.12	0.08	0.08	0.07	0.15	1.00							
2013	0.17	0.02	0.10	0.12	0.07	0.05	0.16	0.05	0.18	0.16	0.19	0.10	-0.08	0.13	0.14	0.48	0.22	0.05	0.04	0.05	1.00						
2014	0.04	-0.09	0.02	-0.03	0.01	0.17	-0.06	0.17	-0.06	-0.14	-0.16	-0.14	-0.08	-0.07	-0.04	-0.08	0.09	0.07	-0.06	0.12	-0.05	1.00					
2015	-0.03	-0.04	0.01	0.02	0.04	0.04	-0.01	0.04	-0.02	-0.07	-0.05	-0.04	-0.05	-0.07	-0.04	-0.04	0.00	-0.06	-0.07	0.02	-0.02	0.25	1.00				
2016	-0.01	-0.03	-0.04	0.01	-0.04	0.02	0.00	0.02	0.02	-0.01	0.02	0.03	0.01	0.05	-0.09	0.04	0.09	-0.01	-0.07	0.02	-0.02	0.08	0.29	1.00			
2017	0.05	0.04	0.06	0.00	0.05	-0.05	-0.02	-0.05	-0.01	0.01	-0.01	0.06	0.02	0.01	-0.07	-0.02	0.01	0.06	-0.02	-0.02	-0.06	0.13	0.21	0.36	1.00		

### APPENDIX-III

#### PLOT OF AVERAGE YIELD AGAINST CLIMATIC FACTORS

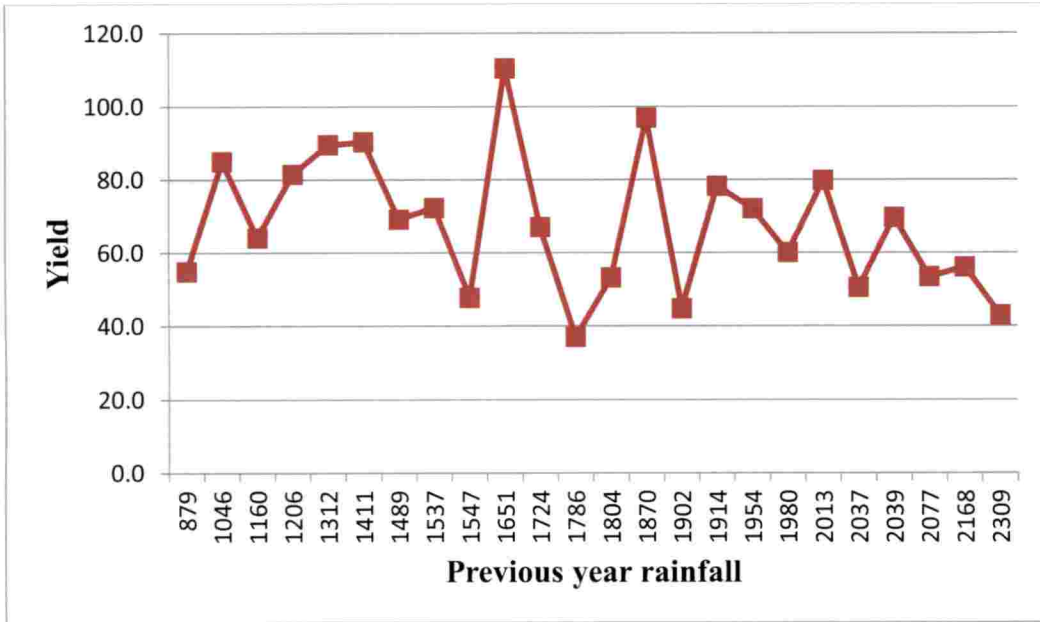


Figure : Plot of yield against previous year total rainfall

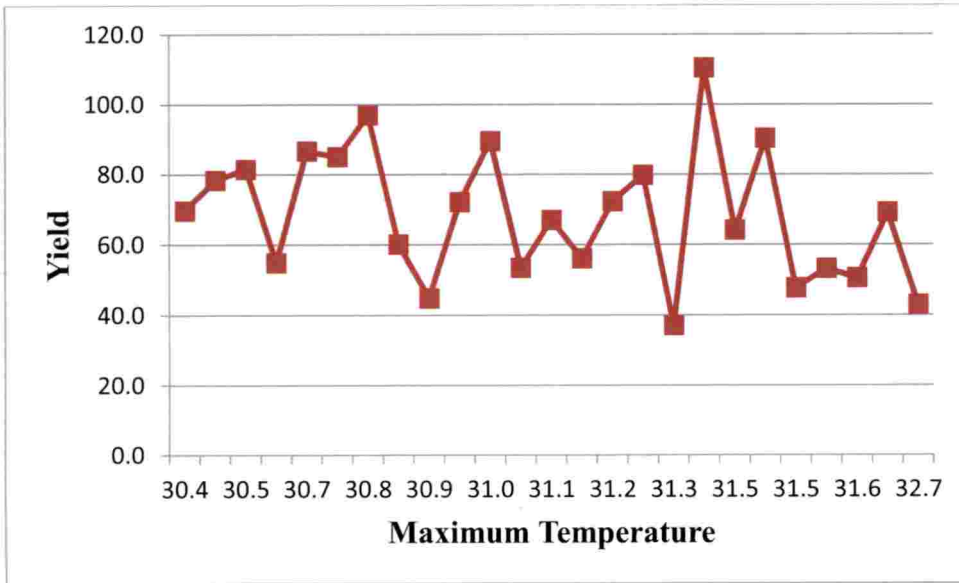


Figure : Plot of yield against Minimum temperature

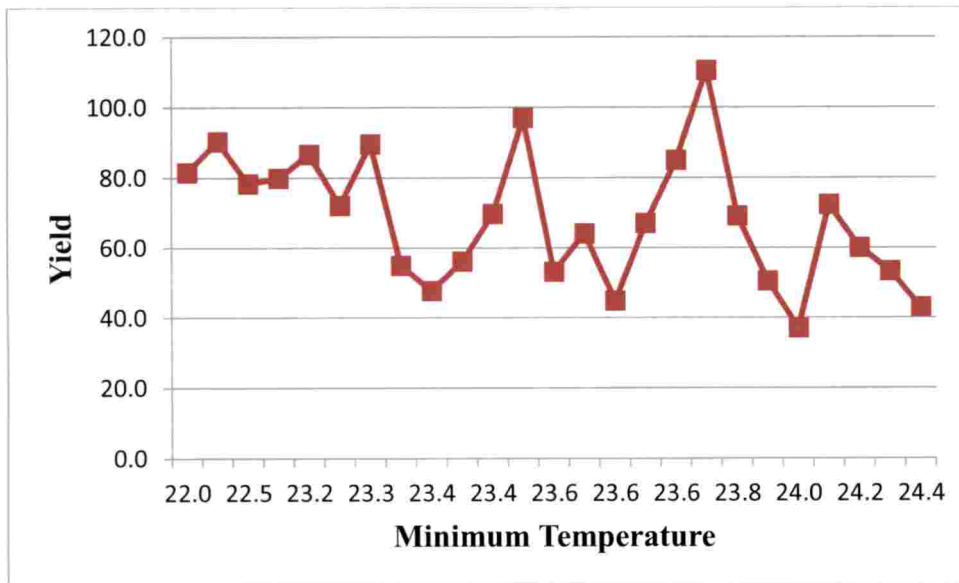


Figure : Plot of yield against Minimum temperature

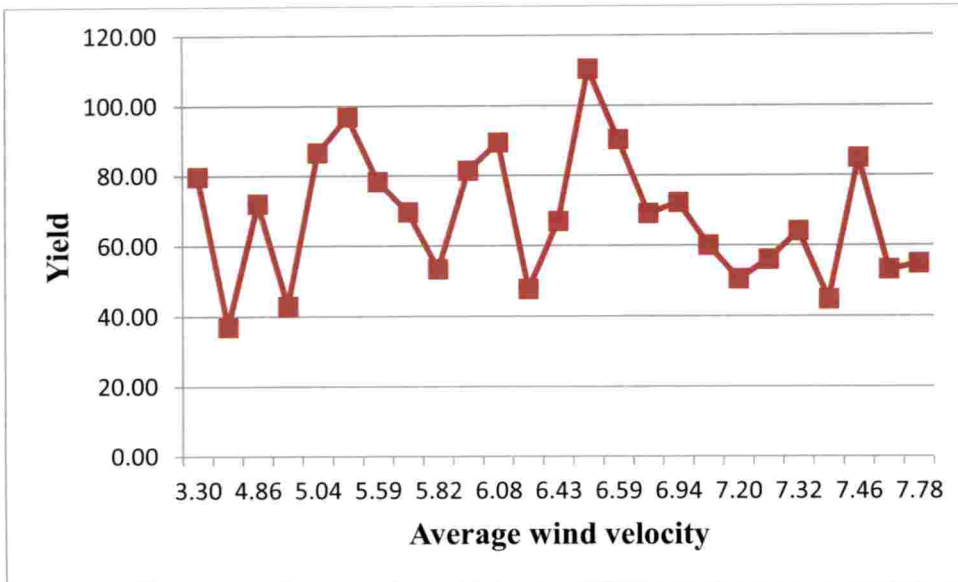


Figure : Plot of yield against Average wind velocity

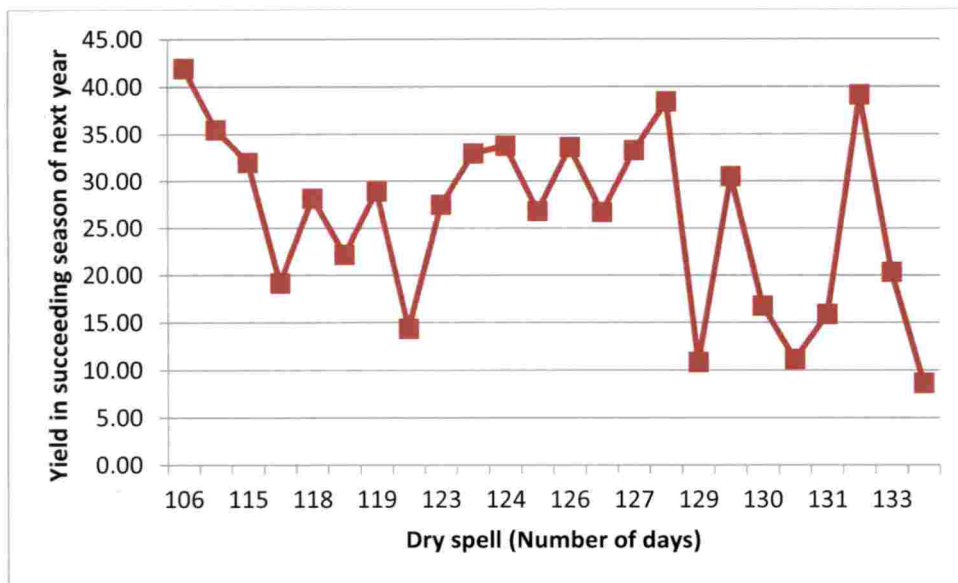


Figure : Plot of Number of non rainy days in Jan-may against yield in June-Dec of next year

**APPENDIX-IV**

**STANDARDIZED REGRESSION COEFFICIENTS AND SIGNIFICANCE**

Model		Coefficients <sup>a</sup>				Sig.
		Unstandardized Coefficients		Standardized Coefficients	t	
		B	Std. Error	Beta		
1	(Constant)	16.897	11.522		1.466	.157
	previousyearyield	.728	.160	.696	4.551	.000
2	(Constant)	-45.097	3.612		-12.486	.000
	previousyearyield	.990	.035	.946	28.617	.000
	ontrees	.224	.010	.746	22.575	.000
3	(Constant)	-34.406	5.561		-6.187	.000
	previousyearyield	.987	.031	.943	31.509	.000
	ontrees	.220	.009	.733	24.106	.000
	rainydays	-.078	.033	-.068	-2.376	.028
4	(Constant)	-27.428	5.567		-4.927	.000
	previousyearyield	.989	.028	.945	35.891	.000
	ontrees	.218	.008	.727	27.076	.000
	rainydays	-.078	.029	-.068	-2.685	.015
	wind	-1.080	.412	-.065	-2.622	.017

a. Dependent Variable: yield

**TRENDS IN PRODUCTION AND BIENNIALITY  
OF COCONUT (*Cocos nucifera* L.) VAR. WCT.**

*by*

**FALLULLA, V.K.**

**(2016-19-003)**

**ABSTRACT**

**Submitted in partial fulfilment of the  
requirement for the degree of**

**MASTER OF SCIENCE IN AGRICULTURE**

**Faculty of Agriculture**

**Kerala Agricultural University**



**DEPARTMENT OF AGRICULTURAL STATISTICS**

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## ABSTRACT

The study entitled 'Trends in production and bienniality of coconut (*Cocos nucifera* L.) var. WCT' was carried out based on data on the number of nuts harvested from 525 WCT palms planted in 1966 at Coconut Research Station, Balaramapuram with its five to six harvests per year, for a period of 25 years viz. 1993 to 2017. The objectives of the study are to identify the extent of bienniality, variations in repeatability and type of yield fluctuations over years and over different harvests. The effect of meteorological factors like rainfall, number of rainy days, maximum and minimum temperature and wind velocity of the above period also formed part of this study.

Initial data analysis using box plot technique was carried out to remove the outliers present in the data. The number of nuts produced by a palm in an year was found to be 68.5 with an overall standard deviation of 37.83 nuts. A plot of the average number of nuts produced in an year against the growing periods showed a steady decrease in yield from 2012 onwards (*i.e.* after 50 years of planting). Preliminary statistical analysis by applying Analysis of variance (ANOVA) for the number of nuts produced by individual palms revealed high significant difference between different palms with respect to each harvest and also with respect to each year.

Pearson's correlation coefficient between yield data of different harvests in an year as well as previous years were estimated and a significant correlation were observed for the previous harvest and rest of the coefficient were non significant. Statistical tools in respect of graphical, parametric and non parametric approaches were tried as an attempt to detect and quantify the biennial bearing tendency. Graphical approach confirmed biennial bearing tendency among different years as well as among different harvests.

The parametric study was carried out using orthogonal contrasts developed by Saraswathi (1983). This method used four F ratios  $F_1$ ,  $F_2$ ,  $F_3$  and  $F_4$ , the significance of which provide biennial tendency and time-trend each for four year periods.  $F_1$  ratio is used to test the biennial tendency under the assumption of absence of time trend and then confirmed by  $F_2$  ratio.  $F_3$  is used to test time trend effect under the assumption of absence of biennial effect. This assumption confirmed by  $F_4$  ratio. For the period 1997-2000,  $F_1$  was found to be significant at 5 per cent level indicating biennial tendency for this period in the absence of time trend, which was then confirmed using  $F_2$  criterion. But this method didn't confirm bienniality for other periods

The non parametric approach using biennial bearing index 'B' (Hoblyn *et al.*, 1936) was made for the period of 1993-2017. The 'B' factor was based on 23 pairs of successive signs positive or negative indicating fall or rise in yield over continuous years for each of the palms. A test of significance of bienniality was obtained by calculating the binomial probabilities. Number of successive change in signs of 16 or above for this period indicate significant departure from the equiprobable hypothesis. Therefore a palm showing a B factor equal to or higher than 16/23 can consider as significantly biennial in bearing; and on this basis 41.1 per cent of the palms were found to be biennial in bearing.

Intensity or degree of crop fluctuations was measured by the 'I' factor (Hoblyn *et al.*, 1936). All palms showed an intensity of crop fluctuations less than 50 per cent; of which in 81.8 per cent, the intensity ranged from 20 to 30 per cent. A zero percent 'I' indicates regular bearing or no alternate bearing behavior. Regular bearing was not observed for any of the palms. 100 per cent I indicates strict alternate bearing behavior. No palms were found to be strict in alternate bearing also. Maximum number of palms were found to exhibit the biennial bearing pattern but are not strict (100 per cent) in bienniality.

Spearman's rank correlation coefficients were calculated for all 23 pair of alternate years and all 24 pair of adjacent years. For palms possessing biennial tendency the coefficients for alternate years should be higher than that of adjacent years and this is tested by rank sum test (Z). The Z value was found to be non significant for the period 1993-2017 indicating no strict alternate bearing behavior in the selected palms. As production is found to be in a steady decrease from 2002 onwards 'Z' is separately estimated for the period 1993-2001, and found to be significant for this period indicating alternate bearing behavior for this period.

Repeatability was estimated for number of nuts per tree using ANOVA estimator for different periods. While considering the whole period 1993-2017 and 2013-2016 repeatability coefficient was very low 0.13 and 0.06 respectively with variances 0.00015 and 0.00052 respectively. High estimate of repeatability, 0.397, 0.355 respectively were observed for the period 1993-1996 and 1997-2000.

Correlation between climatic factors in the current year, previous year, two years before and three years before with the production of nuts for the current year were estimated and were not significant except for the minimum temperature of the current year. It indicated that the parameters of annual climatic factors were not adequate to explain the temporal variation in yield. However Correlation between number of days without rain in summer (dry spell) and yield in succeeding season of next year was found to be -0.43 which is negatively significant, showing this factor will inversely affect the yield of the next harvest. Bienniality also found to be not directly influenced by the climatic factors. A linear regression model with high  $R^2$  value, 0.98 were fitted with current year yield as dependent variables and previous year yield, Number of trees in the 'on' phase, Rainy days and Wind velocity as independent variables.