INFLUENCE OF WEATHER PARAMETERS ON YIELD OF COCONUT

By

B. PANKAJAKSHAN NAIR

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Kerala Agricultural University

Department of Statistics
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DECLARATION

I hereby declare that this thesis entitled " INFLUENCE OF WEATHER PARAMETERS ON YIELD OF COCONUT " is a bonafide record of research work done by me during the course of research and that the thesis has not been 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.

Mannuthy

23. 12. 1985

(B. PANKAJAKSHAN NAIR)

CERTIFICATE

Certified that this thesis, entitled " INFLUENCE OF WEATHER PARAMETERS ON YIELD OF COCONUT " is a record of research work done independently by Mr. B. PANKAJAKSHAN NAIR, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Mannuthy (V K GOPINATHAN UNNITHAN)

23. 12. 1985 (CHAIRMAN, Advisory Board)

ASSOCIATE PROFESSOR OF AGRL. STATISTICS
COLLEGE OF HORTICULTURE,
VELLANIKKARA.

TO MY BELOVED MOTHER
AND IN LOVING MEMORY
OF MY FATHER

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INTRODUCTION

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The coconut palm, Cocos Nucifera Linn. is one of the greatest gifts of nature. Of the cultivated tree species in the tropics, the majestic, tall growing coconut palm is the most widespread. Because of the usefulness of each and every part of this palm and the vast multitude of people that it supports through small scale and ancilliary industries, the Indian classics have rightly given the eulogistic ephithet of 'Kalpa Vriksha'- the tree of heaven. The coconut industry is closely linked with the Socio-economic life of coconut producing countries.

In terms of geographical distribution this crop ranks first among the oil yielding crops of the world. It is grown in as many as 76 tropical countries. The coconut oil ranks 6th among vegetable oil production and fourth among international trade of edible oil. The production of oil from unit area of this crop is next only to that of oilpalm (Nayar, 1983). Total world production of coconut was estimated to be 36 350 million nuts from 8.49 million ha during 1982-83 (FAO, 1984). India produced about 5641.6 million nuts from 1.123 million ha during the same period. The production and area under the crop in different states of the country are given in Table 1.1. It is evident from the table that the four southern states viz., Kerala, Karnataka, Tamil Nadu and Andhra Pradesh accounted for the 90 per cent of the total production of coconut in the country. It contributes about one sixth of the total annual income and one third of the agricultural income of Kerala.

Table 1.1
Area and Production of coconut in the different states of India (1982-83)

State	Area ('000 ha)	Production (million nuts)
Andha Pradesh	44.6	178.8
Assam	6.5	45.9
Karnataka	178.9	930.1
Kerala	670.0	2443.3
Maharashtra	10.2	61.1
Orissa	22.5	98.8
Tamil Nadu	143.0	1650.0
Tripura	1.4	1.7
West Bengal	3.3	29.4
Andaman & Nicobar	21.3	87.0
Goa, Diu & Daman	18.7	100.0
Lakshadweep	2.8	15.5
All India	1123.2	5641.6

Source: Coconut development Board(1984)

1.1 Crop weather Studies

The realization of the impact of weather on crop production is of vital importance for proper planning of production and distribution of important crops. Though man has no control over the climatic factors, an adequate knowledge of the influence of these factors on crops helps to derive maximum benefit through planned measures. Although controlled experiments are neccessary for precise understanding of crop-weather relationship, the need to investigate certain techniques that are capable of extracting useful information from readily available data cannot be neglected. This calls for an investigation into statistical characteristics of crop-weather relationship.

Crop-weather analysis models are practical research tools for the analysis of crop responses to weather and climatic variations. Generally conventional statistical procedures are used in such models to study crop responses to climatic changes.

1.2 Coconut and the Weather

The coconut palm being a crop of humid tropics, climatic factors like rainfall, Temperature, humidity, Sunshine hours etc., play an important role in its growth and productivity. Short term variation in coconut production is generally attributed to these changes in climatic factors. Other factors which cause changes in production are gradual in effect and do not influence the changes in production between one year and the next. An indisputable factor in the growth of coconut crop is a good rainfall, distributed uniformly round the year (Marar and Pandalai, 1957).

Yield is the result of the interaction of genetic and environmental factors. It is observed that a short period of adverse climatic condition is reflected in the succeeding harvest of coconut. It may be recalled that the draught experienced in Kerala during 1981-82 and 1982-83 have drastically reduced the coconut production in the subsequent years, raising the prices of coconut and oil to an all time high. The coconut production in Kerala declined from 3036.4 million nuts in 1980-81 to 3005.7 millions and 2443.3 million nuts during 1981-82 and 1982-83 respectively.

The coconut palm produces perennially one inflorescence per month and each of these have to undergo a series of developmental stages lasting nearly 45 months from the primordia initiation to harvest of nuts(Child, 1964). Any fluctuation in the climatic factors during these stages of growth is expected to affect the production with cumulative effect. Certain critical stages in the growth cycle have been identified and these are extremely susceptible to small climatic variations. A close evaluation of these critical stages provide an insight into the influence of climatic factors on final yield. Several workers have reported that yield is a cumulative function of seasonal conditions prevailing in the preceeding period of 44-45 months since the spadix primordia initiation to harvest of mature nuts. Hence one has to consider the changes in the climatic factors of the foregone seasons for studying the influence of weather on coconut production.

Of all the climatic factors influencing coconut production the prepondarant effect is that of water supply for which rainfall plays the pivotal role. However rainfall alone can't ensure a good crop even if the optimum condition of amount and distribution are realised. There are yet a host of other factors that regulate the water intake by plants. The storage of available water as soil moisture will depend on the topography and the soil texture. Soil evaporation will depend upon the vapour pressure gradient, the soil temperature and plant cover. The intensity of transpiration will depend on wind, temperature and humidity of the air and on the plant itself. Besides this there are other dominant factors such as sunlight, warmth and plant nutrients. A clear idea of the interplay of all these factors is essential before making an effort to study their influence on the crop.

1.~~4~~3 Objectives of the study

Although several workers have studied the influence of rainfall and its distribution on coconut yield, no attempt has so far been made to understand the interplay of cumulative effect of various climatic factors on coconut production. Hence the present study was undertaken envisaging the following objectives

1. To investigate the extent of influence of different climatic factors on coconut production.
2. To identify the lag periods of climatic factors influencing coconut yield.
3. To evolve a suitable regression model so as to forecast the yield of coconut based on weather parameter.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Literature on crop-weather studies in perennial crops is scanty. But much work has been done in annual crops. Coconut production is greatly influenced by variations in climatic factors such as temperature, relative humidity, sunshine hour, wind velocity, rainfall etc. But influence of rainfall and its distribution on coconut production has been studied with more emphasis than other climatic variables. However, the past attempt at quantitively demonstrating the obvious relationship between rainfall and coconut yield did not yield a complete and precise information. Here, a cross section of the studies made on crop-weather relationship of coconut, oil palm, tea and some annual crops is briefly reviewed.

2.1 Coconut

Park(1934) observed that a severe draught lasting eight months affected the coconut crop even two years later. Patel(1938) obsereved that primordia inflorescence can get aborted due to draught. Abeywardane(1955) reported that the weather parameters of different months of an year do not contribute to the yield of the next years' production to the same degree because in the cycle of developement of a bunch there are certain periods (phases) which are extremely susceptible to weather changes.

The climatic requirements and quantitative effects of weather on the perfomance of the coconut crop are briefly reviewed by Marar and Pandalai (1957). They discussed that it was not possible to explain the influence of Seasonal climatic changes in terms of individual weather factors. Salter and Goode(1967) in a review of crop responses to water, pointed out that, with so great a time lapse between the initiation of leaf and inflorescence primordia and flowering, and with many other inflorescences present at different stages at the same time, it was difficult to relate growth flowering or yield to any particular climatic condition accurately (Child, 1971).

2.1.1 Rainfall

Shepherd(1926) observed a significant positive correlation between rainfall over a six month period and the size of the nuts after one year. An attempt to study the rainfall and yield in the coconut was made by Patel and Anandan(1936). They pointed out that yield in any particular year is influenced by the January to April rains during the year of harvest, and the preceeding two years. The rainfall in first three months of a calender year was reported to be influencing yield of the crop, in the next year in Malaya (Cooke, 1953).

Abeyawardane (1955) stated that rainfall alone cannot ensure good crop even if the optimum condition of amount and incidence are realised. He further observed that one of the factors ideal for coconut growing will be a uniform annual rainfall with a little rain and bright sunshine occuring in swift alternation with emphasis on the absence of pronounced dry spell. He further stated that for a particular bunch of coconut the first three months after inflorescence opening are susceptible to weather changes. Thereafter the weather can affect the yield only minimum. He observed that after the phase of maximum susceptibility there is a steep drop and become neglegible by eighth month. Thereafter the weather has a bearing mostly on the quality of nuts and not on the number of nuts. Working on an yearly basis he pointed that current years' crop is decided mainly by the rainfall during the previous year and the first quarter of the current year.

Balasubramanian(1956) studied the rainfall and coconut yield in South Kanara district. He observed that :

1. Rains received in January influences the performance of coconut

plantation appreciably. Rains in September are important at Kasaragod whereas rains of October and November are important at Pilicode.

2. February rains appears to be important at Kasargod than Pilicode. However rains in march and April are important in Pilicode.
3. The differential response in yield to the monthly and seasonal rainfall in these two stations may be due to the difference in the soil build up.

Abeywardane(1962) considered that there is a maximum rainfall in a month upto which the crop may respond beyond which it makes no difference under the assumption that water loss take place by runoff, percolation and surface evaporation. Based on this assumption he worked out an effective quantity of rainfall. He developed a rain distribution index as a better indicator of rainfall distribution considering the number of rainy days as an index.

Laksmanachar(1963) briefly reviewed the effect of rainfall on coconut crops. He observed significant correlation between six to eight months' cumulative rainfall and yield 12 months hence from the months first considered for the successive cumulation.

Further attempt to quantify the relation between rainfall and coconut yield is that of Abeywardane(1968), using data from 32 years record of rainfall and crops on the Bandipura estate of Sri Lanka; considering the separate influence of sub-periods of the critical precropping period of a year or more. Abeyawardane(1968) observed that rainfall above a certain level have a depressing effect on yield. He also observed that the flower primordia initiates as far back as 32 months prior to the opening of an inflorescence. Hence there is a likelihood that rainfall two year prior to the harvest has more influence on the yield than any other year under consideration. However, rainfall during the year of harvest is stated to be correlated with the annual yield. He argued that some of the bunches maturing at the end of the year will have their critical stages of growth during the early part of the year of harvest. He further went on to state that the rainfall during successive year contributes to the yield additively as well as cumulatively.

Seasonal variation in yield, nut character and copra contents in a few cultivars of coconuts was studied by Pillay and Satyabalan(1960). They found that number and size of nuts are low during north-east monsoon compared to the other seasons. Biggest and maximum number obtained during summer.

Rao(1982) studied coconut yield and rainfall in the Pilicode region. He made an attempt to study the relation between the annual coconut yield and rainfall trends using twenty years moving average. The study indicated that both high rainfall during the months of June,July and August as well as the absence of pre and post monsoon showers adversely affect the subsequent years yield.

Davis and Ghosh (1982) made a brief study on the influence of rainfall on coconut production.

Bhaskaran and Leela (1983) reported that seasonal variation in yield and nuts characters are attributed to the cyclical influence of varying seasons on different critical stages during the spadix development from spadix primordia initiation to maturity of nuts. Seasonal rains affecting spadix growth at five critical stages are found to influence the yields in different seasons of succeeding four years. The different stages of growth which are reported to be important in the development of inflorescence is given below (Child, 1972):

1. Primordium opening	First month
2. Male, female flower differentiation	20-24 months
3. Elongation of the internal spathe	26-28 months

4. Opening of inflorescence	32-36 months
5. Harvest of nuts	42-45 months

Temperature, Relative humidity, wind and sunshine hours have only conjoint influence with the main effects of rainfall on yield. Effects of seasonal rains is more pronounced in TxD indicating that this cultivar is more sensitive to low and erratic rainfall. Ultimate cause- effect relationship indicates that coconut yield is related to soil moisture status, and that by providing optimal moisture at critical stages, stabilisation and enhancement of seasonal yields are possible.

2.1.2 Temperature

According to Marar and Pandalai(1957) the coconut palm likes equable temperature neither very hot nor very cold. The optimum mean annual temperature for best growth and maximum yield is stated to be around 26-27^{o}C with a diurnal variation of 7-8^{o}C.

2.1.3 Humidity

Copeland(1931) sums up that relative humidity, though obviously related to rainfall, temperature and insolation, should be such as to permit the most active transpiration without the palm suffering from loss of water. He has established that cloudiness arrests the rate of respiration considerably.

Marar and Pandalai(1957) cited that the coconut palm likes a warm, humid climate. According to Copeland(1931) the prevalance of high humid condition throughout is not favourable for the palm. It is stated that humidity reduces transpiration and thereby reduces the uptake of nutrients.

2.1.4 Sunshine

Copeland(1931) has made extensive observation on the effect of sunlight and transpiration which in turn is a vital growth process in the plant. He established that cloudiness arrests the rate of transpiration considerably.

Sunlight has also been shown to raise the temperature of leaf surface thereby promoting better activity.

Salgado(1955) pointed out that day length has a dominant influence over other factors for maximum harvest of coconuts during April, May and June in Sri Lanka. Wickremasuriya(1968) related accelerated developement of spadix primordia to day length in west Sri Lanka.

2.1.5 Wind velocity

According to Copeland(1931) the effect of wind on the palm depends upon soil moisture condition. A dry and windy atmosphere conduces to the best growth of the palm provided soil moisture condition is favourable. Windiness will accelerate transpiration and thus help in the uptake of nutrients in the soil solution. Strong winds are not desirable and do considerable damage to the plantation.

2.2 Effect of climatic factors on other perennial crops

2.2.1 Oil palm

The climatic need of oil palm is very similar to that of coconut preponderant influence being that of water supply and thus rainfall. The sunshine hours(day length) is one of the important climatic factor which has a significant effect on production in palm oil. Reviews on climatic effects on production in palm oil were made by Hartley(1967) and Ferwerda(1977). But a comprehensive understanding of climatic influences on oil palm is lacking.

Devuyst(1948) found positive correlation between annual yield and the sum of monthly rainfall up to 300 mm during the consecutive 12 months, 33 months before harvest. Hemptinne and Ferwerda (1961) found a negative correlation between bunch yield and precipitation 31 months earlier and positive correlation 12 months earlier in a northern plantation in West Africa but quadratic relationship of yield to precipitation 33 months earlier and no effect at 12 months earlier in a southern region.

Turner(1976), Brockman(1957) and Corley(1973,1976) noted that draught caused floral abortions and reduction in sex ratios after two years. Irrigation during long dry spell in Africa led to huge increase in yield (Desmarest, 1967).

Sparnaaije et al.(1963) found positive correlation between sunshine hour per annum and yield of friut bunches. Though Ferweda(1977) noted that the result may be due to moisture stress, Robertson and Foong (1976) indicated that solar radiation was least influential on the yield of oil palm. Ferweda (1977) further reported that the highest yielding plantation appeared to be in the region with the smallest variation of monthly mean temperature. In general temperature effect on oil palm are not well studied (Hartley, 1963;Ferweda, 1977; William, 1975).

Effects of rainfall and dry spell on oil palm were often studied. Prolonged draught is regarded as dangerous to crop production (Ferweda, 1977). Ochs(1977) reported that annual variation in rainfall is shown to affect the sexualisation of inflorescence and consequently have repurcussion on bunch production with a time lag of about 28 months. It can also play a part in the abortion of the inflorescence and the growth of the bunches in the period preceeding harvest by as little as six months. Knowing the mean annual water defecit in a given place, it was possible to estimate potential yield fairly well.

An explanatory identification analysis was introduced by Ong[1982(a), 1982(b)] as a systematic and objective method of determining the relationship between the oil palm bunch yield and changes in rainfall, dryspell,temperature and sunshine of various months(or lags) before harvest .

Monthly oil palm yields were studied for relationship between monthly rainfall and dry spell as far back as 42 months (or lag 42) before harvest through a series of simple correlations and then reevaluated through a series of partial correlations. Ong identified the oil palm yield to be associated with rainfall at lag 5-7,16-18, 22-23, 28-30 and dry spell at lag 5-6, 9-12, 16-18, 22-23and 29-30; Rainfall at lag 16-18, 22-23 and dry spell at lag 29-30 has association with bunch yield which were partially independent but the other variables interacted completely with at least some of the other. He suggested that an effective way of identifying the spurious variable was to partially correlate the variables against the variables having maximum association with yield. When some climatic factors were partially correlated against variables of the other climatic factors, no new information arose except the identification of one more variable as spurious.

Ong[1982(a)] determined the relationship between the oil palm monthly yield to temperature and sunshine of various lags using a series of simple and partial correlations The yield was associated with diurnal temperature range at lag 7-9, 13-16, 25-29, Maximum temperature at lag 7-11, 14-17, 25-29 minimum temperature at lag 16-18, 22-24, 28-31. Spurious variables and interaction among variables were studied by making use of partial correlation. The result indicated that initiation of floral primordia would be facilitated by cool night, sex differentiation of females favoured by the warm summer weather, early developement of sexually differentiated tissue stimulated by wet condition. Spear development enhanced by warm sunny weather, floral abortion increased by hot dry weather and anthesis facilitated by warm nights. The variables interacted with each other and only five lags viz.,lag 14-17, minimum temperature at lag7-9, maximum temperature at lag 14-17, minimum temperature at lag 6-8 and 36-41 had some independant association with bunch yield.

2.2.2 Tea

Research and observation on how climate affects the growth and yield of tea plant were briefly reviewed by Carr(1972). In Ceylon, Portsmouth (1957) studied 21 months crop data in relation to a range of climatic factors and found, for clonal plants of tea variety, that the weight of individual plucked shoots was positively correlated only with the rainfall recorded one, two and three months prior to plucking. In Malawi, Laycock(1958) found that there was no correlation between annual rainfall or monthly rainfall and annual yield, but by splitting the year into three distinct parts he was able to fit the following highly significant Multiple regression equation of yield on rainfall ;

$$Y=0.091E + 0.047M + 0.06D + 1.79 \quad \cdots\cdots (1)$$

where Y was tea yield in 100 kg/ha

E early rains (November - December)

M main rain (January - May)

D when soil dry (June - October)

For each unit of rainfall received, the early rain was found to be twice productive as the main rain, whereas the dry season rain had a depressing effect on yield.

Laycock(1964) later found a highly significant linear relationship between a weather parameter(E+M) and annual yield from several areas of unshaded tea in Malawi. Eden(1965) observed that if the monthly rainfall average fell below 50 cm, crop production suffered severely for several months.

Sen et al. (1966) adopted an approach similar to Laycock(1958) while attempting to correlate yields with climate in an unshaded area at Tocklai reseach station. Twenty one years crop data(1921-41) were studied in relation to Rainfall, Sunshine hour, mean air temperature, diurnal range in temperature and Relative humidity as well as to the age of plant. They split the year into and Relative humidity as well as to the age of plant. They split the year into four main season based on the relative soil moisture availability. Of all the climatic factors studied, rainfall in the period January to March and the rise in mean temperature during the same time proved to have the greatest influence on early crop, which in turn led to an increase in main crop. An increase in rainfall during this period was not beneficial when the mean air temperature has high, but apparently no correlation between yield and other climatic factors studied. However they observed that April to June rainfall depressed the late crop while during October - December it was beneficial.

An emperical expression for tea was proposed by Devanathan(1975) which relates vegetative growth to the product of rainfall and bright sunshine hour over a specified period. The expression obtained to predict yield was;

$$Y = 0.255\,RS - 0.87 \qquad r = 0.97 \qquad \ldots\ldots (2)$$

where R rainfall and S sunshine hour.

2.3 Crop weather models

The crop weather models may be defined as a simplified representation of the complex relationship between weather or climate on the one hand and crop performance (such as growth, yield components), on the other hand by using established mathematical or statistical technique(Baire, 1979)

Newman (1974) distinguished basically two approaches : 1. modelling based on mathematically formulated relationship with emperical constant when neccessary (deterministic approach) and 2. modelling usually involving some type of statistical regression technique for fitting statistically the best possible emperical relationship between climatological variables and crop production (stochastic approach).

Least square regression has formed the backbone of quantitative research in crop-weather relationship. The general approach has been to regress a time series of the dependent variable(yield) against independant variable comprised of variables selected for trial in regression analysis vary from simple, raw measurements of temperature and precipitation to composite variables derived from these. Usage of composite variables as the predictor variable was suggested by Doll(1967). The foundation for Doll's index is that yield is in some way dependant upon condition prevailing in discrete periods in the growing seasons of crop. The general form of the model is expressed as follows:

$$Y_t = f\{\sum_{j=1}^{k}\int_{S_{j-1}}^{S_j} W_j(S)X_{ij}(S)dS\} \quad \ldots\ldots\ldots 3$$

where Y_t is yield in year t and $W_j(S)X_{ij}(S)$ is a weighting function evaluating the effect of the meteorological variables X upon final yield at a point of time S in period $j(=1,2,\ldots,k)$.

$$Z_{tj} = b_j X_{ij} \sim \int_{S_{j-1}}^{S_j} W_j(S)X_{ij}(S)dS \quad \ldots\ldots\ldots 4$$

so that $Y_t = f\{\sum_{j=1}^{k} Z_{tj}\}$.

By assuming Z_{tj} to be linear function of X_{ij} and yield a quadratic function of Z_{tj}, Doll applied the model to estimate rainfall influence on Missouri corn yield for the period 1930-63.

Williams et al.,(1975) proposed that in view of the possible application of crop-weather studies in macroscale agro-climatic analyses, a model including weather, soil group, soil texture, topography and trend may be utilised. The general form of the model is as follows:

$$Y = \phi\,(C, R_i, E_i, T_x, T_p, S_g, T) \quad \ldots\ldots 5$$

where Y is yield

C = Conserved precipitation prior to May for the crop district and year calculated from precipitation data for the preceeding 21 months.

R_i = May, June , July rainfall for the crop district and year.

E_i = Estimated PE during May, June and July

T_x = Topography index which is highest for flattest topography

S_g = Information on soil group

T = A linear time trend

Sg = Information on soil group

T = A linear time trend.

McQuigg (1976) described two basic approaches to modelling the impact of meteorological variability on crop yield 1. The physiological or causal appraoch which is based on the detailed knowledge of the biological or physical process which take place within a given interval in the plant / soil systems in the immediate enviornment of the plant, and 2. The statistical or correlative approach which is based on the application of some sort of statistical, mostly regression technique to a sample of yield from an area and a sample of weather or climatic data from the same area.

Jones (1982) reviewed some of the methodology employed for investigating aggregate crop weather relationships together with the problems encountered. He used the chi-square test to determine the seasonal significance of weather variables which are then subjected to Principal Component analysis. Employing these components as the explanatory variables in multiple regression the utility of the approach for exploring the economics of the agricultural climate is assessed.

Vaidyanathan (1981) reviewed the agrometereologists' research work explaining the influence of weather on crop-yields . This review gives a good account of the methodology adopted by research workers engaged in crop-weather studies in annual crops. Deshpande (1981) presented a bibliography on the crop-weather studies on annual crops.

A suitble statistical methodology was developed by Agarwal et al.,(1980) to forecast the yield of rice using 25 years yield data and weekly weather variables. Weighted averages of weekly weather variables and their interaction using powers of week numbers as weights were used in the first model. The respective correlation coeffecients with yield in place of week number were taken in the second model. The step-wise regression analysis was followed for obtaining the forecast model.

Mustafi and Chaudhari (1981) developed a monthly tea crop production stochastic process as function of stochastic variables like past values of monthly tea crop production and also of both past and current values of meteorological parameters. This work involves generation of regression polynomials of optimum complexity through the use of a heuristic method known as multilayer group method of data handling. This method provides a prediction of tea crop production a month ahead of crop's picking.

2.3.1 Crop weather analysis models in coconut

~~An~~ Earliest attempt to study the crop-weather analysis model in coconut was ~~made~~ by Patel and Anandan(1936). They computed the correlation coeffecients for 20 different combinations of rainfall. The highest magnitude (r=0.81) was obtained for the combination 'J+F+M of X^2 and X^3, J,F,and M are rainfall during January, February and March respectively. X2 and X3 stands for total rain in same months during the year prior to harvest and two year prior to harvest. The correlation coefficients for seven other combinations were also found significant. Using partial regression the following relationship was calculated for the deviation of yield Y in terms of the duration of respective rainfall total from their mean. The model fitted is :

$$Y = 2.34X^1 + 3.99X^2 + 0.85X^3 \qquad R^2 = 0.80 \qquad \ldots..(6)$$

where X1 total rainfall in the same month during the year of harvest.

X^2 total rainfall in the same month during previous year of harvest

X3 total rainfall in the same period of two years prior to harvest.

Y is the estimated yield of coconut

They found that the relationship between yield and rainfall is not linear. Therefore a second degree function of the closest fit parabola was estimated using ordinary least square methods.

Abeywardane (1968) attempted to quantify the relation between rainfall and coconut yield based on certain assumptions. A prediction equation was obtained based on two assumptions. 1. For most of the perennial crops the period of fruit set is considered as moisture sensitive. Therefore an adequate supply of water during the period of fruiting is important. 2. For The rainfall to be effective it must be well distributed. On the basis of these assumptions it was believed that crop in a given year is governed by the total rainfall and number of rainy days of the previous year. The model is ,

$$Y = 51.93+0.24X^1-0.06X^2 \qquad R^2=0.19 \qquad \ldots\ldots(7)$$

where Y is expected yield of coconut

X^1 Rainfall of previous year

X^2 Number of rainy days

Another model suggested by Abeywardane(1968) was based on the assumption of effective rainfall and rainfall distribution index.

$$Y = 36.32+0.26X^1+1.52X^2 \qquad R2=0.33 \qquad \ldots\ldots(8)$$

where Y is expected yield of coconut

X^1 effective rainfall

X^2 distribution index of rainfall

Yet another model suggested by Abeywardane(1968) was based on the assumption that if a particular sub-period which showed a dry spell is followed by another dry spell , the crop will be depressed. Similarly if a sub-period with good rainfall is followed by another sub-period with good rainfall it will be reflected favourably on the crop. These favourable results are due to additive as well as cumulative effects of rainfall during these sub-periods.

The model suggested by him is,

$$Y =8.98+0.02X^1 -0.60X^2 -0.57X^3 -0.6X^4 +0.13X^5 +0.84X^6 +0.027X^7 \qquad \ldots\ldots(9)$$
$$+0.02X^8 +0.03X^9 +0.023X^{10} -0.013X^{11} +0.048X^{12} \qquad R^2=0.873$$

where Y is estimated yield of coconut

X 1: May-August rainfall(two years prior)

X^{2}: January-April previous year

X 3: May-August previous year

X 4: September-December previous year

X 5: September-December two years prior

X 6: January-May of harvest year

X^{7}: Product of X^1 and X^4

X^{8}: Product of X^2 and X^4

X 9: Product of X^2 and X^3

X^{10}: Product of X^3 and X^5

X^{11}: Product of X^5 and X^6

X 12: Previos years rainfall with an effective monthly maximum of 12.5 cm of rainfall.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Yield and Meteorological data

A total of 167 palms of WCT variety belonging to the age group of 45-50 years was selected from plot No. RS 29 North Block, CPCRI, Kasaragod grown under rainfed condition receiving the recommended dose of fertilisers. Monthly yield data in terms of number of nuts produced by the selected palms for the period from 1955 to 1983 were obtained from CPCRI farm records.

To obtain a comprehensive idea about the impact of climatic factors on the coconut production it is neccessary to consider as many climatic factors as are relevant. So far the study on the influence of climatic factors was carried out in isolation without considering their possible overlapping or interaction effects. Most of the studies were concentrated on the influence of rainfall and its distribution.

There are as many as 21 weather factors identified to be influencing crop yield (White,1979). Most of them are highly interrelated and some are not relevant to our condition. The decision regarding the selection of weather parameter was based on the assumption that crop yield depends basically on three agro-climatological variables; solar radiation, temperature and soil moisture (or evapo-transpiration). These three variables modify each other on any particular period of time and produce a positive or negative effect on the yield.

The following weather parameters were considered accordingly.

Sl. No.	Weather Parameters	Abbreviation
1.	Maximum Temperature	MXT
2.	Minimum Temperature	MNT
3.	Soil Temperature at 5 cm depth(o C) (forenoon)	STF5
4.	Soil Temperature at 15 cm depth(o C) (forenoon)	STF15
5.	Soil Temperature at 5 cm depth(o C) (Afternoon)	STA5
6.	Soil Temperature at 15 cm depth (oC) (Afternoon)	STA15
7.	Vapour Pressure (forenoon)	VPF
8.	Vapour Pressue (Afternoon)	VPA
9.	Relative Humidity(FN)	RHFN
10.	Relative Humidity(AN)	RHAN
11.	Wind velocity (kmph)	WV
12.	Sunshine hour	SSH
13.	Rainfall(mm)	RF
14.	Evaporation	EV
15.	Number of rainy days	NORD
16.	Range in temperature	RT
17.	Range in Soil temp.(5cm)	STR5
18.	Range in Soil temp.(15cm)	STR15

These observations were collected from the daily weather chart of meteorological observatory maintained at CPCRI, Kasaragod for the period 1955-1980(26 years). Daily observations were converted to weekly data as per standard weeks (see Appendix I).

The data were entered into the computer system (HCL - Workhorse) at the college of Horticulture, Vellanikkara Kerala and were verified.

In a bid to study the monthly influence of weather parameters weekly observation were converted to monthly average based on standard weeks. But in the case of rainfall and number of rainy days totals for months were considered. To study the seasonal influence of weather parameters monthly observations were further averaged to four seasons. Following Pillai and Satyabalan (1960), months were grouped into seasons as follows.

December, January and February : 1st season
March, April and May : 2nd season
June, July and August : 3rd season
September, October and November : 4th season

The entire study was based on the assumption that all the climatic factors under study follow a multivariate normal distribution. We suppose that a p dimensional random vector of the weather varibale and yield $X \sim N_p(\mu,\Sigma)$, where μ is the mean vector of order $p \times 1$ and Σ is the dispersion matrix of the order $p \times p$.

3.1.1 Lagged Variables

The term lagged variables denotes past values of the exogenous and dependent or endogenous variable. It is often more realistic to assume that the effect of a variable is distributed over several time periods. If a causal factor X_t produces a component $B_0 X_t$ in Y_t, a component $B_1 X_t$ in Y_{t+1} and so forth upto $B_s X_t$ in Y_{t+s}, and if this system of reaction is constant over time, Y in any period may be expressed as a linear function of the previous values of X, namely,

$$Y_t = B_0 X_t + B_1 X_{t-1} + \ldots + B_s X_{t-s} + u_t \qquad \ldots\ldots.1$$

under the usual assumption about the distribution of u and the independence of X and u. Least square methods will give best linear unbiased estimators.

The lagged variables were used based on the following assumptions:

1. The primordium initiation of the coconut inflorescence begins 44 months prior to the harvest of nuts.
2. Coconut palm produces inflorescence, perennially at the rate of one per month and each of this undergoes a cycle of developmental stages.

3. The climatic variations during the developmental stages influence the growth of the inflorescence cumulatively.

In other words yield of coconut at a particular point of time (either month or year) is the cumulative effect of the weather fluctuations in the preceeding 45 months or twelve seasons i.e.,

$$Y_t = f(X_1, X_2, \ldots, X_n) \qquad \ldots\ldots\ldots 2$$

where $$X_{it} = (X_{i,t-1}, X_{i,t-2}, \ldots, X_{i,t-0}) \qquad \ldots\ldots\ldots 3$$

$X_{i,t-j}$ is the value of ith independent variable at j th lag period. $0 = 45$ in the case of weather parameters taken for months and $0 = 12$ when they are taken for seasons, and Y_t is the yield of coconut at time t. The effect of climatic variation in the immediate past upto ten months were not included as it is assumed to have insignificant influence on yield.

3.2.1 Monthly and Seasonal climatic variation on monthly yield

To identify the climatic factors and their effective lag periods, linear correlation coefficients between yield and eighteen climatic factors were worked out for 36 lag months ranging from 10-45 months before harvest. Similarly to identify seasonal effect correlation between seasonal climatic factor from 4th to 15 lags were worked out. This may be expressed mathematically as follows.

A correlation matrix $\underset{\sim}{A} = (r_{ij})_{18x36}$, where r_{ij} is the coefficients ofcorrelation between monthly yield and ith climatic factors at (j+9)th lag was worked out.

A correlation matrix $\underset{\sim}{B} = (s_{ij})_{18x12}$, where s_{ij} is the coefficients of correlations between seasonal climate and monthly yield at (j+3) lag, was worked out. Here, $\underset{\sim}{A}$ was estimated from 312 data points and $\underset{\sim}{B}$ from 103 data points. A weather factor at any lag period was identified to have influence on yield, if it has a correlation coefficient significant at 5 per cent level with yield.

3.2.2 Correlogram

With a view to study the hidden pattern of relationship between yield and climatic variables at different lags correlograms were drawn for monthly data for all climatic factors.

3.2.3 Month-wise climate and monthly yield of coconut

Simple coefficients of correlation were worked out between monthly yield and climatic factors of each calender month for a period ranging from 10-45 months prior to harvest. Coefficients of correlation which were significant at 5 per cent level were earmarked.

3.2.4 Season-wise climate and monthly yield of coconut

Coefficients of correlation between monthly yield and climatic factors of each season for three consecutive years before harvest were worked out to study the pattern of relationship. Coefficients of correlation which were significant at 5 per cent level were identified.

3.2.5 Month-wise and Season-wise climatic factors and annual yield

Annual yield of coconut was subjected to square root transformation (Mathew, 1982). To study the effect of climatic factors for each month of a calender year on annual yield, simple linear correlations were worked out between annual yield (square root) and climatic factors of each calender months for three previous years. In the same way season-wise climatic factors and annual yield were also correlated.

3.3 Forecasting models

The objective of the forecasting model is to estimate an equation which will account for the dependence of the crop yield on weather. Multiple regression analysis is an ideal technique for studying cause and effect relationship.

However its application to the crop-weather studies is by no means straight forward. The linear model is of the form,

$$\underline{Y} = \underset{\sim}{X}\underline{\beta} + \underline{\epsilon} \qquad \ldots\ldots\ldots\ldots\ 4$$

where $\underline{Y}$ is a nxl vector of the n years of observation, $\underset{\sim}{X}$ is a nxp matrix of the n year of observation for the $\underline{\beta}$ predictor variables, $\underline{\beta}$ is pxl vector of regression coeffecients and $\underline{\epsilon}$ is a nxl vector of errors.

A further problem raised by correlated variables is variable selection. Since there are too many candidates for use as predictor variables in yield model, it is desirable to exclude predictor variables which apparently do not have a significant effect on yield. The standard technique used to perform variable selection is step-wise regression. However, this also becomes inappropriate when there exist substantial correlations among the predictor variables (Marquardt and Snee, 1975). Since the significance of an individual predictor variable may be masked by its correlation with other predictor variables, important predictor variables may be erroneousely excluded from the model. Therefore, in order to reduce the dimensionality and interdependance of explanatory variables, Principal Component Analysis was carried out before adopting step-wise regression. The methods of Step-wise regression and Principal component analysis are given in section 3.3.7 and 3.3.8.

3.3.1 Model for monthly yield from monthly climate

The coefficients of correlation between climatic factors and monthly coconut yield showing significant effect for different lag periods were identified. Since the number of lagged variables identified in this case was too large (140) principal component analysis could not be adopted straight away. The following procedue was therefore adopted. ~~Factors were marked out in this manner. These variables were classified into seven groups as explained below.~~

The climatic factors were catagorised into seven groups as shown below so as to reduce the number of variables systematically.

1. Maximum and minimum temperature.
2. Rainfall and number of rainy days.
3. Sunshine hour, evaporation and wind velocity
4. Soil temperature at 5 cm depth
5. Soil temperature at 15 cm depth
6. Vapour pressure
7. Relative humidity

The lagged variables identified from these groups were later subjected to Path coefficient analysis for further selection. The variables with high direct effect and those with low direct effect but high indirect effects were selected as exogeneous variables to be included in the prediction model. Twenty six variables thus selected were used as the predictor variables in the regression equation. The method of Path coefficient analysis is described in section 3.3.6. The variables thus selected were subjected to Principal Component Analysis and step-wise regression as explained earlier.

3.3.2 Model for annual yield from seasonal climate

Crop yield basically depends on three agro-climatic variables namely, solar energy, temperature and soil moisture (or evapo-transpiration)[William et al. 1975]. In view of this and the correlation among the climatic factors and annual yield, six climatic factors viz., RHAN, SSH, RF, EV, NORD and RT were identified for developing the model.

Estimation of annual yield was envisaged in two stages. At the first stage, models to estimate annual yield(square root) from each of the climatic factors at different lag seasons was arrived at using step-wise regression. These estimators were used as predictor variables to arrive at the final model again by step-wise regression at the second stage.

The models in the first stage are of the form,

$Y_{it} = f\{X_{i,t-4}, X_{i,t-5}, \ldots, X_{i,t-n}\} \quad i=1,2,\ldots,6$ .... ~~10~~ 5 $X_{i,t-5}$

where Y_{it} is the annual yield at year t estimated from ith climatic factors.

$X_{i,t-j}$ is the value of ith independent variables at the jth lag period.

The final model is,

$Y_t = g\{Y_{1t}, Y_{2t}, \ldots, Y_{6t}\}$ .... ~~12~~ 6

where Y_t is the annual yield of coconut(square root) at year t.

3.3.3 Model for annual yield from month-wise climate

Annual yield estimates of the crop were obtained from mean month-wise climatic factors developed in two stages of analysis. The variables influencing annual yield for each month were obtained by performing step-wise linear regression on weather variables of that month. Annual yield of coconut for the previous year was treated as one of the predictor variables in each month. The basis for considering the previous years' yield of coconut is that, the yield can be assumed to be the index of climatic factors of the previous years. The variables of different climatic factors of different months were selected based on their contribution to the annual yield variation. Those contributed above 20 per cent were selected as the predictor variables for the second stage of analysis. Nineteen variables were thus selected from the first stage of analysis. The model in the first stage is of the form,

$Y_{it} = a_{i0} + a_{i1} Y_{i,t-1} + \sum_{i,j} b_{ij} X_{ij}$ .... ~~13~~ 7

where Y_{it} is the annual yield obtained using ith months weather variables X_{ij} (i,j = 1,2, ... , 12).

Principal Component Analysis was performed on these selected variables since it was noticed that variables were highly intercorrelated. In the second stage of analysis the model becomes,

$$Y_{it} = c_0 + c_1 Y_{t-1} + \sum_i d_i W_i \qquad \ldots\ldots\ldots\ldots \; \cancel{14}\,8$$
$$w = 1,2, \ldots, 12$$

where W_i, $i = 1,2,\ldots, k$ are the first k components and d_i's are their regression coefficients.

3.3.4 Season-wise variable lag model

Similar to the month-wise varibale lag model, climatic factors from four seasons were selected based on their contribution to the variation in the annual yield of coconut. Here also the model is developed in two stages. In the first stage lagged variables of different climatic factors from four seasons were identified by performing step-wise linear regression. In the second stage of analysis components of variables selected in the first stage was taken as explanatory variables and the final model was obtained by step-wise regression PCA was also performed, so that the interdependence of different lag variables can be taken care of. The model is similar to that of in section 3.3.3.

3.3.5 Generated lag model

With a view to understand the interactive effect of various climatic factors influencing yield, 44 generated variables (variables with their squares, their product combinations) were considered. The climatic factors considered for generating first order variables are STF15, STA15, RHAN, SSH, RF($\log_e$), EV, NOR and RT. Four sets of generated variables for four seasons were separately derived in the first stage of analysis. Coefficients of correlation between annual yield and the generated variables (including the originally selected variables) were obtained for preliminary screening. Those variables which showed significant effect on yield at 5 per cent only were considered for the second stage of modelling. Step-wise linear regression was performed on these selected variables for each season separately. The subset of variables obtained through the step-wise regression from four seasons were treated as the predictor variables in the second stage of analysis.

The model is of the form,

$$Y_t = A0 + \sum_{i} Ai\ Xi + \sum_{i,j} Bj\ Xj\ Xi + C0\ Yt\text{-}1 + et. \quad \ldots \quad \cancel{15}\ 9$$

$i = 1,2,3,4$ and $j = 1,2, \ldots, p$ in the first stage and,

$$Y_t = f\{Xi1, Xi2, \ldots, Xip\} \qquad \ldots\ldots\ldots\ldots \ 10$$

in the second stage.

At both stages annual yield of coconut for the previous year is included as one of the predictor variables since all the lag periods were not considered in the model.

3.3.6 Path coefficient Analysis

The technique of Path coefficient analysis developed by Wright(1921) is useful to study the functional relationship between causal factors and their effects. This method can be used in the present context to identify the lagged variables to be retained in the prediction equation.

Path coefficient analysis decomposes of simple linear correlation coefficient between every causative variable and the effect into its direct effect and its indirect effect through other causative factors.

Consider the linear model of the form,

$$Y = b0 + b1\ X1 + \ldots + bn\ Xn \qquad \ldots\ldots\ldots\ldots \ \cancel{14}\ 11$$

where b_i's are partial regression coefficients and Xi's are the exogeneous and Y the endogenous variables. The direct effects are nothing but path coefficients which are standardized regression coefficients, and are given by $P_{iy} = bi\ \sigma i / \sigma y$. σi and σy are standard deviations of X and Y respectively. The indirect effect of Xi through Xj is rij Piy. The coefficient of correlation, r_{yk}, can be broken down as,

$$r_{yk} = P1y\ r1k + P2y\ r2k + \ldots + Pnk\ rnk + Puy\ ruk$$

$$= \sum_i P_{iy}\ r_{ik} \qquad \ldots\ldots\ldots\ldots\ \cancel{5}\ 12$$

Σ ?

The residual effect may be obtained as follows.

$$h \quad = \sqrt{(1-\sum_i P_{iy}\ r_{iy})} \qquad \ldots\ldots\ldots\ldots\ \cancel{6}\ 13$$

?

where h is the residual effect and h2 measures the degree of determination of Y by residual factors and $\sum_i P_{iy}$ riy measures the degree of determination Y by the endogenous variables.

3.3.7 Step-wise regression

In many regression situation the researcher doesn't have sufficient information about the order of importance of the independant variables X1, X2 ,..., X_p in predicting the dependent variable Y.

Since the statistic for determining the effectiveness of a set of independent variables as predictors is the multiple correlation coefficient, one solution to the above the problem is to regress Y on all possible subsets yielding largest R. But when the number of predictor variables is large it becomes impracticable to determine the best subset. Under such conditions one solution is the technique of forward step-wise regression in which the independent variables X_1, X_2, ... , X_p are entered one by one into the equation according to some preestablished criterion. Once a variable is in the equation, however it may be swapped with a variable not in the equation. The set of criteria determining how a variable is entered or swapped is called stepping procedure. In the present study the standard stepping procedure (F method) is adopted as explained by Afifi and Azen (1979) to select the parsimonious set of variables from the ordered list which has high predictive capability.

3.3.8 Principal Component Analysis (PCA)

PCA is a method by which a larger set of observed variables could be expressed as a fewer set of derived variables which are orthogonal to each other. Its ability to reduce interdependence between a group of varibales has given it considerable respectability in crop-weather studies (Jones, 1982). The method requires no particular assumption about the underlying structure of the variables. Each component is simply a linear combination of variables that account for as much variance as possible displayed by the data. Thus the first Principal component provides the single best summary of linearity exhibited by the data. The second component gives the next best variance and so on.

The characteristic equation of PCA is,

$(R - \lambda I)f = 0$ where R is correlation matrix of order n. The solution to the system is based on the determinant $|R - \lambda I| = 0$.

Expansion of this determinant yields a polynomial of degree n with roots $\lambda_1, \lambda_2, \ldots, \lambda_n$. Taking λ_1, the largest root, the system is solved for the vector f. The first Principal component will be ,

$$P_1 = f_1 z_1 + f_2 z_2 + \ldots + f_n z_n. \qquad \ldots\ldots\ldots \cancel{8}\ 14$$

Subsequent components are obtained from the remainaing eigenvectors. It is then possible to explore the relationship between a given dependent variable and the regressor variables now expressed in terms of a smaller number of orthogonal components. This may be expressed as,

$X^* = X A'$ where X is the matrix of the original variable of the order nxp.

A' is the matrix of eigen vectors of the order pxp_* where

p^* the number of eigen values selected.

X^* is the matrix of the generated variables of the order nxp^*

The OLS of these new variables is of the form,

$$Yt = a0 + a1\ P1 + \ldots + a_p\ P_p + et \qquad \ldots\ldots \cancel{9}\ 15$$

Since most of the correlation matrices obtained from Principal component Analysis did not show orthogonality, step-wise regression was performed on these components.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 Monthly climatic factors and monthly coconut yield

The coefficients of correlation between 18 weather parameters for a period ranging from 10-45 months prior to harvest and monthly yield of coconut were worked out and values significant at 5 per cent level along with lag months are presented in table 4.1.1. It may be noted that most of the factors have significant correlation with yield at lags 15-16, 27-28, 33-34 and 44-45. The influence of different climatic factors on yield are briefly explained below.

Temperature: MXT showed significant positive effect at 5 per cent level on yield at lag months 13, 25, 28 and 37 and negative effects at lags 20, 32, 39 and 44-45. MNT positively correlated with yield at lags 12, 24, 35 and negatively correlated at lags 15-16, 27-28 and 40.

Soil Temperature: STF5, STF15, STA5 and STA15 influenced the yield significantly at 5 per cent level at lags 12-13, 20-21, 24-25, 36-37 and 44-45. Out of these 20-21 and 45 lag periods showed negative effects.

Relative Humidity and Vapour Pressure: VPFN and VPAN showed significant positive effects on monthly yield at lag months 10-11, 15-16, 23, 27-28, 35 and 39-40 whereas RHFN and RHAN showed significant effects at lag months 15-16, 21, 27-28, 32-33, 39-40 and 44-45. Every alternative lag period showed negative correlation with yield.

Sunshine hour, wind velocity and evaporation: WV and monthly yield were correlated significantly only at lag months 32 and 44 months and the correlation was negetive. SSH affected the yield significantly at lag periods 10, 15-16, 21, 27, 33, 40 and 44-45. Correlations at alternative lag periods begining from lag 10 was negative. EV and monthly coconut yield were significantly correlated at lag months 13, 25, 27, 33, 37 and 45. Begining from the second significant lag group the effect was negative alternatively.

Rainfall and number of rainy days: Monthly yield was correlated significantly to RF and NORD at lag months 10, 15, 20-21, 27, 32-33,40 and 45. Negative effect on yield was obsereved in lag months 15-17, 25-29 and 40.

Range in temperature: RT showed significant corrleation with yield at lag months 10, 15-16, 21, 27-28, 33, 39-40 and 45. STR5 showed significant effect on yield at lag 10, 21, 26, 33, 37 and 45. Very few of the lag periods showed significant correlation between STF15 and yield.

It may be seen from the correlogram [fig 1(a)-1(e)] that all the climatic factors under study, when considered on monthly basis followed a relationship with seasonal cyclicity of 12 months. The graph shows that the relationship becomes significant every six months alternatively changing sign between negative and positive.

Bhaskaran and Leela (1983) also opined that relation between weather parameters and coconut yield exhibit a cyclical pattern of relationship and coincide with the seasonal periodicity of lagged variables. When the relationship is of cyclical nature as seen in the present study a reliable conclusion could not be drawn on the importance of any weather variable. However a group of weather parameters at various lags could be identified to have sufficient contribution on yield though they are interrelated. Identification of weather variables based on significant coefficient of correlation alone leads to unreliable interpretations. Hence path coefficient analysis was resorted to for identifying the most important explanatory variables.

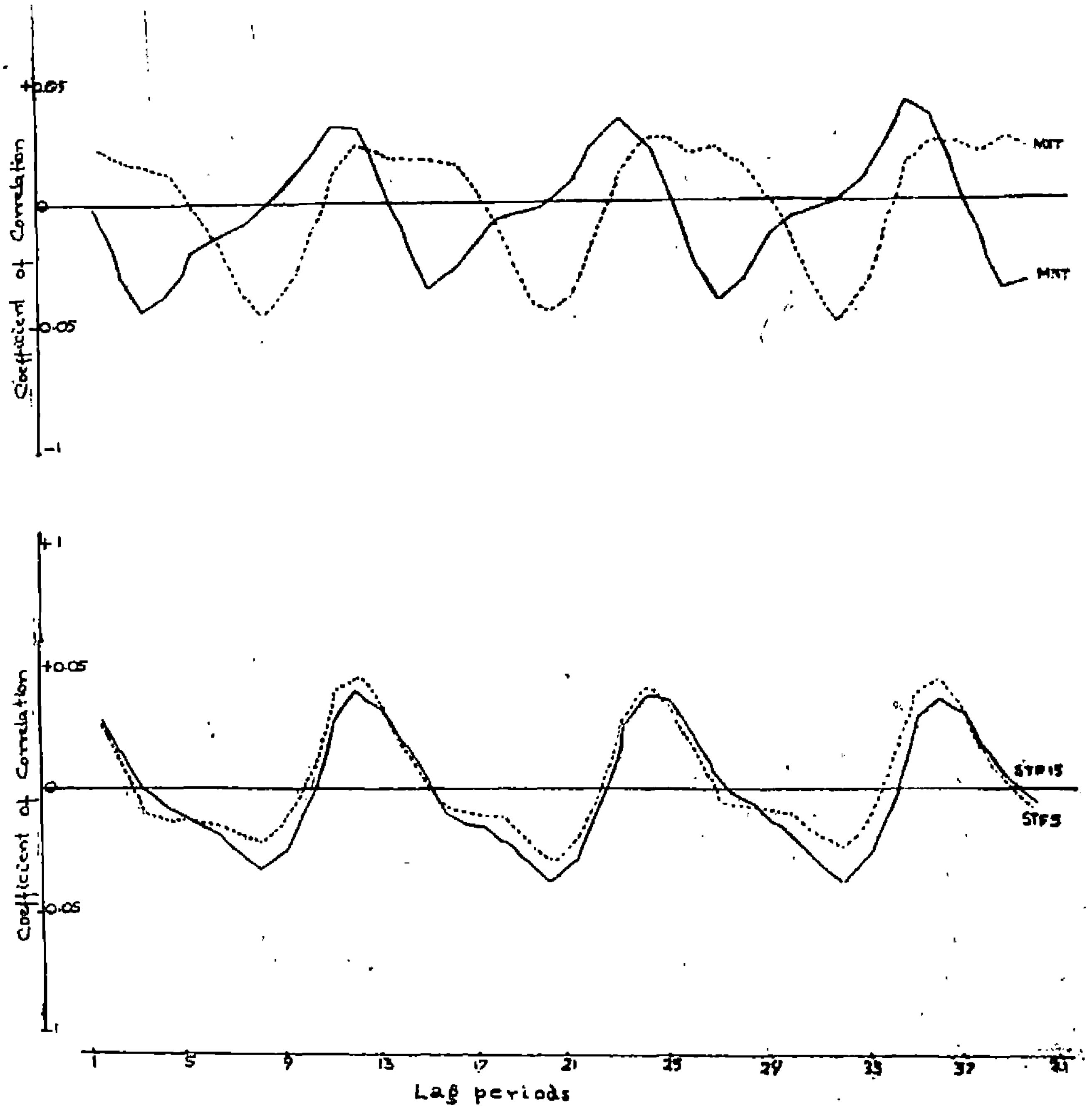

Fig.1(a). CORRELOGRAM SHOWING CYCLICAL PATTERN OF RELATIONSHIP BETWEEN MONTHLY COCONUT YIELD AND MONTHLY CLIMATIC FACTORS

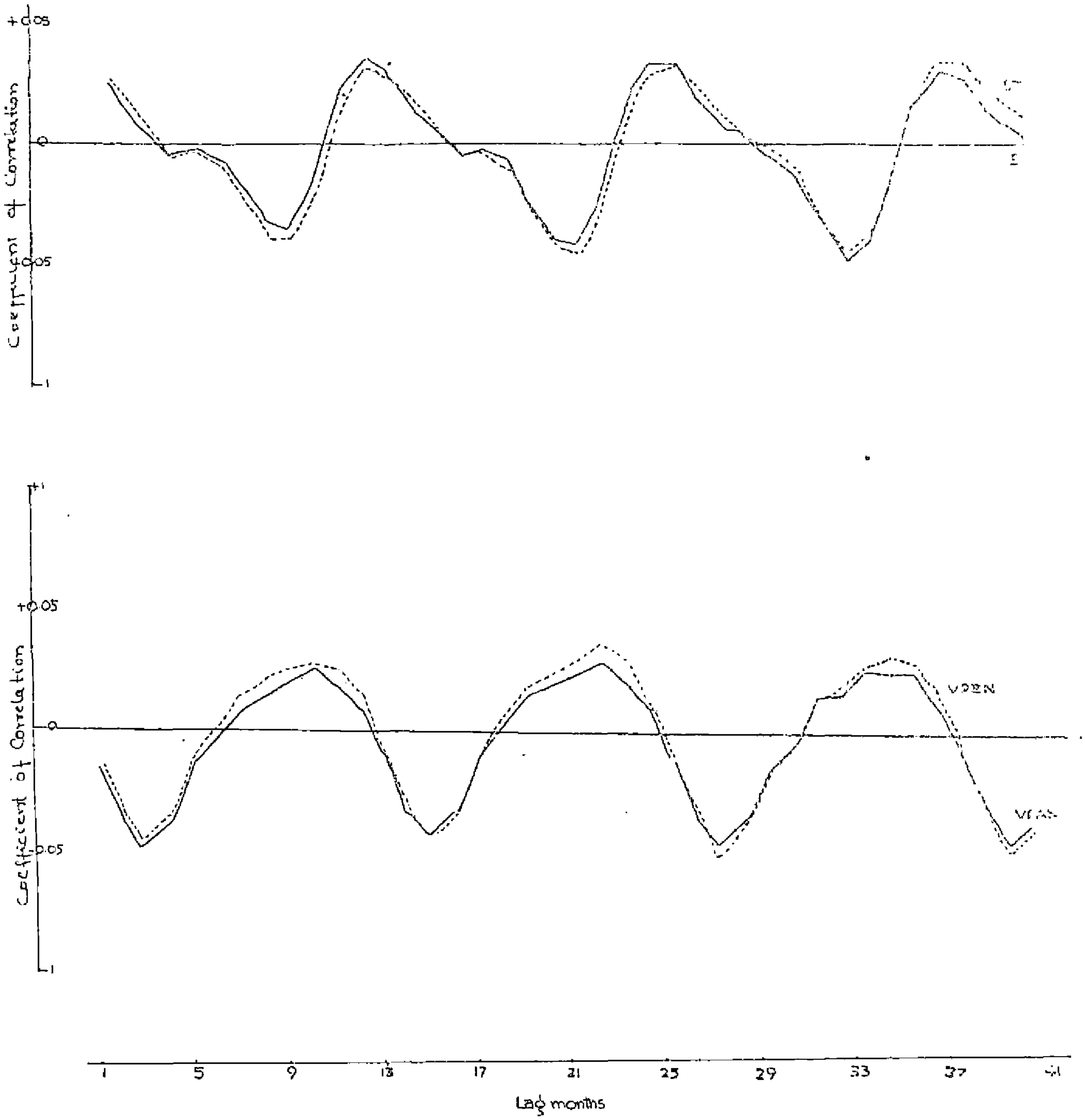

Fig-1(4) CORRELOGRAM SHOWING CYCLICAL PATTERN OF RELATIONSHIP BETWEEN MONTHLY COCONUT YIELD AND MONTHLY CLIMATIC FACTORS

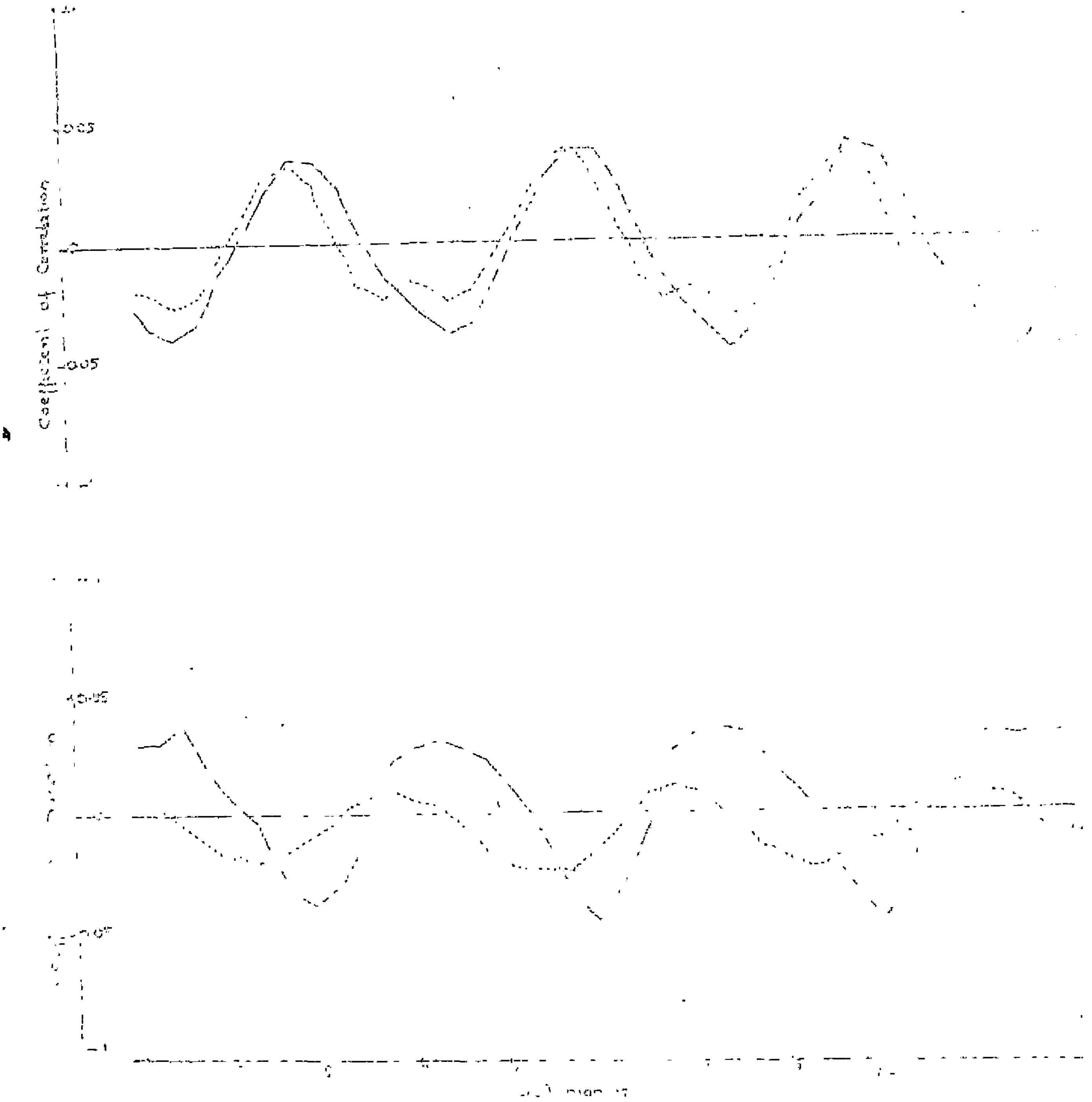

FIG.4(b) CORRELOGRAM SHOWING [illegible] OF [illegible]

BETWEEN MONTHLY COCONUT YIELD AND MONTHLY CLIMATIC FACTORS

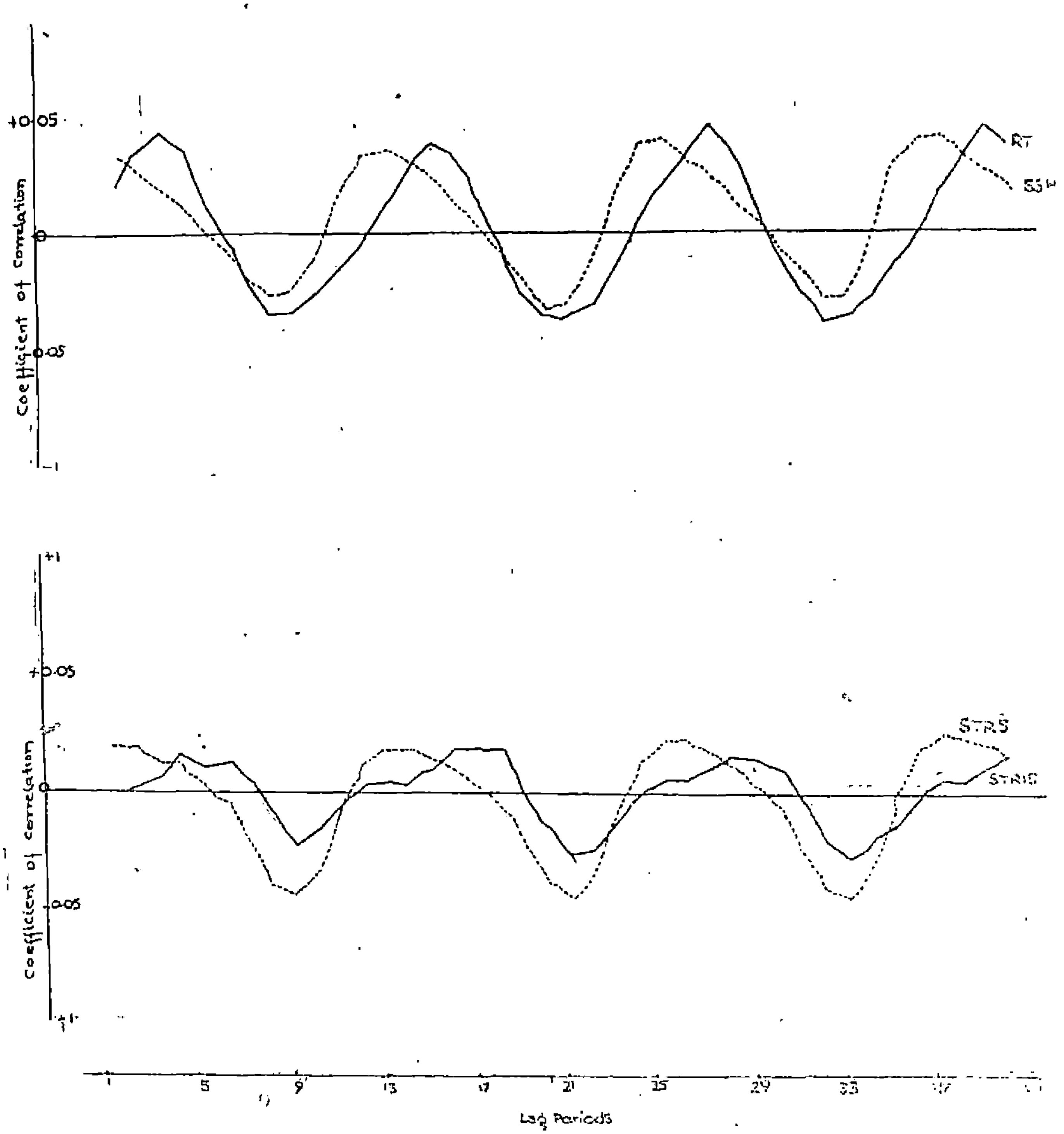

Fig. 3(d). CORRELOGRAM SHOWING CYCLICAL PATTERN OF RELATIONSHIP BETWEEN MONTHLY COCONUT YIELD AND MONTHLY CLIMATIC FACT

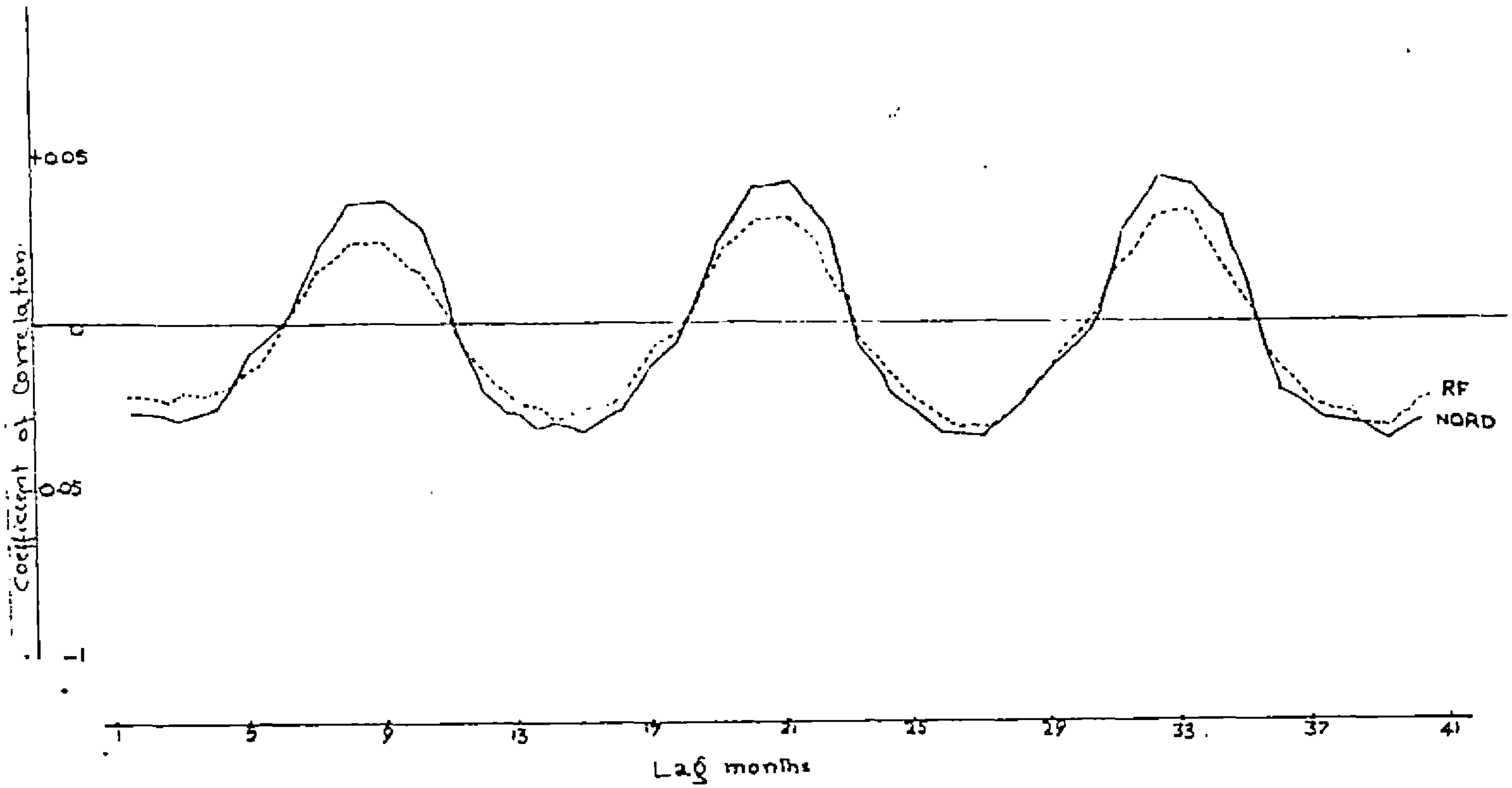

Fig 1(e) CORELOGRAM SHOWING CYCLICAL PATTERN OF RELATIONSHIP BETWEEN MONTHLY COCONUT YIELD AND MONTHLY CLIMATIC FACTORS

Identification of predictor variables is to be achieved by tackling the problem of interdependence and avoiding the spurious correlations. These problems were tackled in two ways, i.e., the use of path coefficient analysis and principal component analysis. Several workers have pointed out that a genuine solution to tackle the multicolinearity of stochastic variables in a time series is by adopting principal component analysis (Jones, 1982; Katz, 1979; Huda and Runge,1985; Huda et al. 1985). However literature on the use of path coefficient analysis to identify explanatory variables in the presence of multicollinearity is scanty.

About 140 lagged variables of different climatic factors which had significant correlation at 5 per cent with yield were identified. These variables were further grouped into seven categories as explained in section 3.3.1. Path coefficient analysis was performed on variables of each group seperately. Twenty six variables which had either high direct effect or low direct effects but high indirect effect were further selected and presented in Table 4.1.2.

Due to the presence of large number of explanatory variables and multicollinearity, Principal Component Analysis was performed on these twenty six selected variables. The first nine Principal Components which explained 89 per cent of variation were considered for the forecasting model. The eigen vectors and eigen values corresponding to these components are presented in Tables 4.1.3. Contrary to the expectation, orthogonality of derived variables could not be achieved. Hence step-wise regression was carried out for selection of variables in the prediction equation. Variables which contributed one per cent or more only were included in the model. The prediction model thus formed consisted of four generated variables and had a coefficient of determination of 0.221. The serial numbers of these explanatory variables, the regression coefficients, their standard errors, t-values are provided in table 4.1.4.

Many authors have favoured the use of Step-wise regression technique as a reliable technique to overcome the defects of multiple regression technique directly (Dyer and Gilloly, 1977; Katz,1979).

4.2. Month-wise climatic factors and monthly coconut yield

The coefficients of correlation between 18 climatic factors for each calender month and yield of the crop at different lead months were calculated and those significant at 5 per cent along with their corresponding lead months are presented in Tables 4.2.1 to 4.2.12.

It may be noted from the tables that largest number of lagged variables are found to exist in May and the least in July. In other words, the climate during monsoon do not exhibit much influence on yield whereas during summer months significant influence are found to exist. It may be seen that RH showed substantially negetive influence on yield during every calender month, whereas SSH showed positive relationship throughout. The probable reason for the increased influence of climatic factors during May could be attributed to the soil moisture condition prevailing during that month. Soil moisture during this months undergo changes due to highly variable weather prior to the onset of monsoon. It is found that the variability of climatic factors such as RF, RH and SSH were higher during this month. It is also well known that soil moisture is greatly influenced by the climatic factors and especially the rainfall. However, non existance of significant relationship during monsoon period do not indicate that the climatic factors have no influence, but the lower variability of the climatic factors masks the influence.

In the light of the above results it may be worthwhile to mention that the climatic factors studied here, though important by themselves, affects the crop perhaps more through its influence on soil moisture. It is therefore, important to study the reaction of soil moisture to climatic factors to understand the crop-weather relationship more clearly.

understand the crop-weather relationship more clearly.

The reason attributed to the positive relationship exhibited by SSH may be due to the fact that it increases the activity of the crop through increased photosynthesis and evapo-transpiration and thereby influences the yield beneficially. Whereas RH shows negetive relationship on yield and the probable reason for this is due to the fact that as RH increases evapotranspiration decreases and hence the nutrient and water uptake by the plant is adversely affected which in turn affects the final yield.

It may also be noted from the tables that RF and NORD, during pre and post monsoon periods showed increased variability compared to that during monsoon. Hence it may me argued that RF and NORD remains the limiting factors in determining the future yield.

4.3. Season-wise influence of weather on monthly yield of coconut

It is observed from the table 4.3.1 to 4.3.4 that the pattern of influence of weather on monthly yield of coconut shifted from season to season. RHAN and EV had more number of lagged variables showing significant relationship with yield during first season(March, April and May). During second and third seasons very few lagged variables of different climatic factors showed significant relationship compared to that of others. However climatic factors MXT and EV showed increased influence during these seasons. Climatic factors viz., STF5, RHFN, SSH, RF and EV showed significant influence on yield during fourth season(December, January and February).

RH predominantly showed negative influence on yield, whereas SSH had positive influence. EV also exhibited significant influence on yield during monson season. Here, it may be noticed that increased activities of climatic factors were in evidence during pre and post monsoon period. And the reason for this phenomena is explained in section 4.2. It may be seen that RH, SSH and EV plays an important role in influencing monthly coconut yield.

The classification of seasons used here may not be an ideal one to explain the relationship between weather and yield. It may be worthwhile to study the influence of climate on yield by using different grouping of seasons. Present classification of seasons showed, to some extent, the inherent influence of climatic variation during pre and post monsoon periods. It may be noted that from the comparison of the magnitude of correlation of season-wise and month-wise climate on yield that season-wise comparison exhibited higher influence than that of month-wise climate. Similar observations were made in oil palm (Ong, 1982a,b). He reported that combined months often had greater association with bunch yield of oil palm than an individual month's weather variables. This indicates that while a single months change of climatic factors could be associated with yield, a larger duration of these could be more influential due to cumulative effect of the factors involved.

4.4. Month-wise climatic factors and Annual yield of coconut

Mean values of month-wise climatic factors and their standard deviations are presented in table 4.3.5. Coefficient of correlation between the selected climatic factors for each calender month and annual yield of coconut for the succeeding years are presented in table 4.4.1. STF15 and STA15 during April and December and May and December respectively showed significant correlation with yield. While the association for STF15 during April and May was negative, STA15 showed positive relationship during May and negative during December month. RHAN correlated significantly with yield during the months of January, May, September, October and December. Only during December the correlation was positive. Sunshine hours during February, May, September, October and December and annual yield of the succeeding year were correlated significantly. However SSH of December showed negative relationship with annual yield.

RF and NORD during December and October showed significant effect on yield. While rainfall had positive influence, NORD showed negetive influence. Annual yield and EV during May, July, August, September and October months of the previous year showed significant correlation

RT during August had positive significant correlation and that during December, negetive significant correlation with annual yield.

It may be noted that climatic factors during the pre and post monsoon periods - May, September, October and December show significant influence on annual yield of the succeeding years of harvest. Evaporation influenced the annual yield during rainy seasons, especially during July and August months and the relationship was positive.

The climatic factors showing significant association with annual yield in frequent lag months were RHAN, SSH and EV. An important aspect noticed was the association of climatic factors during the pre and post monsoon seasons with yield. One of the reasons for this could be the high variability of climatic factors during the period. The absence of significant influence of RF and NORD during rainy seasons may be due to their low variability. There were high variability for RF and NORD during October and December and they showed significant influence on yield.

The coefficient of variation was noticed to be higher during these months compared to the other months for this variable. A possible physiological explanation may be that higher rate of evaporation increases gasseous exchnge in the plant and thereby increases the photosyntheses.

A forecasting model for annual yield of coconut was estimated using month-wise weather parameters of the yester years. The effects of the previous lag periods were represented by the annual yield of coconut in the previous year. The assumption underlying is that the previous years yield is the result of cumulative and interactive effects of climatic factors of the foregone seasons. However the effect of climatic factors less than ten months prior to the harvest were not considered in the model.

Adopting step-wise regression for annual yield and selected climatic variables of individual months, 18 lagged variables was selected based on their contribution to annual yield and are provided in table 4.4.3. In obtaining the final model, step-wise regression analysis, taking eighteen lagged variables selected in the first stage and previous years' yield as another explanatory variable, was performed. The final model included seven lagged variables and is also shown in table 4.4.4. The coefficient of determination was 0.853 indicating the predictability of this model.

It may be observed that large contributions to yield were attributed by SSH, RHAN, EV and STF15. SSH contributed highly during April, May and December. RHAN showed higher contribution to the variablity in annual yield during January, August and September. EV contributed significantly during July, August and October. Climatic factors showing high contribution were treated as predictor variables in the 2nd stage of modelling. The higher R^2 were obtained during December, August and January months i.e., 0.61, 0.58, 0.575 respectively. One of the reasons for the low coefficient of determination observed during different months may be due to the fact that climatic factors affect the yield cumulatively and the effect due to a single month could not explain the yield variability to a desired level. Inclusion of previous year's yield as a predictor variable did not add much weight to the forecast modelling. Non significance of relationship between annual yield and previous years' annual yield suggests that they are independent, atleast linearly.

Another model was proposed using the variables selected at the first stage of each month to predict annual yield of coconut by generating a new set of orthogonal variables through Principal components. Nine Principal Components which explained 89 per cent of variation was selected to be considered as explanatory variables at the second stage as shown in table 4.4.5. The coefficient of determination, Regression coefficient etc., obtained by using the new set of variables as predictor variables are presented in Table 4.4.6.

One of the main drawbacks in the above model is that one has to include all the selected variables from the first stage of modelling and their corresponding eigenvectors were treated as weighing coefficients in the first stage. This leads to too much of computation to arrive at the estimate of yield.

In the first model(month-wise variable model) the method of estimation is comparitively easier than the second model using principal components, though the coefficient of determination can be increased by including more eigenvectors in the second model. The t values obtained to test the regression coefficients were seen to be significant more frequently in the second model than in the first model suggesting the presence of multicollinearity in the first model which is reduced through principal components in the second model.

4.5. Seasonal climate and annual yield

Table 4.5.1. shows the season-wise mean value of 18 climatic factors for 3 years lag apart with their standard deviations. Coefficients of correlation between season-wise weather and annual yield of coconut are presented in table 4.5.2. The result shows that weather variables of pre and post monsoon seasons only influenced the annual yield. The climatic factors during monsoon did not influence the yield significantly. RHAN, SSH and EV influenced the yield at all lag periods of first and third seasons. Climatic factors of the second and fourth seasons did not have much effect on yield during all the lag periods studied. The second being a rainy season, the variablility of weather

variables remains low and the imapact remains implicit. The impact of individual weather variables on annual yield are briefly mentioned below.

Temperature: Annual coconut yield was positively correlated to RT at third lag of third season. For the sake of simplicity this is denoted as season (3,3). MXT and MNT did not exhibit significant correlation with annual yield.

Soil temperature : STF5 and STA5 positively correlated to annual yield at season (2,1). STF15 and STA15 did not correlate with yield significantly.

Relative humidity : RHFN, VPAN and RHAN showed significant but negative correlation with yield. VPAN showed significant relation at season (2,4). Relative humidity during season (2,1) and season (2,2) showed significant relationship. Whereas RHAN significantly correlated with yield during season (2,1), season (3,3) and season (2,4).

Sunshine hour : A significant positive correlation was observed between annual yield and SSH at season (1,1), season (2,1), season (3,1), season (1,3) and season (3,3).

RF and NORD were significantly and negatively correlated with annual yield during season (2,1). Also RF at season (1,4) and NORD at (1,3) were also found significantly correlated with yield.

Evaporation : EV was positively correlated with annual yield at seasons (2,1), (2,2), (3,3), (1,3) and (2,3).

The seasonal climatic factors did not show a cyclical pattern of relationship with annual yield of coconut contrary to the observations made in the monthly yield versus monthly weather. Most of the variables showing a decreased magnitude of relationship as the lag period increases. This evidently explains that some of the climatic factors had shown their importance during the inflorescence opening and had less importance in the growth stages of previous lag periods. However RHAN, SSH, EV and NORD influenced the yield during the primordial initiation and also at the time of inflorescence opening. Most of the climatic factors did not influence the growth stages during the middle of the growth periods ranging upto 36 months after primordium initiation. During most of the time RHAN showed negative influence on yield while SSH showed ~~negative~~ positive correlation. Allmost all the climatic factors correlated to yield at one or the other seasons of different lag periods prior to harvest.

4.6. Model for annual yield using season-wise climate

A forcasting model was attempted to predict annual coconut yield using the selected variables from four seasons of different lag periods. ~~Two methods of approach was made to obtain two prediction equations.~~

In this ~~first~~ method the four lag periods of six climatic factors were considered. Two stages of analysis was envisaged here. As a first stage climatic factors of first, second, third and fourth seasons were separately treated as predictor variables. Step-wise regression technique was adopted on these and the variables selected in four seasons are listed in table 4.6.1.

The selected variables were STA15, RHAN, SSH, EV, NORD and pre-yield in the first season, STA15, RHAN, EV, NORD and RT in the second season, RF, EV, NORD and pre-yield in the third season and STA15, SSH, RF, EV, NORD, RT and pre-yield for fourth season. The coefficients of determination~~s~~ for four seasons were 0.60, 0.51, 0.31 and 0.64 respectively for first, second, third and fourth season.

In the second stage of analysis the selected variables of four seasons were together treated as predictor variables. Step-wise regression analysis was used on the selected variables for further selection. The coefficient of determination obtained for the prediction equation, in this manner was 0.68.

The prediction equation with its coefficients are given in table 4.6.2.

4.7. Model for annual yield using seasonal climate

In this ~~second~~ method of forecast modelling two stages of analysis is envisaged. All the lag periods of selected climatic factors (six climatic factors) were treated as explanatory variables for each factor separately. Using step-wise regression technique variables for each factors were selected. In this manner six prediction equations were obtained for six climatic factors. The selected lag variables of six climatic factors, their coefficients, SE, t values and other related parameters were presented in Table 4.7.1.

In the second stage of analysis the estimates from the six prediction equations were treated as explanatory variables and using step-wise regression technique a final prediction equation was obtained. The final model with their relevant parameters were presented in Table 4.7.2. The coefficent of determination of the equation was 0.914.

It may be noted that the final model consists of RHAN and SSH at different lag periods and these factors together contributed 91.4 per cent of variation in yield. On examining the model at first stage RHAN alone explained 85.6 per cent of variation whereas SSH also explained 85.4 per cent of variation in yield. In other words a reasonably reliable prediction of annual yield can be made from RHAN and SSH alone.

This may be considered as one of the most successful method described in coconut to predict annual yield using RHAN and SSH. Similar results were obtained in oil palm also. The most successful method described so far in oil palm would be based on effective sunshine (Sparnaaij et al., 1963). Similar results were reported in Nigeria, where effective sunshine could be used to predict annual yield of oil palm with considerable success (Corley et al., 1976).

4.8 First order generated variables and annual yield

In a bid to study the interactive effects of selected climatic factors on annual yield, correlations were worked out between 42 generated variables (variables with their squares, their product combinations) of the eight selected climatic factors with annual yield. The coefficients of correlation worked out for four seasons are presented in Table 4.8.1.

Climatic factors which showed significant effects on yield in the first season were SSH and EV. First order interaction of these variables with others also showed significant influence on yield except X_{74} (product of SSH and NORD), X_{84} (product of RT and SSH), X_{76} (product of NORD and EV) and X_{86} (product of RT and EV). The effects of these variables were positive.

During second season the variables X_{32} (product of RHAN and STA 15), X_{64} and X_{81} (product of RT and STF15) showed negative and positive correlation with yield respectively. Also X_{86} (product of EV and RT) significantly correlated with annual yield in the same season.

RHAN, SSH, EV and NORD with their first order combination with other variables showed significant correlation on yield during the third season. However the variables X_{41}, X_{43}, X_{74}, X_{75}, X_{76}, X_{83} and X_{87} did not show significant correlation on yield. The climatic factors RHAN, NORD and the product of each with the other factors showed a negative correlation.

During the fourth season STF15 and RT showed negetive significant correaltion with yield. Their product variables viz., X_{41}, X_{81}, X_{82}, X_{84} were also found significant with negetive effect.

In this case also the seasons of pre and post monsoon period showed significant effect on yield whereas climatic factors of rainy seasons didn't show significant influence on yield.

4.9 Models using generated variables

A forecasting model was designed to use the selected generated variables derived from the four seasons. From the 42 interactive variables, those showing significant correlation to annual yield, at 5 per cent were selected. The variables selected are marked with asterix in Table 4.8.1., which gives the correlation coefficients of all the generated variables with annual yield. This model was envisaged in two stages.

Prediction equation for annual yield with the selected climatic variables of each season as explanatory variables were first obtained by step-wise regression. The estimated annual yield using these four predictor modelswere used as the explanatory variables for the final model. This model was also estimated by step-wise regression. The regression coefficients, t-value for testing the significance and coefficient of determination for the five different models are given in Table 4.9.1. It may be observed from the result that for the first season the variables STF15, STA15, RHAN, RF($\log_e$) and RT in combination with SSH came out as the candidates for the prediction equation of first season. A combination of EV with RF and RHAN also found place in the selected variables of first season. The coeffecient of determination obtained for this season is 0.557.

RHAN, EV, RT were prominant among selected variables in the second season. Here also the combination of RF and EV was selected as one of the predictor variables. R^2 for the second season was 0.625.

Nine variables were selected in the third season predominantly occupied by the combinations of SSH, EV and NORD. R^2 was 0.65 for the third season. Among the seven variables selected in the fourth season RHAN, SSH and RT were the important climatic factors. Here the coefficient of determination was 0.797.

It may be noticed that the value of R^2 increased as the season advanced. SSH was one of the very important variables found to influence the annual yield beneficially. However, it became deleterious when combined with STF15, RHAN, NORD and RT.

EV was another variable which influenced the annual yield of coconut beneficially. Beneficial effect was noticed even when it was combined with other important climatic variables. RT, RF, NORD and their combination with other variables were the next important climatic factors in the prediction equation.

The prediction model fitted using the weigheted variables of four seasons gave a satisfactory estimate of annual yield (square root) of coconut with coefficient of determination of 0.881(Table 4.9.2)

4.10 Comparision of different models

The models attempted in this study were emperical-statistical models, where a sample of yield data from an experimental field and a sample of weather data from the same field are used to estimate the coefficients by regression technique. The validity and potential application of such data depends upon the representativeness of the input data, the selection of variables and the design of the model.

This approach does'nt easily lead to an explanation of the cause-effect relationship, but it is a feasible procedure making use of available yield and climatic variables for weather based evaluation of past, present and to some extent the expected coconut yield statistic.

The criteria used to select the best model were relatively simple, which had comparatively high R^2 value.

Conclusions :

The relationship between monthly climatic factors and monthly yield showed seasonal cyclicity of 12 month period. An yield prediction model based on monthly climatic factors for monthly yield was not successful. Month-wise and season-wise climatic effect on monthly yield was studied and it is seen that during monsoon seasons there is lack of influence. Month-wise and season-wise climate on annual yield was studied. It is found that predictability increased when seasonal or season-wise climatic factors were considered. A best linear prediction model was developed using seasonal lagged variables of RHAN and SSH alone. The interaction effect of climatic factors on annual yield was studied using generated variables. The predictability was satisfactory when generated variables of climatic factors were used as explanatory variables.

1. For further work it is worthwhile if efforts are made for obtaining prediction model to estimate monthly yield of coconut so that crop-weather relationship may be studied more explicitly.

2. More emphasis may be given to soil moisture reaction in relation to climatic changes because it is well known fact that climate, though affects crop growth directly, its influence may be more prominant in association with soil climate.

3. Dependence of number of female flower opening on the climatic factors may provide an insight into the influence of climate before and after the opening of inflorescence.

4. Data from different agro-climatic condition may be considered with more emphasis while deriving a general prediction model for coconut production.

TABLES

Table 4.1.1 Coefficients of correlation between monthly weather and monthly yield of coconut

climatic factors	Coefficients of correlation									
MXT	.24(13)	-.43(20)	.22(25)	0.24(28)	-.40(32)	0.24(37)	-.38(39)	-.43(44)	-.41(45)	
MNT	.31(12)	-.38(15)	-.35(16)	.34(24)	-.28(27)	-.30(28)	.24(35)	-.40(40)		
STF5	0.40(12)	-.21(21)	0.41(24)	.35(36)	-.25(45)					
STF15	0.37(13)	-.34(21)	0.32(25)	-.31(32)	0.36(37)	-.30(44)	-.30(45)			
STAB5	0.29(13)	-.42(21)	0.34(25)	-.40(33)	-.31(34)	0.33(37)	-.34(44)	-.41(45)		
STAB15	0.34(13)	-.36(20)	-.43(21)	0.33(25)	-.32(32)	-.38(33)	0.32(37)	-.34(44)	-.40(45)	
VPFN	0.32(10)	0.33(11)	-.45(15)	-.41(16)	0.30(23)	-.39(27)	-.42(28)	0.28(35)	-.38(39)	-.42(40)
VPAN	0.27(10)	0.27(11)	-.44(15)	-.39(16)	0.23(23)	-.37(27)	-.42(28)	0.23(35)	-.38(39)	-.44(40)
RHFN	-.27(15)	-.28(16)	0.33(21)	-.22(24)	-.28(27)	-.36(28)	0.30(32)	-.21(36)	-.26(40)	0.35(44)
RHAN	0.30(10)	-.41(15)	-.36(16)	0.36(21)	-.33(27)	-.39(28)	0.33(33)	-.35(39)	0.32(44)	0.35(45)
WV	-.20(32)	-.20(44)								
SSH	-.33(10)	0.33(15)	0.27(16)	-.40(21)	0.30(27)	-.34(33)	0.27(40)	-.28(44)	-.40(45)	
RF	0.36(10)	-.21(15)	-.22(16)	0.40(21)	-.24(28)	0.34(33)	0.39(34)	0.35(45)		
EV	0.37(13)	0.38(25)	0.31(27)	-.25(33)	0.36(37)	-.26(45)				
NORD	0.35(10)	-.30(15)	0.33(20)	0.42(21)	-.30(27)	0.34(32)	0.36(33)	-.27(40)	0.40(45)	
RT	-.31(10)	0.42(15)	0.39(16)	-.32(21)	0.36(27)	0.41(28)	0.26(33)	0.40(39)	0.45(40)	-.28(45)
STR5	-.37(10)	-.41(21)	0.23(26)	-.40(33)	0.24(37)	-.40(45)				
STR15	-.24(21)	-.23(33)	-.24(45)							

Lag months corresponding to the coefficient of correlation are given in parantheses, which are significant.

Table 4.1.2 Direct effects and coefficients of Determination of seven groups of climatic factors

Group No.	Climatic factors	Direct effects								R^2	no. of Variables selected
1.	MXT	-.015	-.13	-.08	0.31(28)	-.01	0.054			0.291	4
	MNT	-.186(15)	0.08(2)	0.045(3)	-.248(35)	-.207(49)					
2.	ST75	0.036	-.053	.199	-.051	.041				0.221	3
	STA5	-.195(13)	-.067	.249(23)	-.016	.121	-.204(45)				
3.	ST715	.111	-.049	-.338(25)	-.109	0.081	0.106			0.255	4
	STA15	0.067	-.282(21)	.282(25)	0.146	0.006	-.232(45)				
4.	VP7N	0.552(11)	-.149	.252(23)	0.085	-.176	0.129			0.29	5
	VPAN	-.300(11)	-.133	-.242(23)	-.136	-.03	-.209(40)				
5.	RH7N	-.061	0.211(21)	-.142	-.320(28)	0.064	-.155	0.203(44)	-.023(46)	0.29	3
	RHAN	-.061	0.013	-.075	-.054	-.126					
6.	WV	-.113	-.037							0.24	4
	SSH	-.015	-.282(21)	-.071	0.309(33)	0.071	-.326(45)				
	EV	0.016	0.143	-.102	.126	.185					
7.	RF	0.053	0.044	.278(21)	-.066	0.202(34)	-.002	.001		0.21	3
	NORD	-.009	0.087	-.046	-.229(33)	0.045	0.098				

The values in parentheses are lag periods which were selected as explanatory variables.

Table 4.1.3. Principal components selected with their corresponding eigen values

	1	2	3	4	5	6
	0.1563	0.3401	0.0110	0.0600	-.0423	-.1811
	-.1266	0.2709	-.0176	0.4059	-.4293	0.0593
e	0.1980	0.1181	0.0143	-.3894	-.2754	-.0768
	-.1554	0.2863	0.0242	-.3023	-.1765	0.1482
i	0.1988	-.2046	0.0062	0.2294	-.0379	-.1391
	0.1581	-.3234	0.0044	-.0597	-.0578	-.1609
g	0.1611	-.3356	0.0169	0.0029	-.0733	-.1568
	-.2328	-.9887	0.0049	0.0299	-.1946	-.1029
e	-.2098	-.9995	-.0013	-.0412	-.2493	-.2908
	0.1531	-.3213	0.0129	0.1213	-.0984	-.1831
n	-.2129	-.9772	0.0102	0.0414	-.2655	-.1226
	0.1961	0.2594	-.0590	0.0083	-.0738	-.3074
	0.1969	0.2619	0.0572	0.0163	-.0813	-.2830
v	0.1681	0.1819	-.7031	0.0044	-.0525	-.0895
	0.1626	0.1937	0.7041	0.0203	-.0303	-.1014
e	-.2036	0.0949	0.0040	-.3907	-.2185	0.1219
	0.1807	-.0086	0.0123	0.4323	-.2704	0.4922
c	-.1461	-.2770	0.0181	-.1537	-.4576	0.1663
	0.1941	-.1137	-.0195	-.1445	-.2669	-.2472
t	-.2399	0.0167	-.0067	0.0505	0.1263	-.1928
	-.2388	0.0089	0.0071	0.0686	0.1328	-.0822
o	-.2425	0.0110	-.0064	0.0532	0.0669	-.0591
	0.2203	-.0709	-.0102	-.2378	0.0422	0.2952
r	0.2213	-.0625	0.0117	-.2211	0.1231	0.1803
	-.2133	-.0848	-.0071	-.0958	0.2035	-.1062
s	0.2395	-.0388	-.0037	-.0616	-.0528	0.0719
eigen values	14.92	4.29	1.78	0.97	0.745	0.663

Table 4.1.4 components selected with their regression coefficients, SE, t-valus and coefficient of determination for monthly climate and monthly yield

Serial No. of selected components	Regression Coefficients	SE	t-value
1	0.0502	0.0139	3.614
3	-.1946	0.0637	-3.055
4	0.05826	0.0142	4.087
5	0.0323	0.0172	1.879

Intercept : 8.683 R^2=0.221 SE of Estimate : 1.7

Table 4.2.1 Coefficients of correlation between and monthly coconut yield and climatic factors of January month

Climatic factors	coefficients of correlation				
MXT	-.42(32)	-.41(33)	-.71(34)	-.51(35)	-.50(42)
MNT	-.42(32)	-.45(33)	-.60(34)		
STFN5	..	..	..	..	..
STF15	-.46(21)	-.44(25)			
STAN5	-.49(14)	-.44(34)	-.44(45)		
STAN15	0.39(12)	-.55(45)			
VPFN	-.41(22)	-.48(40)	-.41(43)		
VPAN	-.49(22)	-.44(40)			
RHFN	-.50(15)	-.40(40)	-.54(43)		
RHAN	-.48(15)	-.48(22)	-.43(23)	-.50(43)	
WV	-.49(16)	-.51(29)	-.42(41)		
BSH	0.41(22)	0.42(34)	-.47(39)	-.48(41)	
RF	0.41(27)	-.39(37)			
EV	-.42(41)				
NORD	0.40(27)	-.38(37)			
BT	0.40(39)	0.60(42)			
STR5	-.47(14)				
STR15	..	..	..	..	..

Lag months corresponding to coefficient of correlation are given in parentheses.

Table 4.2.2 Coefficients of correlation between monthly coconut yield and climatic factors of February

climatic factors	Coefficients of correlation				
MXT	-.43(22)	-.33(35)			
MNT	-.49(380	-.46(43)			
STF5	..	..	..		
STF15	-.42(37)				
STAN5	-.61(14)				
STAN15	-.49(36)				
VPFN	-.50(38)				
VPAN	-.42(38)				
RHFN	-.45(29)				
RHAN	-.45(29)				
WV	-.49(16)	-.52(29)	-.41(41)		
SSH	0.41(16)	0.44(22)	0.39(32)	0.44(33)	0.59(34)
RF	..	..	...	..	..
EV	0.41(23)				
NORD	0.43(43)				
RT	0.42(42)	0.43(43)			
STR5	-.53(14)				
STR15	..	..	..	..	..

Lag months corresponding to correlation coefficients are given in paranthoses.

Table 4.2.3 Coefficients of correlation between monthly coconut yield and climatic factors of March

climatic factors	Coefficients of correlation			
MXT	-.49(13)	-.57(16)	-.42(35)	
MNT	-.41(34)	-.43(35)	-.47(38)	
STF5	0.43(44)			
STF15	-.43(320			
STAN5	-.60(14)	-.40(34)		
STAN15	-.40(44)	-.57(45)		
VPFN	-.47(14)			
VPAN	0.40(40)			
RHFN	0.45(42)			
RHAN	..	..	..	
WV	-.46(29)	-.51(41)		
SSH	0.40(43)			
RF	0.60(15)	-.43(25)	0.51(42)	0.49(44)
EV	0.45(24)	0.43(46)		
NORD	0.43(13)	0.57(44)		
RT	..	..	..	..
STR5	-.52(14)	-.41(34)		
STR15	-.43(45)			

Lag months corresponding to correlations are in bracket

4·2·4· coefficient of correlation between monthly yield of coconut and climatic factors of April

Climatic factors	Coefficients of correlation					
MXT	-.53(13)	-.52(14)				
MNT	-.55(13)	-.52(14)	-.54(22)			
STF5	0.50(14)	0.56(26)	0.46(31)	0.41(35)		
STF15	-.53(21)	0.41(28)				
STA5	-.58(14)	0.39(26)				
STA15	0.40(28)					
VPFN	..	..	..	..		
VPAN	-.39(33)					
RHFN	0.41(21)	-.52(28)	-.47(31)	-.40(33)		
RHAN	-.46(28)	-.47(31)	-.47(33)			
WV	-.46(29)	-.56(41)				
BSH	0.39(24)	0.51(32)	0.48(33)	0.44(43)	0.41(45)	
RF	-.54(28)	-.39(32)	-.59(33)	-.54(34)	-.51(35)	
EV	0.39(24)					
NORD	-.45(28)	-.48(31)	-.48(32)	-.60(33)	-.53(36)	-.49(35)
ET	..	..	..	..	..	..
STR5	-.35(34)					
STR15	0.45(24)					

Lag months corresponding to correlation coefficients are given in brackets

Table 4.2.5 Coefficients of correlation between monthly coconut yield and climatic factors of May

Climatic factors	Coefficients of correlation						
MXT	0.43(40)	0.49(41)					
MNT	0.41(25)	0.45(30)					
STF5	0.30(22)	0.58(21)	0.41(25)	0.45(30)	0.35(37)		
STF15	0.52(22)	0.55(23)	0.43(21)	0.51(34)			
STAN5	0.46(23)	0.54(21)	0.50(24)	0.41(33)	0.43(34)	0.45(35)	0.43(37)
STAN15	0.39(23)	0.48(21)	0.57(24)	0.42(35)			
VPFN	-.47(33)	-.42(36)					
VPAN	••	••	••	••			
RHFN	-.41(22)	-.42(21)	-.41(24)	-.54(31)	-.56(33)	-.47(34)	
RHAN	-.48(22)	-.49(21)	-.49(31)	-.44(33)	-.51(34)	-.44(37)	
WV	-.40(29)	-.53(41)					
SSH	0.49(22)	0.52(21)	0.40(34)	0.43(37)	0.48(38)		
RF	-.39(22)	-.49(21)	-.47(37)				
EV	0.66(23)	0.58(21)	0.47(33)	0.49(34)	0.43(37)	0.39(38)	
NORD	-.41(22)	-.40(23)	-.47(21)	-.43(34)	-.45(37)		
RT	0.47(39)	0.49(41)					
STR5	0.40(24)	0.49(35)					
STR15	0.45(13)	0.74(24)					

Lag months corresponding to correlations are given in parentheses.

Table 4.2.6 Coefficients of correlation between monthly coconut yield and climatic factors of June

climatic factors	Coefficients of correlation					
MXT	••	••	••	••	••	••
MNT	-.47(44)	-.36(45)				
STF5	0.55(22)	0.51(37)				
STF15	0.60(22)					
STAN5	-.44(27)	0.44(33)	0.41(37)			
STAN15	-.56(14)	0.39(33)	0.39(37)			
VPFN	0.57(23)	0.35(21)	-.47(45)			
VPAN	-.41(13)	0.39(21)				
RHFN	-.41(22)	-.51(23)	-.58(33)	-.53(34)		
RHAN	-.55(33)	-.46(34)				
WV	0.47(23)	-.50(29)	-.47(41)			
SSH	0.39(22)	0.40(33)				
RF	-.45(29)					
EV	0.47(23)	0.45(33)	0.43(34)	0.57(35)		
NORD	0.50(15)					
RT	0.46(38)	0.60(43)				
STR5	0.43(12)	-.39(22)				
STR15	-.66(14)					

Lag months corresponding to correlations are given in brackets.

Table 4.2.7 Coefficients of correlation between monthly

Table 4.2.7 Coefficients of correlation between monthly coconut yield and climatic factors of July

Climatic factors	Coefficients of correlation			
MXT	-.43(34)	-.44(35)	-.41(44)	-.44(45)
MNT	-.53(45)			
STF5	..	..	..	..
STF15	..	..	..	..
STAN5	-.43(33)			
STAN15	-.47(23)			
VPFN	..	..	..	..
VPAN	0.47(13)	0.38(21)	-.46(26)	0.42(39)
RHFN	-.69(22)	-.46(23)	-.49(34)	
RHAN	..	..	..	..
WV	-.51(29)	0.50(41)		
SSH	..	..	..	..
RF	..	..	..	..
EV	0.63(22)	0.65(23)	0.57(21)	0.66(25)
NORD	0.52(34)			
RT	0.37(15)	0.39(43)		
STR5	-.39(13)	-.43(35)	0.43(38)	
STR15	-.41(25)			

Lag months corresponding to correlations are given in brackets

Table 4.2.8 Coefficients of correlation between monthly coconut yield and climatic factors of August

Climatic factors	Coefficients of correlation					
MXT	0.42(37)					
MNT	-.65(15)	-.51(38)	-.62(43)			
STF5	..	..	..			
STF15	..	..	..			
STAN5	..	..	..			
STAN15	-.46(29)	..	..			
VPFN	-.44(35)	-.43(41)				
VPAN	..	..	..			
RHFN	-.53(22)	-.49(23)	-.49(25)	-.49(34)	-.55(37)	
RHAN	-.46(23)	-.44(21)	-.49(37)			
WV	0.44(25)	-.49(29)	-.50(41)			
SSH	0.43(21)	-.45(29)	0.41(37)			
RF	-.53(37)					
EV	0.55(22)	0.41(23)	0.54(21)	0.46(25)	0.49(34)	0.49(35)
NORD	0.57(29)					
RT	0.67(15)	0.48(21)	0.50(38)	0.50(43)		
STR5	-.62(29)					
STR15	-.41(29)	-.48(41)				

Lag months corresponding to correlations are given in brackets.

Table 4.2.9 Coefficients of correlation between monthly coconut yield and climatic factors of September

Climatic factors	Coefficients of correlation						
MXT	••	••	••	••			
MNT	-.40(38)	-.44(44)	-.47(45)				
STF5	••	••	••	••			
STF15	-.40(22)	-.48(32)					
STAN5	-.56(41)						
STAN15	-.41(28)	-.44(41)					
VPFN	••	••	••	••			
VPAN	-.54(18)	0.47(27)	0.40(34)	-.50(37)			
RHFN	-.40(13)	-.63(22)	-.48(23)	-.45(21)	-.44(35)	-.43(37)	0.52(41)
RHAN	-.38(22)	-.62(35)	-.47(37)	-.41(38)			
WV	0.39(32)	-.58(41)					
SSH	0.31(22)						
RF	0.46(41)						
RY	0.48(22)	0.55(23)	0.46(21)	0.41(33)	0.43(35)		
NORD	-.39(21)	-.50(37)	0.41(41)				
RT	0.42(43)	0.43(45)					
STR5	-.47(41)						
STR15	-.49(41)						

Lag months corresponding to correlations are given in brackets.

Table 4.2.10 Coefficients of correlation between monthly coconut yield and climatic factors of October

Climatic factors	Coefficients of correlation				
MXT	0.40(22)	0.48(24)	-.41(26)		
MNT	0.40(22)	-.44(45)			
STF5	0.44(14)	0.48(22)	0.39(28)		
STF15	••	••	••		
STAN5	0.50(23)	0.43(24)	-.39(32)	-.49(45)	
STAN15	0.52(12)	-.43(30)			
VPFN	0.46(24)				
VPAN	••	••	••	••	
RHFN	-.62(31)	-.46(34)	-.42(44)		
RHAN	-.31(32)	-.40(33)	-.48(37)		
WV	-.55(29)	-.50(41)	-.42(44)		
SSH	0.47(22)	0.40(35)			
RF	0.52(42)	0.44(44)	0.46(45)		
RY	0.56(22)	0.60(23)	0.52(24)	0.41(33)	0.51(35)
NORD	-.61(22)	-.52(24)	-.42(38)	0.45(45)	
RT	0.48(37)				
STR5	••	••	••	••	
STR15	••	••	••	••	

Lag months corresponding to correlations are given in brackets.

Table 4.3.1 Coefficients of correlation between monthly coconut yield and first seasonal climatic factors

Climatic factors	Correlation coefficients							
MXT	-.49(13)	-.59(14)	0.45(41)					
MNT	-.43(13)	0.43(28)						
STF5	0.45(10)	-.43(12)	0.43(22)	0.56(26)	0.42(31)	0.50(34)	0.45(37)	
STF15	-.48(20)							
STAN5	-.65(14)							
STAN15	0.46(13)	0.47(24)						
VPFN	0.38(11)	-.52(33)						
VPAN	..	..	..	..				
RHFN	0.43(18)	-.46(27)	-.42(30)	-.60(31)	-.55(33)	-.39(34)		
RHAN	-.41(31)	-.41(33)	-.41(34)					
WV	-.45(29)	-.56(41)						
SSH	0.45(15)	0.42(21)	0.55(22)	0.40(31)	0.48(34)	0.42(37)	0.52(38)	0.39(40)
RF	-.43(21)	-.41(22)	0.53(23)	-.57(26)	-.40(31)	0.40(33)	-.43(34)	-.45(37)
EV	0.46(20)	0.45(21)	0.46(22)	-.40(23)	0.44(24)	-.51(33)	0.46(44)	
NORD	-.43(26)	-.47(31)	-.50(34)	-.38(37)				
RT	0.49(41)							
STR5	0.42(13)	-.51(14)						
STR15	0.57(24)							

Values in parantheses are lag periods at which correlation coefficients are significant.

Table 4.3.2 Coefficients of correlation between monthly coconut yield and second sesonal climatic factors

Climatic factors	Coefficients of correlation								
MXT	..	..	..	..					
MNT	-.45(15)	-.44(38)	-.50(43)	-.46(44)	-.49(45)				
STF5	0.40(10)	0.49(22)	0.45(37)						
STF15	-.40(16)	0.40(22)	0.40(23)						
STAN5	..	..	..						
STAN15	-.40(10)	-.49(14)	-.39(26)						
VPFN	..	..	..						
VPAN	0.48(21)								
RHFN	-.65(22)	-.59(23)	-.39(26)	-.52(33)	-.61(34)	-.44(35)			
RHAN	-.53(22)	-.42(33)	-.41(34)						
WV	0.42(23)	-.48(29)	-.55(41)						
SSH	0.43(22)	0.40(37)	0.39(38)						
RF	-.46(15)	0.42(25)							
EV	0.62(10)	0.55(21)	0.60(22)	0.60(23)	0.48(25)	0.40(33)	0.48(34)	0.48(34)	0.58
NORD	0.49(11)	0.44(13)	0.69(15)	0.48(25)					
RT	0.41(20)	0.45(21)	0.55(38)	0.40(41)	0.60(44)				
STR5	-.45(10)	-.40(22)							
STR15	-.43(10)	-.44(11)	-.56(14)	-.42(26)					

Values in parantheses are lag periods at which coefficients of correlations are significant.

Table 4.3.3 Coefficients of correlation between monthly coconut yield and third seasonal climatic factors

Climatic factors	Correlation coefficients			
MXT	-.52(11)	-.44(22)	-.52(34)	-.40(45)
MNT	-.44(10)	-.52(11)	-.46(34)	
STV5	0.43(14)	-.45(20)		
STV15	-.42(16)	-.53(32)		
STAN5	-.44(14)	-.54(26)		
STAN15	0.44(18)	-.42(23)	0.45(24)	0.46(25)
VPFN	0.47(20)			
VPAN	-.45(29)	-.46(34)		
RHFN	..	..	..	..
RHAN	-.49(27)	-.53(29)	-.51(41)	
WV	-.45(16)	-.44(28)	-.50(28)	
SSH	0.40(11)	-.54(12)	0.49(36)	
RF	0.48(28)	0.52(42)		
EV	..	..	..	
NRD	-.45(30)	0.39(43)		
RT	-.46(14)	-.49(15)	-.47(22)	-.52(42)
STR5	-.52(14)	-.47(26)		
STR15	0.55(12)	0.53(18)		

Values in parantheses are lag periods at which coefficients of correlation are significant.

Table 4.3.4 Coefficients of correlation between monthly coconut yield and fourt seasonal climatic factors

Climatic factors	Correlation coefficients							
MXT	-.49(13)	-.58(14)	0.45(41)					
MNT	-.43(13)	0.43(28)						
STV5	0.45(10)	-.43(12)	0.43(22)	0.56(26)	0.42(31)	0.50(34)	0.45(37)	
STV15	-.48(20)							
STAN5	-.65(14)							
STAN15	0.46(13)	0.47(24)						
VPFN	0.38(11)	-.52(23)						
VPAN	..	..	..	..				
RHFN	0.43(18)	-.46(27)	-.42(30)	-.60(31)	-.55(33)	-.39(34)		
RHAN	-.41(31)	-.41(33)	-.41(36)					
WV	-.45(29)	-.56(41)						
SSH	0.65(15)	0.42(21)	0.53(22)	0.40(31)	0.48(34)	0.42(37)	0.53(38)	0.39(40)
RF	-.43(21)	-.41(22)	0.53(23)	-.57(26)	-.40(31)	0.40(33)	-.43(34)	-.45(37)
EV	0.46(20)	0.43(21)	0.46(22)	-.48(23)	0.44(24)	-.51(33)	0.66(44)	
NORD	-.43(26)	-.47(31)	-.50(34)	-.38(37)				
RT	0.49(41)							
STR5	0.42(13)	-.51(14)						
STR15	0.57(24)							

Lag months corresponding to correlations are given in parantheses.

Table 4.3.5 Mean Month-wise climatic factors with standard deviations

Months	Climatic factors							
	SYP15	STA15	RHAN	SSH	RF ($\log_e$)	EV	NORD	RT
Jan	29.32	34.5	53.63	9.35	0.17	4.47	0.08	11.45
	(1.28)	(1.54)	(4.27)	(0.38)	(0.60)	(0.31)	(0.27)	(0.73)
Feb	31.18	36.64	57.04	9.63	0.12	4.73	0.08	10.33
	(1.36)	(1.68)	(3.78)	(0.36)	(0.44)	(0.49)	(0.27)	(1.10)
Mar	33.28	37.97	61.11	9.38	0.59	5.20	0.27	9.03
	(1.32)	(1.56)	(2.90)	(0.38)	(1.22)	(0.64)	(0.45)	(0.64)
Apr	34.07	39.09	62.50	8.96	3.63	5.29	3.41	8.10
	(1.33)	(1.27)	(2.98)	(0.62)	(1.19)	(0.90)	(2.23)	(0.70)
May	31.77	36.48	69.19	7.29	5.06	4.91	9.57	7.41
	(1.71)	(2.17)	(4.88)	(1.31)	(1.33)	(1.10)	(3.99)	(0.75)
Jun	28.15	30.75	81.69	3.55	6.71	2.70	21.85	6.19
	(1.70)	(1.99)	(4.45)	(1.60)	(0.46)	(1.20)	(5.10)	(0.73)
Jul	26.34	29.09	85.76	2.79	7.07	1.92	30.92	5.52
	(0.64)	(1.15)	(1.56)	(0.95)	(0.29)	(0.94)	(3.46)	(0.91)
Aug	26.81	30.67	83.08	4.33	6.70	2.46	20.98	5.71
	(1.0)	(1.86)	(3.38)	(1.36)	(0.46)	(0.93)	(3.46)	(0.91)
Sept	27.54	33.14	78.94	6.0	5.47	2.69	13.77	6.45
	(1.30)	(1.87)	(3.97)	(1.37)	(0.66)	(0.91)	(4.79)	(0.61)
Oct	26.22	34.11	73.36	6.84	5.19	3.24	11.95	7.59
	(0.91)	(1.79)	(4.03)	(0.76)	(0.61)	(0.87)	(5.08)	(1.04)
Nov	28.34	34.20	63.09	8.37	3.72	3.70	4.19	9.55
	(1.34)	(1.69)	(7.10)	(1.01)	(1.35)	(0.55)	(3.39)	(1.24)
Dec	28.26	33.97	53.20	8.93	1.68	4.20	1.33	11.67
	(1.51)	(1.70)	(5.37)	(0.67)	(1.73)	(0.47)	(1.87)	(1.65)

The values in parentheses are standard errors.

Table 4.4.1 Coefficients of correlation between annual yield of coconut and monthly climatic factors of previous year

	Climatic factors							
Months	STF15	STA15	RHAN	SSH	RF	EV	NORD	RT
Jan	-.17	0.05	-.51*	-.03	-.34	-.18	-.34	0.08
Feb	-.22	0.20	0.02	0.38*	-.36	0.24	-.36	0.01
Mar	-.32	-.10	0.16	0.05	0.20	0.36	0.20	-.31
Apr	-.46*	-.05	0.01	0.34	0.03	0.15	-.02	-.01
May	0.29	0.38*	-.38*	0.52*	-.12	0.42*	-.27	0.06
Jun	0.19	-.15	-.09	0.13	-.10	0.06	0.03	0.35
Jul	-.03	-.23	-.32	0.05	0.02	0.48*	-.28	0.13
Aug	-.02	-.23	-.33	0.31	-.05	0.46*	0.04	0.39*
Sept	-.19	-.05	-.60*	0.38*	-.11	0.40*	-.20	0.34
Oct	-.05	0.32	-.48*	0.46*	-.28	0.59*	-.57*	0.23
Nov	-.13	-.07	-.001	0.07	0.14	0.26	0.15	-.10
Dec	-.41*	-.38*	0.40*	-.61*	0.42*	-.22	0.31	-.57*

The values with * marks are significant at 5 per cent level.

Table 4.4.3 Month-wise selected variables and coefficients of determination

Months	number of variables	Variables selected	R2
January	2	RHAN RF	0.575
February	1	RF	0.393
March	1	EV	0.220
April	2	STF15 SSH	0.370
May	1	SSH	0.520
June	1	RT	0.380
July	1	EV	0.370
August	3	EV RT RHAN	0.580
September	1	RHAN	0.410
October	2	EV NORD	0.560
November	1	NORD	0.320
December	2	SSH STF15	0.610

Table 4.4.4 Regression coefficients,SE and t-values of month-wise climate and annual yield of coconut (square root)

Selected variables	months	Regression coefficients	SE	t-value
	Jan	:	:	:
RHAN	Aug	:	:	:
	Sept	-.0518	0.0154	-3.359
	Jan	:	:	:
RF	Feb	:	:	:
	Mar	:	:	:
	Jul	0.1177	0.0662	1.778
EV	Aug	:	:	:
	Oct	:	:	:
	Apr	-.0790	0.0504	-1.567
STF15	Dec	-.0621	0.0448	-1.386
	Apr	:	:	:
SSH	May	0.1159	0.0449	-2.581
	Dec	-.3899	0.0841	-4.63
Pre-yield		-.1890	0.1040	-1.819

Intercept : 20.68 R2=0.653 SE of est. 0.298

Table 4.4.5 Eigen vectors and Eigen values for the selected components of month-wise climate and annual yield

Variable selected	Selected principal components 1	3	4	6	7	9
RHAN(JAN)	0.1761	0.1564	-.1088	0.3025	-.1529	0.0427
RF(JAN)	0.1760	-.2608	0.2336	-.1095	0.0504	0.0098
RF(FEB)	0.0621	0.3442	0.1704	0.4430	0.1226	-.0351
EV(MAR)	-.1929	-.4402	0.2391	0.0866	-.1088	-.2250
STP15(APR)	0.2106	-.1555	-.4529	-.1010	0.2096	0.2062
SSH(APR)	-.1700	-.2218	0.0552	-.0059	0.0315	0.2114
SSH(MAY)	-.3178	0.3966	-.2489	-.1130	0.3482	0.2602
RT(JUN)	-.2360	0.1191	-.1511	0.0462	0.0909	0.1192
EV(JUL)	-.3707	-.0532	-.0987	0.0201	-.0262	0.4158
EV(AUG)	-.3381	-.2169	0.0087	0.0201	-.0282	0.4158
RT(AUG)	-.1883	0.4008	0.1068	0.2790	0.1649	-.0909
RHAN(AUG)	0.1776	-.3814	-.0301	0.2902	-.2570	0.3265
RHAN(SEP)	0.2716	0.0450	0.2503	-.4635	0.2552	-.0724
RF(OCT)	-.3302	-.1926	-.1249	-.0375	-.0973	0.0800
NORD(OCT)	0.2435	-.3265	0.0488	0.1116	0.0967	-.4259
NORD(NOV)	-.1406	0.0608	0.3224	0.3101	0.1698	0.0714
SSH(DEC)	0.1175	-.2521	-.0645	0.2601	0.7035	0.2165
STP15(DEC)	0.2646	0.0759	-.3391	0.2990	-.1889	-.2507
PYLD	-.2113	-.1937	-.2440	0.1743	0.1094	-.4057
EIGENVALUES	5.19	1.90	1.69	1.05	0.96	0.71

Table 4.4.6 Regression coefficients, t-value, SE and coefficient of determination for month-wise climate and annual yield

Components selected	Regression coefficient	t- value	SE of estimates
1	0.1652	-7.77	0.019
3	0.0291	1.17	0.025
4	0.0493	1.91	0.026
6	-.0506	-2.82	0.028
7	-.2240	-4.14	0.054
9	-.0082	-2.44	0.025

Intercept: 20.04 R2 = 0.876

Table 4.5.1 Mean and standard deviations of seasonal lagged variables of six climatic factors

Season	Climatic factors					
	MCRD	SSH	RF	WV	RHAM	RT
1(DJF)	0.45 (0.59)	9.30 (0.32)	6.66 (8.91)	4.44 (0.32)	54.49 (3.04)	11.16 (0.58)
2(SON)	9.88 (2.84)	7.00 (0.71)	187.95 (79.82)	3.34 (0.66)	71.15 (3.48)	8.07 (0.68)
3(JJA)	24.38 (1.75)	3.64 (0.88)	892.47 (176.0)	2.42 (0.84)	83.35 (2.27)	5.83 (0.66)
4(MAM)	4.25 (2.45)	8.63 (0.61)	102.76 (68.87)	5.04 (0.75)	64.09 (2.68)	8.18 (0.56)
5(DJF)	0.54 (0.73)	9.31 (0.32)	6.46 (8.91)	4.43 (0.32)	54.48 (3.04)	11.14 (0.36)
6(SON)	10.03 (2.77)	7.014 (0.70)	191.69 (79.04)	3.26 (0.69)	71.35 (3.64)	8.05 (0.70)
7(JJA)	24.54 (1.69)	3.66 (0.88)	880.08 (176.82)	2.31 (0.80)	83.43 (2.25)	5.81 (0.66)
8(MAM)	4.58 (2.41)	8.60 (0.64)	113.33 (72.55)	4.95 (0.74)	64.20 (2.65)	8.15 (0.56)
9(DJF)	0.53 (0.74)	9.34 (0.31)	6.36 (8.98)	4.43 (0.32)	54.46 (3.04)	11.18 (0.55)
10(SON)	10.13 (2.79)	6.99 (0.70)	196.31 (80.81)	3.20 (0.70)	71.84 (3.78)	8.03 (0.71)
11(JJA)	24.45 (1.61)	3.68 (0.84)	879.97 (171.78)	2.23 (0.81)	85.36 (2.14)	5.82 (0.65)
12(MAM)	4.52 (2.35)	8.60 (0.64)	109.44 (63.89)	4.91 (0.74)	64.17 (2.63)	8.14 (0.56)

Values in parantheses are standard deviations.
DJF — December, January and February
SON -- September, October and November
JJA -- June, July and August
MAM -- March, April and May

Table 4.5i2 Coefficients of correlation between seasonal lagged variables and annual yield for 18 climatic factors

factors	S(1,1)	S(1,2)	S(1,3)	S(2,1)	S(2,2)	S(2,3)	S(3,1)	S(3,2)	S(3,3)	S(4,1)	S(4,2)	S(4,3)
MXT	-.34	0.05	-.02	0.089	-.119	-.037	0.28	-.363	0.221	-.385	-.211	-.30
MNT	-.20	0.159	-.273	-.292	-.043	-.635	0.032	-.179	-.358	0.203	-.311	0.028
STM5	0.009	0.519	0.193	0.035	0.264	0.095	0.292	0.074	0.002	-.032	-.02	0.041
STM15	-.175	0.042	0.062	0.125	0.052	-.032	-.140	-.055	-.212	-.412	-.178	-.237
STA5	-.184	0.241	-.139	-.118	0.094	-.176	0.059	-.216	-.196	-.280	-.279	-.218
STA15	0.157	0.225	-.035	-.279	-.121	-.150	0.087	-.284	-.207	-.053	-.030	-.177
VPMN	0.041	-.303	0.166	0.069	-.162	-.011	0.298	-.084	-.212	0.309	-.249	-.064
VPAN	-.100	-.099	0.061	-.025	-.133	-.002	-.106	-.232	-.451	0.155	-.396	-.132
RHMN	0.121	-.627	0.113	-.236	-.479	-.199	-.161	-.035	-.357	0.247	-.190	-.179
RHAN	-.171	-.476	-.207	-.326	-.254	-.155	-.379	-.205	-.492	0.293	-.403	-.057
WV	-.151	-.149	-.261	-.057	-.013	-.190	-.126	-.121	-.233	-.251	-.233	-.208
SSH	0.533	0.483	0.524	0.257	0.200	0.183	0.438	0.163	0.416	-.253	0.171	0.236
RF	-.231	-.525	-.113	-.117	0.088	-.065	-.210	-.132	0.176	0.468	0.182	0.081
EV	0.362	0.439	0.341	0.354	0.435	0.148	0.453	0.439	0.482	0.035	0.128	0.232
RDRD	-.212	-.617	-.053	-.095	0.019	-.005	-5.424	0.0208	-.103	0.224	-.008	-.113
RT	-.106	-.118	0.279	0.362	-.06	0.576	0.184	-.112	0.532	-.060	0.169	-.309
STE5	-.157	-.034	-.202	-.129	0.181	-.230	-.099	-.234	-.175	-.184	-.160	-.171
STE15	0.235	0.155	-.067	-.303	0.127	-.111	0.216	-.278	-.08	0.298	0.124	0.049

S(i,j) denotes ith lag of jth year i=1,2,3,4 and j=1,2,3,/

Table 4.6.1 Regression Coefficients, SE and t-values and coefficients of determinations of seasonal climatic factors and annual yield of coconut (1st stage of 1st method)

season selected	variable selected	Regression coefficients	SE	t-value	Intercept	R2	SE of est
1. Mar-May ~~season 1~~	SSH	11.18	2.86	3.91	-176.37	0.60	6.33
	NORD	2.04	0.71	2.86			
	Pryld	0.20	0.14	1.51			
	EV	2.83	1.94	1.46			
	RHAN	1.04	0.63	1.67			
	STA15	1.14	1.02	1.12			
2. Jun-Aug ~~season 2~~	EV	3.27	1.66	1.97	232.78	0.516	7.15
	RT	5.23	2.52	2.08			
	STA15	-2.87	1.53	-1.87			
	NORD	-1.48	1.23	-1.20			
	MXT	-2.47	3.82	-0.65			
3. Sept-Nov ~~season 3~~	EV	3.47	2.49	1.39	49.77	0.305	8.13
	NORD	-1.43	0.99	-1.45			
	Pryld	0.20	0.17	1.18			
	RF	0.03	0.03	0.97			
4. Dec-Feb ~~season 4~~	RT	-12.42	2.75	-4.51	263.06	0.639	6.352
	Pryld	0.50	0.13	3.87			
	NORD	-2.13	2.30	-.93			
	EV	8.52	3.92	2.17			
	SSH	-8.34	5.13	-1.63			
	STA15	-1.39	1.17	-1.19			
	RF	-0.28	0.24	-1.18			

Table 4.6.2 Regression coefficients, SE and t-values and coefficient of determination for seasonal climate and annual yield of coconut (2nd stage 1st method)

Selected variables	Regression coefficients	SE	t-value
SSH(1)	6.69	1.32	5.06
RT (2)	-6.08	2.07	-2.94
NORD(1)	4.76	1.95	2.43
NORD(3)	7.82	2.44	3.21
RT (4)	1.72	2.22	0.77

Intercept : 90.009 R2= 0.675 SE of estimate : 6.83

figures in brackets are the serial number of the seasons from which this variable is selected in the first stage.

Table 4.7.1 Regression coefficients, SE, t-values and coefficients of determinations for six selected seasonal wise variables vs. annual coconut yield (square root) 1st stage , ~~2nd method~~

Climatic factors	Lag variables	Regression coefficient	SE	t-value	Intercept	R2	SE of estimate
RHAN	2	-.1031	0.0176	-5.85			
	4	-.1477	0.0231	-2.07			
	8	-.0389	0.0255	-1.53			
	9	0.0611	0.0221	2.77			
	11	-.0780	0.0274	-2.84	24.22	0.854	0.282
SSH	2	0.3263	0.1385	2.356			
	12	0.5076	0.1866	2.720			
	9	-.7540	0.2262	-3.33			
	6	-.2290	0.1342	-1.71			
	7	-.2521	0.0977	-2.58			
	10	0.2645	0.1490	1.77			
	8	0.2415	0.1774	1.36			
	4	-.1946	0.1554	-1.25			
	1	0.2279	0.2290	0.995	6.713	0.856	0.364
RF	9	0.0268	0.009	-2.97			
	12	-.0035	0.0013	-2.72			
	2	-.0424	0.0012	-3.52			
	1	0.0242	0.0092	2.63			
	3	0.0015	0.0005	2.95			
	6	0.0024	0.0011	2.14			
	11	0.0007	0.0005	1.35	6.6258	0.749	0.416
EV	2	0.6665	0.2723	2.45			
	4	-.4051	0.2460	-1.65			
	10	0.5320	0.2596	2.05			
	6	-.3695	0.3300	-1.12			
	11	0.1867	0.1690	1.10			
	8	-.3061	0.2602	-1.18			
	5	0.4628	0.5274	0.88	6.5239	0.580	0.541
NORD	2	-.0891	0.369	-2.167			
	10	-.0484	0.0368	-1.317			
	1	0.1891	0.1686	1.116			
	6	0.1226	0.0399	3.074			
	12	-.1184	0.0483	-2.453			
	4	-.448	0.0442	-1.013			
	5	-.1083	0.1219	-.889			
	8	-.0424	0.0478	-.888	9.11	0.723	0.469
RT	9	-.4128	0.1936	-2.13			
	11	0.4302	0.1961	2.19			
	6	0.2669	0.1530	1.75			
	4	0.4624	0.2141	2.16			
	8	-.4186	0.2119	-1.98			
	3	-.1886	0.1753	-1.08			
	10	0.1375	0.1752	0.79	7.75	0.639	0.502

Table 4.7.2 Regression coefficients, SE, t-value and coefficient of determination of selected variables of 1st stage (2nd stage)

Variables	Regression	SE	t-value
SDAW	0.5972	0.1306	4.573
SSH	0.4867	0.1319	3.691

Intercept : -.6643 R2= 0.914 SE of est. : 0.185

Table 4.8 Coefficients of correlation between annual yield and Generated first order variables for four seasons of previous year.

Variables	Season 1 (Mar-May)	Season 2 (Jun-Aug)	Season 3 (Sept-Nov)	Season 4 (Dec-Feb)
X_1	-.174	0.129	-.149	-.41.
X_2	0.139	-.270	0.084	-.053
X_3	-.172	-.355	-.383	0.284
X_4	0.539	0.315	0.439	-.365
X_5	-.090	-.107	-.139	0.337
X_6	0.370	0.330	0.685	0.064
X_7	-.212	-.141	-.419	0.200
X_8	-.085	0.373	0.188	-.585
$(X_1)^2$	-.174	0.134	-.144	-.418
X_{12}	0.004	-.153	-.019	-.311
$(X_2)^2$	0.157	-.271	0.090	-.050
X_{31}	-.276	-.299	-.4332	-.059
X_{32}	-.0335	-.507	-.264	0.179
$(X_3)2$	-.176	-.352	-.395	.272
X_{41}	0.3387	0.310	0.338	-.477
X_{42}	0.519	0.260	0.416	-.283
X_{43}	0.566	0.297	0.308	0.127
$(X_4)2$	0.539	0.332	0.444	-.246
X_{51}	-.145	0.002	-.207	0.318
X_{52}	0.049	-.320	-.097	0.333
X_{53}	-.131	-.274	-.307	0.382
X_{54}	0.475	0.09	0.376	0.325
$(X_5)2$	-.083	-.112	-.155	0.306
X_{61}	0.326	0.351	0.458	-.204
X_{62}	0.363	0.328	0.512	0.019
X_{63}	.375	0.339	0.449	0.279
X_{64}	0.460	0.397	0.553	-.058
X_{65}	0.386	0.342	0.432	0.314
$(X_6)2$	0.366	0.331	0.478	0.023
X_{71}	-.221	-.110	-.490	0.180
X_{72}	-.205	-.323	-.429	0.192
X_{73}	-.216	-.168	-.451	0.239
X_{74}	-.143	0.236	-.320	0.180
X_{75}	-.215	-.117	-.380	0.352
X_{76}	-.088	0.394	-.076	0.170
$(X_7)2$	-.215	-.117	-.380	0.352
X_{81}	-.147	0.390	0.113	-.682
X_{82}	-.012	0.245	0.215	-.509
X_{83}	-.174	0.300	-.031	-.312
X_{84}	0.323	0.347	0.378	-.558
X_{85}	-.117	0.357	0.033	0.290
X_{86}	0.284	0.425	0.471	-.275
X_{87}	-.193	0.295	-.364	0.190
$(X_8)2$	-.081	0.396	0.174	-.574

X_1: STF15 X_2: STA15 X_3: RHAM X_4: SSH
X_5: RF(LOG_e) X_6: EV X_7: BORD X_8: RT

Table 4.9.1 Regression coefficients, SE, t-value and coefficient of determinations of first order generated variables and annual coconut yield (square root)

Season	variables selected	Regression coefficient	SE	t-value	Intercept	R2	SE of estimate
season 1	X43	-0.0219	0.0229	-.952			
	X_{85}	-6.4384	4.9517	-1.300			
	X41	-0.0199	0.0091	-2.187			
	X_{42}	0.0098	0.0082	1.208			
	X54	4.7741	3.1771	1.503			
	X_{63}	0.0537	0.0398	1.349	0.9391	0.56	0.69
Season 2	X12	-.0037	0.0014	-2.65			
	X_8	-.0653	2.9273	-.022			
	X_{65}	-.1954	0.7484	-.786			
	X_{81}	-.0825	0.0422	-1.957			
	X_3	-8.0379	3.5119	-2.289			
	$(X_3)2$	0.0458	0.0205	2.239			
	X_{83}	0.1049	0.0786	1.334			
	$(X_6)2$	0.3630	0.2482	1.462			
	X_6	-9.0478	7.5978	-1.191			
	$(X_9)2$	.1764	0.2090	0.881	378.077	0.60	0.59
Season 3	X_{64}	0.6543	0.2319	2.80			
	X71	-0.0166	0.0114	-1.49			
	X_7	-0.3692	0.4004	-0.922			
	X72	0.0094	0.0087	1.090			
	X_{63}	0.1215	0.0979	1.241			
	(X6)2	-0.7798	0.2731	-2.85			
	$(X_4)2$	-0.1660	0.0681	-2.44			
	$(X_8)2$	0.0161	0.0139	1.156	11.344	0.632	0.50
Season 4	X_{81}	-0.0169	0.0054	-3.12			
	Pryld	0.4206	0.1234	3.41			
	X_{84}	-0.0345	0.0219	-1.58			
	X83	-0.0061	0.0027	-2.24			
	X_{65}	-0.4407	0.1211	-3.31			
	X53	0.0309	0.0093	3.138			
	$(X_8)2$	0.0208	0.0164	1.278	15.25	0.777	0.36

Table 4.9.2 Regression coefficients, SE, t-value and coefficient of determination of generated first order seasonal climatic factors and annual yield of coconut (2nd stage)

Variable selected	Regression coefficient	SE	t-value
Season 4	0.6289	0.1312	4.79
Season 1	0.3422	0.1389	2.46
Season 3	0.2872	0.1489	1.93

Intercept : -2.122 R2= 0.881 SE of estimate :0.225

SUMMARY

SUMMARY

Influence of eighteen climatic factors for a period ranging from 10 to 45 months prior to harvest on monthly and annual yield of coconut were studied. Monthly climatic factors revealed a cyclical pattern of influence on monthly yield with a period of 12 months. The correlations become significant every six months changing sign consecutively. Four distinct groups of lag periods for the weather elements could be identified to have significant effect on yield viz., 10-16, 20-28, 32-37 and 39-45.

One hundred and forty ~~two~~ lagged variables of different climatic factors which had significant correlation at 5 per cent level with yield were identified. Twenty six out of these 140 variables were selected for a forecasting model by path coefficient analysis. Principal component analysis was used to remove the multicollinearity and dimensionality of the variables. Step-wise regression was carried out to arrive at the final model. The coefficient of determination for this model was only 0.124 suggesting a very poor fit.

Month-wise and season-wise climatic fators were used to study the influence on monthly yield of coconut. Some of the important weather variables such as RHAN, SSH and RT showed significant effect during pre and post monsoon season. RF and NORD showed significant influence only during off-monsoon seasons. Lower variability existed during rainy months may be one of the reasons for non significance of correlation coefficients of RF and NORD. Another reason for the non significane may be that RF beyond a particular level do not influence the yield of coconut.

Month-wise and season-wise climatic factors were also correlated to annual yield of coconut. It was observed that climatic factors during pre and post monsoon periods affect the annual yield of coconut. May, September, October and December months of yester years showed significant influence on annual yield. RHAN, SSH and EV showed significant association with annual yield most frequently than the other climatic factors. During monsoon months EV alone associated with annual yield.

Forecasting models to estimate annual yield of coconut was tried using monthly and seasonal climatic factors. When monthly climatic factors were considered, the effect of previous lag periods(beyond 22 months) were represented by the annual coconut yield of yester year. The model was envisaged in two stages. Nine weather variables of individual months were identified at the first stage by step-wise regression. Variables selected through step-wise analysis were used as explanatory variables in the second stage of analysis. Seven variables were identified in this manner and they are SSH(May,Dec), RHAN(Sept), STF15(April, Dec), EV(July) and previous yield. The coefficient of determination was 0.853.

Another model was proposed using the selected variables of each month to predict annual yield of coconut by generating new set of orthogonal variables by means of PCA and the coefficient of determination obtianed for this model was 0.823.

A forecasting model to estimate annual yield of coconut using season-wise climatic factors was attempted. The model was developed in two stages of analysis. Separate prediction equations were developed for weather factor each season by performing step-wise analysis. The coefficients of determination obtained for the four prediction equation were 0.60, 0.51, 0.31 and 0.64 respectively for four seasons. The selected variables from the above prediction equations were treated as explanatory variables in the second stage of analysis. Principal components on these selected variables were used to obtain the final model and the coefficient of determination obtained for this model was 0.675.

In another method of modelling, six prediction equations were developed using all lag variables of six climatic factors (RHAN, SSH, EV, RF, NORD and RT) using step-wise regression analysis at the first stage. The estimates of these six prediction equations were treated as explanatory variables for developing prediction equation at the second stage. RHAN and SSH were the only two climatic factors in the final model using step-wise regression. The coefficient of determination for this model was 0.914. Two prediction equations obtained using the lag variables of RHAN and SSH obtained from the first stage of analysis may be also used to predict annual yield of coconut with coefficents of determination 0.88 and 0.85 respectively.

In a bid to study the interactive effect of weather variables on annual yield of coconut, pair-wise products of eight climatic factors were correlated to annual yield of coconut. The combinations involving RHAN, SSH and EV showed significant correlations with yield. And the significant influence was more in evidence during pre and post monsoon periods.

A forecasting model using generated first order variables were tested to predict annual yield of coconut. In the first stage of analysis, four prediction equations were developed for each season using step-wise regression analysis. The estimates of these four prediction equations were treated as explanatory variables in the second stage of analysis and a final prediction equation was obtained with a coefficient of determination of 0.881.

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* Original not seen, title of the article not available.

APPENDIX

APPENDIX - I

The Standard Weeks

Week No.	Months	Dates	Week No.	Months	Dates
1	January	1-7	27	July	2-8
2		8-14	28		9-15
3		15-21	29		16-22
4		22-28	30		23-29
5		29-4	31		30-5
6	February	5-11	32	August	6-12
7		12-18	33		13-19
8		19-25	34		20-26
9		26-4*	35		27-2
10	March	5-11	36	September	3-9
11		12-18	37		10-16
12		19-25	38		17-23
13		26-1	39		24-30
14	April	2-8	40	October	1-7
15		9-15	41		8-14
16		16-22	42		15-21
17		23-29	43		22-28
18		30-6	44		29-4
19	May	7-13	45	November	5-11
20		14-20	46		12-18
21		21-27	47		19-25
22		28-3	48		26-2
23	June	4-10	49	December	3-9
24		11-17	50		10-16
25		18-24	51		17-23
26		25-1	52		24-31‡

* In leap year the week No. 9 will be 26 February to 4 March (8 days)

‡ Last week will have 8 days, 24 to 31 December.

INFLUENCE OF WEATHER PARAMETERS ON YIELD OF COCONUT

By

B. PANKAJAKSHAN NAIR

ABSTRACT OF THE THESIS
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ABSTRACT

Influence of eighteen climatic factors for a period ranging from 10-45 months before harvest of coconut, were studied on monthly and annual coconut yield. Monthly climatic factors showed a seasonal relationship with monthly yield changing sign alternatively.

Month-wise and season-wise climate and their influence on monthly and annual yield was also studied. The influence of climatic factors were more in evidence during pre and post monsoon seasons. RH, SSH and EV were frequently showed significant relationship with monthly yield than the rest. Seasonal grouping of climate showed stronger relationship on annual yield than month-wise climate. May, September, October and December months of yester years showed explicit association with annual yield.

To study the interactive effect of climate on coconut yield 42 generated variables were obtained and coefficients of correlation were worked out between annual yield and generated variables for four seasons separately. The combinations of SSH, RHAN and EV showed significant influence on yield more frequently.

Several Forecasting models to predict annual and monthly yield of coconut were attempted. Using selected variables from month-wise climate a forecasting model was developed with a coefficient of determination of 0.853. Similarly model for annual yield using selected lagged variables of climatic factors from different seasons as explanatory variable. The best prediction model was obtained from lagged variables of RHAN and SSH of seasonal climate. This model gave a coefficient of determination of 0.914.

A forecasting model from generated variables were tried and the prediction equation obtained to estimate annual yield showed a coefficient of determination of 0.881.