AGROMETEOROLOGY OF PLANTATION CROPS

PROCEEDINGS OF THE NATIONAL SEMINAR

organised by the

KERALA AGRICULTURAL UNIVERSITY

at the

REGIONAL AGRICULTURAL RESEARCH STATION,
PILICODE

12—13 March 1987

Editors:

G. S. L. H. V. PRASADA RAO and R. R. NAIR

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AGROMETEOROLOGY OF PLANTATION CROPS

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Foreword

The agricultural production in our country depends mainly on the weather conditions. The proverb 'climate decides the crop, weather decides the yield' still holds good in spite of the technological advances achieved in the field of agriculture. The effects of newer technologies are often mitigated by the aberrant weather phenomenon.

The impact of abnormal weather on plantation crops, unlike seasonal crops, is felt not only in the same year but in the subsequent years also. Consequently, the management technologies to combat the illeffects of adverse weather on plantation crops differ from those of annual crops. So far no concentrated effort has been made in our country to study the interaction between weather and plantation crops. The National Seminar on the Agrometeorology of Plantation Crops organised by the Kerala Agricultural University at Pilicode has set the stage for furthering the research efforts in all aspects of agrometeorology as related to plantation crops.

I trust that the Proceedings of the National Seminar would be read with interest by the scientists wedded to the cause of research in plantation crops.

Kerala Agricultural University
April 21, 1988

E. G. SILAS
Vice-Chancellor

About this publication

This volume embodies the proceedings of the National Seminar on the Agrometeorology of Plantation Crops held at the Regional Agricultural Research Station, Pilicode, Kasaragode District, Kerala during March 12—13, 1987. The seminar brought together more than sixty scientists from different Universities and Central Institutes in India facilitating exchange of ideas and utilization of available knowledge on agrometeorology of plantation crops.

A total of 27 papers were presented on various aspects of agrometeorology as related to plantation crops in five technical sessions. The key note address was delivered by Dr. A. R. Subramaniam, Professor, Department of Meteorology and Oceanography, Andhra University, Waltair. The sessions were chaired by Dr. P. S. Sreenivasan, Consultant in Agricultural Meteorology, India Meteorological Department, Pune (Retd.), Dr. V. Ranganathan, Joint Director, UPASI, Coonoor, Dr. O.P. Bishnoi, Head, Department of Agricultural Meteorology, Haryana Agricultural University, Hisar, Dr. M. Aravindakshan, Director of Research, Kerala Agricultural University, Vellanikkara, Dr. S. Jayaraj, Director, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore and Dr. R. C. Mandal, Joint Director i/c., National Research Centre for Cashew, Vyttal.

The editorial work was handled by Dr. R. R. Nair, Associate Director and Dr. G. S. L. H. V. Prasada Rao, Associate Professor (Agricultural Meteorology).

Kerala Agricultural University,
April 21, 1988.

A. G. G. MENON,
Director of Extension.

Acknowledgement

Altogether thiry three papers were presented and discussed in the National Seminar. However, only twenty seven papers could be included in the proceedings. We would like to express our appreciation to each of the authors for his contribution.

The publication of the proceedings would not have been in the present form but for the generous help of the Vice-Chancellor, Dr. E. G. Silas. We are deeply indebted to him for sanctioning necessary funds to bring out the publication and for writing the foreword.

It is our great pleasure to acknowledge the help and encouragement received from Dr. A. G. G. Menon, Director of Extension and Dr. M. Aravindakshan, Director of Research during the course of the publication of the proceedings.

April 21, 1988.

G.S.L H.V. PRASADA RAO
R. R. NAIR

Contents

KEYNOTE ADDRESS

Agroclimatology and Plantation Crop Production

Prof. A. R. SUBRAMANIAM

Department of Meteorology & Oceanography, Andhra University, Waltair, Visakhapatnam—530 003

Respected Vice-Chancellor, distinguished delegates, ladies and gentlemen,

The basic questions in agricultural research are to what extent the are a under the plough can be increased and to what extent the agricultural production can be enhanced. Hence it is necessary to study the agroclimate of any region where attempt is made to increase agricultural productivity.

Since plantation crops are as much affected as regular crops by the climate, several aspects of climatic studies are common to both. Further, the word 'Plantation crop' is some what not clearly understood, as several workers have used the word for different crops with different perspectives. For example, sugarcane is deemed as a plantation crop by some and not by others. The same may be true of crops like coconut also. However, it is in seminars and conferences like this that a clearer perspective of the precise area of study will emerge as guideline for others.

With this background, I would like to discuss the role of agrometeorology in plantation crop production. Crop production depends upon four important factors: (1) climate (2) soil (3) crop and (4) farmer. All the four factors contribute to the success or failure of agricultural productivity. The weakest link in the chain determines the final productivity. It is primarily controlled by thermal and moisture factors if the other environmental factors are homogeneous. In most parts of India there is no dearth for thermal energy. The main source of water supply to plants is through rainfall but it has to be balanced with the potential evapotranspiration (water need) of the crop. Hence the water budgeting methods utilizing estimated values of potential evapotranspiration on climatological basis can provide useful guidelines for supplemental irrigation for optimal crop productivity. Periods of water surplus can help in storage of water for profitable use at a later time. The water balance approach can provide an insight into the need for irrigation. It can also climatologically provide information on agricultural droughts of individual crops, water availability periods to schedule crop growing season and periods of water surplus to facilitate storage for use at a later stage.

Based on the estimation of potential evapotranspiration and water balance studies, the irrigation requirement of crops can be suggested. In England and Wales estimations of potential evapotranspiration are circulated once in every fortnight among the farmers so that irrigation is regularly applied to keep the soil moisture close to field capacity The atlas of long term water needs for England and Wales prepared by Hogg (1967, 1970) contains maps based on standard water balance sheets over a twenty-year period which enable certain parameters to be read off directly (For example, total 20 year water need and the need in the driest year). Similar maps may be prepared for plantation crops in Kerala.

Yao (1973) investigated the water relationship in Central Tanzania for production of groundnut which requires adequate soil moisture both near the surface and in the deeper root zone. Using daily water balance sheet, irrigation was provided to restore the entire root zone to field capacity. However, it has been found that the mosture index could also be employed for providing supplemental irrigation. In Canada, Baier and Robertson (1966) estimated actual evapotranspiration at different depths of the soil and the soil moisture deficit in the root zone using versatile soil moisture budget technique. This can be fruitfully employed.

Among the applications of climatology, another area which is important is the agroclimatic classification of different regions. Several workers have proposed to identify areas which can potentially support different types of crops based on the agroclimatic zonation. Murthy and Pandey (1978) for India and Panabokke (1979) for South East Asia took the soil map and superimposed it with the rainfall map to identify different soil and rainfall combinations which support various crops. We at the Andhra University suggested that the map of isolines showing index of moisture adequacy may be superposed on the map of soil types and the resultant permutation and combination of soil type and moisture adequacy can indicate the crop potential of different areas. This enables us in long term planning in agricultural areas for a particular enterprise. This is because only crops suited for a given agroclimatic region will be grown for optimum production.

In medium term operations over a period of several months, water balance and energy balance studies are of significance. Hudson has shown how two cotton varieties in Sudan were affected by the individual seasons' weather. If the seasonal weather is forecasted in time, appropriate variety can be planted. The assessment of suitable crops and varieties must be based on the probabilities of the different seasonal types.

Short term operations relate to a period ranging from a few hours to a few days. These often involve decisions based on the stage of the crop and current weather or forecast-whether for such farm operations as preparatory cultivation, sowing, irrigation, spraying and harvesting. Many benefits result from the application of climatological advice and and assistance to agricultural practices. The agrometeorologist can be of considerable help for assessing the probability of weather suitable for all agricultural operations.

I am sure that the seminars like this will pave the way for better interaction among scientists of different disciplines and encourage them to do meaningful research in all aspects of plantation crop production.

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SESSION 1

Radiation, Energy and Soil moisture balance

Chairman : Dr. P. S. SREENIVASAN

Rapporteurs : Dr. N. K. VIJAYAKUMAR
Dr. G. S. SULIKARI

Distribution of radiation in rubber plantations (*Hevea brasiliensis*) with special reference to determination of evapotranspiration and canopy photosynthesis—A review

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ABSTRACT

Work done so far in characterising the radiation climate in rubber plantations and its application in determining the evapotranspiration and canopy photosynthesis is reviewed. Fully foliated canopies of *Hevea* transmitted nearly five per cent of the incoming photosynthetically active radiation (PAR). The pattern of PAR distribution within *Hevea* canopy reveals that the maximum interception of incident PAR (85 per cent) is effected by the upper layer, within 4.6m from the top of the canopy. During the whole vegetative growing period of a rubber stand, the radiation budget is found to be nearly constant. This is very similar to what is observed in the tropical rain forest. The radiation budget is disturbed only during 1 to 2 months when the rubber stands are leafless and the solar energy penetrates more deeply into the stand down to the soil. To estimate the evapotranspiration from a *Hevea* stand, the use of the radiative expression of the Penman equation modulated with a crop coefficient which takes account of the plant factors as well as the soil and climatic conditions, is suggested. The evapotranspiration rate of rubber plantations ranges from 4 to 6 mm a day after refoliation with plenty of soils water. The need for further studies is emphasized to get a thorough understanding of the radiation balances of *Hevea* stand in relation to canopy photosynthesis and evapotranspiration, which will help in forecasting the development as well as yield potential of rubber plantations.

Introduction

The productivity of any crop, including that of *Hevea* is influenced by it's photosynthetic assimilatory capacity. Photosynthesis of a tree stand, such as rubber plantation. is regulated by additional factors viz. interception of photosynthetically active radiation (PAR), level of leaf insertion and microclimate (Helms, 1976). It is of fundamental importance to understand the amount of radiational energy available to the canopy and it's partition for different processes. Characterisation of solar radiation available under tree canopies had been widely attempted in forestry (Anderson, 1964 a, b; Hutchinson and Matt, 1977; and Zavitkovski, 1982). But such studies are meagre in horticultural tree crops as well as plantation crops. Also the studies carried out to understand the actual water requirement of rubber stand at different stages of growth in a given area are very few. In this presentation, the information available on distribution of radiation in rubber plantations with particular reference to determination of evopotranspiration and canopy photosynthesis has been reviewed.

The plant

Hevea brasiliensis, the para rubber tree produces 99 per cent of world's natural rubber. The plant is a sturdy perennial tree which attains a height of about 30 m. The tree has a straight trunk. Branches are usually developed in such a way as to form on open leafy crown. In most of the clones, canopy is dense and is restricted to the top. Branching habit is variable. Some trees have only one leader branch while others have several. Latex is present in almost all parts of the plant, but the bark of the trunk is usually exploited. Budded plants are considered as tappable when they attain a girth of 50 cm at a height of 125 cm from the bud union. Since girth is a major component influencing latex yield, total biomass production and hence canoy photosynthesis are of considerable importance in this crop having a direct bearing on economic yield.

For optimum growth and yield, rubber plants require a warm and humid climate with an evenly distributed rainfall of 2000—3000 mm in an year. A humid atmosphere throughout the year without much variation is found to be ideal for successfull cultivation of rubber. The relative humidity varies from about 70 per cent during January to 95 per cent during August in most of the rubber growing regions in India. When relative humidity is higher, evapotranspiration is lower. Higher rates of evapotranspiration results in lower turgor pressure of cells. Since the turgor pressure of laticiferous system influences the yield of latex, evapotranspiration indirectly influences the yield.

Characterisation of radiation—Climate in rubber plantations

Satheesan, Gururaja Rao and Sethuraj (1982) estimated the transmission of PAR in fully foliated rubber plantations grown at two spacings of 4.26 x 4,26 m and 5.7 x 6.7 m. The per cent transmission by the fully foliated canopies was in the range of 3.8 to 5.5. These valves were quite high when campared to other deciduous trees like populus where the transmission values being 0.5 to 1 per cent (Zavitkovski, 1982) as well as for typical tropical rain forests where the values being as low as 0.15 per cent (Bjorkman and Ludlow, 1972). The study also revealed the importance of sunflecks in the distribution of PAR in rubber plantations. The contribution oi sunfleck PAR ranged from 52.4 to 55.2 per cent under the *Hevea* canopies (Table I). Sunflecks are characterised by their constant movement because of the wind and movement of sun across the sky. In tree crops like *Hevea* with a dense canopy, planting density has to be maintained in such a way that the radiation available to the lower leaves are not depleted detrimentally. Sunflecks are therefore very important for the survival and functioning of lower shaded leaves, which are otherwise receiving inadequate amount of light.

Radiation budget

The net radiation flux density (Rn), an important climatic characteristic represents the amount of energy available to canopy processes such as transpiration and photosynthesis. Monteny, Barbier and Bernos (1983) determind the energy exchanges from a 23.5 m high rubber stand located in the tropical rain forest of Ivory Coast using the energy balance Bowen ratio method. The following relations were obtained between the net radiation flux density (Rn) and incident solar radiation (Rg) where Rn and Rg are expressed in W m $^{-2}$

1. For a humid atmosphere
   (water vapour pressure : 28 to 32 mb)
   a. Young leaf canopy Rn = 0.72 Rg — 4.0
   b. Old leaf canopy Rn = 0.70 Rg — 0.8
   c. Without foliage Rn = 0.62 Rg + 4.0
2. For a dry atmosphere
   (Water vapour pressure : 8 to 10 mb)
   Old leaf canopy Rn = 0.78 Rg — 50.0

The slope of the relationship between the incident solar radiation and the net radiation is quite constant thereby showing that during the whole vegetative growing period of rubber stand, the radiation budget is nearly constant. This is very similar to what is observed in tropical rain forest. The only marked difference which significantly changes the relation is the period when trees are leafless and when dry continental air blows over the region (2 to 3 weeks per year in December-January).

Evapotranspiration rate

In order to estimate forest evapotranspiration from some practical measurements such as net radiation. Monteny, Barbier and Bernos (1983) presented the relationship obtained between net radiation and the measured latent heat flux for different soil and climatic conditions for the same rubber stand adopting the following relationships.

1. For all days under the influence of oceanic air when the water vapour pressure deficit is in the range of 3 to 12 mb.

a) The latent heat flux of trees with young leaves and high soil water availability.
   $\lambda E = 0.82\ Rn - 21\ (Wm^{-2})$

b) If the availability of soil water is restricted
   $\lambda E = 0.70\ Rn - 4\ (Wm^{-2})$

c) For trees with older foliage and no soil water restriction
   $\lambda E = 0.48\ Rn - 22Wm^{-2})$

These results showed that the evapotranspiration rates are progressively reduced by the activity of the stomata. The stomatal apertures of young leaves are much better regulated as a function. of the soil water availability and the incoming radiation than those of older leaves.

2. For days under the influence of dry continental air the latent heat flux raises considerably in spite of the old leaves as a consequence of the increase of the air water vapour pressure deficit.

$\lambda E = 0.95\ Rn - 52\ (Wm^{-2})$

These studies revealed that the energy budget which is actually divided into latent heat and sensible heat depends more upon the soil water availability and the leaf area than upon the air water vapour pressure deficit which acts only when dry continental air is blowing. Thus it cannot be considered as an important environmental factor for tropical rain forest of the region which is under dominant oceanic trade winds for most of the time.

To estimate the daily water consumption of the *Hevea* forest, Monteny, Barbier and Bernos (1983) suggested the use of the radiative expression of the Penman equation modulated with a crop coefficient. The introduction of a crop coefficient, C, will allow the estimation of the maximum water consumption of the *Hevea* stand. This coefficient characterises the importance of the stomatal regulation to soil or to meteorological factors. The values proposed for C to estimate the water consumption during the period of foliage activity in the case of an *Hevea* forest located in the humid tropical region of West Africa are given in Table 2. Adopting this method, the following values of daily evapotranspiration had been worked out by Monteny (1984).

1. Evapotranspiration rates of 4 to 6 mm a day are recorded after refoliation with plenty of soil water.
2. Evapotranspiration rates of 2 to 3 mm a day with older foliage (9 to 11 month) with plenty of soil water.
3. Evapotranspiration rates of 1 to 2 mm a day with old foliage when soil water is depleted.

Canopy photosynthesis

The estimation of canopy photosynthesis can be attempted in two ways:-

i Using light interception model and leaf light—assimilation relationship.

ii Using micrometeorological data.

Intercepted light is a fundamental parameter in any model for estimating canopy photosynthesis. Satheesan *et al.*, (1984) examined the PAR distribution pattern in relation to canopy photosynthesis in *Hevea*. The maximum interception of PAR is effected by upper layer, within 4.6m from the top of the canopy (Table 3). Only a slight increase in cumulative interception of lower levels of the canopy suggests that the relationship between light penetration and leaf density may be non-linear. There was a greater incidence of PAR at the base of canopy than at the top in early hours of clear days. Such a phenomenon has been noticed also in coconut (Satheesan, 1984).

Gururaja Rao, Satheesan and Sethuraj (1982) found that PAR received by shade leaves in any part of the year may not exceed about 30-50μE m^{-2} s^{-1} and the maximum PAR received by the leaves in the top layer may reach values over 1500μE m^{-2} s^{-1}. The leaves get adapted to these light regimes in a manner that shade leaves are photosythetically more efficient in lower light intensities.

Satheesan, Gururaja Rao and Sethuraj (1982) observed that there was no marked difference for the total PAR transmission between a densor planting (4.26 x 4.26 m) and a less dense planting (5.7 x 5.7 m). This can be related to the canopy characteristics under these two densities (Table 4). While the crop height was higher, the spread of canopy was less under higher densities.

Consequently the leaf area indices did not register any significant difference between these two plantings. Further observations on light interception would be useful in selection and manipulation of *Hevea* canopies for optimal utilization of solar energy.

Monteny, Barbier and Bernos (1983) estimated the fraction of energy used by canopy photosynthesis in relation to the net radiation for a rubber stand located in the tropical rain forest of Ivory Coast. The assimilation rate of *Hevea* stand is estimated to be 20 Wm^{-2} (1.8 10^{-6} Kg CO_2 m^{-2} S^{-1}) when the leaves are young and well supplied with water. There is a gradual reduction of photosynthesis as the leaves grow older.

It is well known that large scale vegetation such as tropical rain forest and other tropical tree plantations of rubber, oil palm, cocoa and coffee can affect the climate, especially air temperature, the amount of water vapour and carbon dioxide in the atmosphere. More information is needed to have a better understanding about the energy flow in rubber plantations and its influence on the microclimate, which will perhaps indicate how the plant community affect the climatic conditions. The review has also revealed the need for further studies to get a thorough understanding of the radiation balances of rubber stand in relation to canopy photosynthesis and evapotranspiration. This will enable us to forecast the possibility of extending the cultivation of *Hevea* to newer and untraditional areas, and to predict the potential yield accurately.

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Discussion

R. C. Mandal (NRCC, Puttur): 1. In radiation studies, both thermal effect and phytochemical effect have to be looked into. The first aspect has not been considered.

2. In phyto-chemical effect, canopy temperature and air temperature measurement in relation to radiation balance is important. This has to be attended to.

K. V. Satheesan: It is a review paper, suggestions are accepted.

E. Sivaraman (KAU, Mannuthy): What will be the difference in the extent of photosynthetic activity in the lower level of leaves when compared to the higher canopy leaves.

K. V. Satheesan: At lower light intensities. photosynthetic rate of lower shaded leaves was higher than that of sun leaves in the top layer of canopy. But at higher light intensities, the photosynthetic rate of sun leaves was 40% higher than that of shaded leaves.

R. C. Dubey (IMD, Pune): Have you studied the variation of albedo with E variation also.

K. V. Satheesan: This aspect has not been reported.

P. B. Pillai (KAU, Vellanikkara): If a wider spacing is given between rows in North-South direction, whether it will increase the yield of rubber and other plantation crops.

K. V. Satheesan: This aspect can be taken up in future experiments.

U. Mohamed Kunju (RARS, Kumarakom): From the table, it is seen that spread of canopy, height, girth and weight/tree in *Hevea* is more in wider planting. But the total dry matter production/ha has not increased substantially. How can you account for such a result.

K. V. Satheesan: In closer planting with more number of trees per hectare, highep dry matter production can be expected. But in this planting system, tree height is significantly higher, and spread of canopy is lesser than in the other planting density. This will result in lower girth and less weight/tree. But in widely spaced system, even-though the spread of canopy, girth and weight/tree are higher, the number of plants/ha is fewer. This may be the reason why the dry matter production/ha has not registered any significant difference between these two planting densities.

Table 1: Sunfleck par intensity ($\mu E\ m^{-2}\ S^{-1}$) in Rubber plantations

	4.26 x 4.26 m	5.70 x 5.70 m
Par in the open	1560	1561
Par in shade under the canopy (Avoiding sunflecks)		
Mean	35.0	28.8
% of the open	2.2	1.9
Par of sunflecks under the canopy mean	845.2	787.5
% of the open	54.2	50.5
Percentage of area under sunflecks	4.9	3.9
Ratio (par of sunflecks/par in shade)	24.2	27.3
Percentage of sunfleck par under the canopy	55.2	52.4

Table 2: Values of the plant coefficient C.

Air origin	Foliage	Soil water*	Values of C	Month
Oceanic	Young	120—200mm	$0.85<C<1.00$	March—April
Oceanic	Young	<200mm	$0.95<C<1.10$	April—August
Oceanic	Young	120—200mm	$0.75<C<0.90$	Sept.—October
Oceanic	Old	<200mm	$0.50<C<0.80$	Nov.—December
Continental	Old	120—200mm	$1.00<C<1.25$	Dec.—January
Oceanic	Old	60—120mm	$0.40<C<0.60$	January

* Fraction of extractable water in the root zone

Table 3: Par budget of three strata in *Hevea* canopy

Observation	Clear day			Cloudy day		
Average PPFD ($\mu E\ m^{-2}\ s^{-1}$)		1083			689	
Day's integration ($E\ m^{-2}$)		49			31	
Canopy strata	*Top*	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*
% of incoming PPFD						
Reflection	2.3	0.5	0.4	2.8	0.6	0.4
Transmission	10.3	7.2	6.2	12.4	9.2	5.6
Interception	87.4	92.3	93.4	84.8	90.2	94.0

Table 4: Canopy characters and dry matter production in *hevea* under two planting densities

Characters	4.26 x 4.26 m	5.70 x 5.70 m
Leaf area index	3.77	3.78
Spread of canopy (cm)	234.4	377.4*
Crotch height (cm)	640.1	340.9*
Girth (cm)	77.5	90.5*
Dry weight per tree (Kg)	486.9	732.1*
Dry weight per hectare ($t\ ha^{-1}$)	263.1	215.4

* Significant at 5% level.

Some Agroclimatological Radiation Relationship in Vegetations

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ABSTRACT

Agroclimatological relationships between solar radiation, net radiation, albedo, sunshine duration, and diffused radiation over field crops have been formulated using the measured data on these parameters at the Agromet observatory, Hisar. These relations can be widely used in the region even if limited measurements are available or over the adjoining places where radiation data are not available.

Introduction

Solar radiation measurements are limited in India as radiation equipment are costly and not easily available. Another important reason for developing the relationship between radiation parameters is that if we know one component, the other parameter can be computed from the relationship so developed. Some relationships on these parameters have been reported by Flischer (1953), Monteith and Szeich (1961). Standhill *et al.* (1966), Idso (1968), Gay (1971) and Nkemdirin (1972). Also, if the relationships are known for a particular station, the data can be used for a location in the adjoining areas where limited data are available. Most of the observatories record only the duration of sunshine, but very few meteorological stations are available where the total, net and diffuse radiation, abedo and duration of sunshine are recorded. It is possible to develop the relationship between these variables and they can be utilized for computing any unobserved data in the region if the associated parameters are known. Net radiation is an important parameter because it is utilized in partitioning the energy used in evapotranspiration, soil heat and sensible heat. Net longwave radiation is highly variable and needs to be assessed most accurately for radiation balance studies.

Materials and methods

Field observations on total solar radiation, diffuse radiation, net radiation and short wave reflected radiation over crops were recorded during 1983 and 1984 on clear days at the agromet observatory, Hisar (Lat. 29°-10' N, 75°-46' E). The diurnal observations on these parameters recorded for 21 days at hourly intervals have been utilized in the present study. The short wave and diffuse radiation data were recorded continuously using a recorder. Direct and reflected radiation, and net radiation were measured with solarialbedometer and net radiometer of Medoes & Co., Australia. The solarialbedometer consists of two pyranometers, one facing upward for solar radiation (R_s) and the other downwards for measuring reflected radiation (Rf). These instruments were placed about 1 metre above the canopy surface and perfectly levelled. The output from the sensors were measured hourly by a digital microvoltmeter. The bright sunshine hours were measured with Campbell Stock's sunshine recorder which was erected at the agromet observatory. Linear regressions were developed using the measured data.

Results and discussion

Table 1 gives the ratio of diffuse radiation reaching the earth's surface to the total shortwave radiation under Hisar conditions. This ratio is about 0.31 with higher values at lower solar elevation, but decreases to 0.25–0.26 at noon hours. These ratios can function as coefficients to convert the total shortwave radiation at earth surface into the diffuse component.

Table 1: Ratio of diffuse and total solar radiation at Hisar

Hourly intervals										
7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	day
0.68	0.33	0.26	0.26	0.25	0.26	0.31	0.33	0.47	0.53	0.31

Many meteorological stations recorded only the duration of sunshine, but radiation and sunshine are recorded at a few locations in India. It is possible to device relationship between these two variables in the following form.

$$\frac{R_s}{R_{so}} = 0.256 + 0.61 \frac{n}{N} \quad (R^2 = 0.98)$$

Where n is the actual sunshine hours and N is the maximum possible hours of sunshine.

Linear regressions were developed between net radiation and total incoming short wave radiation over wheat, barley, mustard, maize, berseem, bajra, moong. winter maize as follows:

$R_n = -41.65 + 0.5933\ R_s$ ($R^2 = 0.90$) for all crops
$R_n = -11.81 + 0.7164\ R_s$ ($R^2 = 0.96$) for wheat
$R_n = -7.27 + 0.668\ R_s$ ($R^2 = 0.86$) for mustard
$R_n = -5.87 + 0.5944\ R_s$ ($R^2 = 0.88$) for barley
$R_n = -2.43 + 0.577\ R_s$ ($R^2 = 0.92$) for winter maize
$R_n = -6.51 + 0.59\ R_s$ ($R^2 = 0.94$) for berseem
$R_n = -10.77 + 0.65\ R_s$ ($R^2 = 0.99$) for bajra
$R_n = -10.79 + 0.65\ R_s$ ($R^2 = 0.99$) for moong
$R_n = +3.45 + 0.572\ R_s$ ($R^2 = 0.99$) for kharif maize

Net radiation values over crops are not available and therefore, can be computed from the solar radiation data available over India from the records of the India Meteorological Department.

Net radiation over crops is also a function of the reflectivity of the cropped surface. The linear regression equations developed between net radiation and albedo over crops were:

$R_n = 606.75 - 1462.43\alpha$ for all crops ($R^2 = 0.85$)
$R_n = 855.70 + 1462.45\ (1 - \alpha)$ ($R^2 = 0.85$)

The reflectivity of crops is dependent upon the colour of the leaves, the moisture conditions, the density of crop cover and the angle of the sun. The reflection coefficient of the surface changes with the sun's angle during the course of the day. The albedo was least during mid day, but increased with decreasing solar elevation. For most crops at mid day it was around 0.20, but increased to 0.30–35 at lower solar elevation over most crops. Reflectivity generally increases with the visual brightness of the surface. Cloud cover reduces the reflectivity by proportionately increasing in the diffuse radiation.

Net radiation available at the earth's surface is dependent on the amount of total shortwave radiation falling on the cropped surface and its reflectivity.

$R_n = 36.9596 + 0.5756\ (1-\alpha)\ R_s$ ($R^2 = 0.92$) for crops

Where, α is reflectivity of the cropped surface and R_s is solar radiation.

Net radiation depends upon the surface conditions which results in the longwave emission. The net radiation available at the earth-surface is dependent on net longwave radiation.

$R_{LN} = 22.2873 — 0.5976\ R_n$ for field crops ($R^2 = 0.61$)

Where, R_{LN} is net longwave radiation and RN is net radiation.

The net longwave radiation is ultimately a function of the surface temperature which is sensible heat component directly influenced by the incoming shortwave radiation. It also depicts the heating coefficient at the vegetation surface.

$R_{LN} = 112.62 — 0.4613\ R_s$ for crops ($R^2 = 0.84$)

The net longwave radiation also influences the albedo of the vegetation surface with the relation of the type:

$R_{LN} — = 354.06 + 940.86\,\alpha$ for crops ($R^2 = 0.77$)

The only available instrument for measuring outgoing radiation is the pyrgeometer, which is used rarely because it is suitable only for spot-reading on clear nights. Effective outgoing radiation can be estimated with the above developed empirical equations.

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Soil moisture balance in relation to rainfall and evaporation

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ABSTRACT

The precipitation was considerably in excess of evaporation from June to October. The maximum surplus (988.5 mm) was in July followed by June (876.3 mm) and August (551.7 mm). The precipitation fell short of evaporation in November and continued till May, the maximum shortage being in March. The soil moisture deficit developed from September and gradually increased upto March and again decreased till May. The availablility of soil moisture in the top soil (0-15 and 15-30 cm) was nil from from November to April while the lower layers maintained 54% in March. Coconut palms should be irrigated from November to May for realising potential yield under Kasaragod conditions.

Introduction

Water balance studies are useful tools to know the general water conditions in an area, to assess the suitability of an area for a particular crop, to estimate water use by a particular crop and to examine water–yield relationships (Jackson, 1977).

Different criteria have been used by different workers in water balance approach for assesing irrigation need. Dagg and Tapley (1967) used monthly water balance approach in assessing development of water stress due to close spacing. Munro and Wood (1964) for analysing water requirements and yield of maize in Malawi used water balance approach where readings of a pan evaporimeter (122 cm dia. and 42 cm deep) were multiplied by a series of 'irrigation factors' ranging from 0.6 to 2.4. Thornthwaite ane Mather (1956) used a simple water balance approach based on rainfall and evaporation. In Kenya, Wallis' (1963) examined the use of water balance method to estmate soil-water deficit and crop water use. Smith (1966) used modulated water balance approach, for coconut in Trinidad. He assumed that the ratio of the actual evaporation to the potential evaporation varies linearly with the soil moisture deficit. The water balance approach was used on weekly basis to determine soil moisture deficit which was then correlated against yield of dry copra. This relation was compared with the relation between rainfall and yield for various periods, and in almost every case moisture deficit was more closely related to yield than was rainfall. In this paper, an attempt has been made to assess water need based on the findings of Gopalasundaram (1985) and substantiated by actual soil moisture measurements.

Materials and Methods

Rainfall, evaporation, soil moisture and soil temperature data from the Agri-meterological observatory at CPCRI, Kasaragod, were used for this study. The soil was a red sandy loam having FC and PWP value of 10 and 5.2 per cent (w/w), respectively. The bulk density was 1.4 g/cc. The water holding capacity of the soil was 302.4mm (upto 120 cm depth) and available water capacity 168 mm. When rainfall was in excess of evaporation, it was considered as excess and deficit when rainfall was less than evaporation. Similarly, when the total amount of available soil moisture exceeded 168 mm, it was considered as surplus and deficit when it was less than 168 mm.

Results and Discussion

A comparison of rainfall and evaporation data (Table 1) shows that from June to October, rainfall was considerably in excess of evaporation. The maximum surplus (988.5 mm), was in July followed by June (876.3 mm) and August (551.7 mm). Rainfall fell short of evaporation from November to May, the maximum shortage being in March. On annual basis, the rainfall of 1542.4 mm was in excess of evaporation. Surplus moisture was recorded from June to August which were the high rainfall months. Soil moisture deficit developed during September and gradually increased upto March and again decreased till May. This indicates the necessity of irrigation from November to May.

The data presented in Table 2 gives the picture of availability of soil moisture in different soil depths. The availability of soil moisture on top layers

Table 1. Actual soil moisture balance in different months

Month	Rainfall mm*	Evaporation mm*	Deficit/ surplus rain (mm)	Moisture balance (mm)**	Deficit surplus moisture (mm)
January	2.8	137.0	−134.2	121.4	−46.6
February	3.7	135.5	−131.8	112.8	−55.2
March	9.8	163.4	−153.6	107.3	−60.7
April	46.9	160.7	−113.8	118.0	−50.0
May	129.7	163.4	− 33.7	138.2	−29.8
June	989.7	113.4	+876.3	187.3	+19.3
July	1073.5	85.0	+988.5	187.5	+19.5
August	637.3	85.6	+551.7	170.7	+ 2.7
September	270.2	135.0	+135.2	163.0	− 5.0
October	210.8	115.3	+ 95.5	151.8	−16.2
November	89.3	117.9	− 28.6	143.2	−24.8
December	22.4	130.2	−107.8	133.6	−34.4
Total	3486.1	1542.4	1943.7		−281.2

* Mean of 20 years. ** Mean of 6 years

Table 2. Soil moisture availability (depthwise) in different months (mean of 6 years)

Month	Soil depths 0—15 Act. %	Avail. %	15—30 Act %	Avail. %	30—45 Act. %	Avail. %	45—120 Act. %	Avail. %	Temperature 5 cm	15 cm	30 cm
January	2.8	Nil	4.3	Nil	7.7	52	8.6	71	42.1	35.5	32.3
February	2.2	Nil	4.7	Nil	6.8	33	8.0	58	44.8	37.7	33.8
March	1.9	Nil	4.2	Nil	6.0	17	7.8	54	46.6	39.6	35.2
April	3.3	Nil	5.2	Nil	6.7	31	8.2	62	46.7	40.8	37.5
May	5.6	8	5.9	15	7.3	44	9.4	87	44.6	38.6	35.2
June	11.0	100	10.3	100	9.9	98	11.6	100	32.6	31.9	29.0
July	10.0	100	8.9	77	9.9	98	12.1	100	31.9	30.6	28.6
August	7.9	56	8.0	58	9.4	87	11.2	100	34.1	32.2	29.1
September	8.5	69	9.2	83	8.9	77	10.2	100	38.9	35.4	32.4
October	5.9	15	6.5	27	7.9	56	10.4	100	39.5	37.1	32.3
November	3.9	Nil	6.1	19	7.7	52	10.1	100	39.3	36.5	31.9
December	1.9	Nil	4.3	Nil	7.5	48	9.8	96	41.2	36.7	32.5

FC = 10%, PWF = 5.2%
Act.—Actual; Avail.—Available

(0-15 and 15-30 cm) was zero from November to April. This reflects inadequacy of rainfall during this period and fast depletion of stored soil moisture due to more exposure to solar radiation as is evident from the data on surface soil temperature. (Table 2). The lower layers maintained 100% available mositure from June to November and thereafter gradually decreased to 54% in March obviously because the lower layers were less exposed to solar radiation. This points out that heavy irrigations are not required to recharge the entire soil profile.

From the soil moisture balance studies, it is clear that for realising potential yield under Kasaragod conditions, coconut palms need to be irrigated from November to May. As the soil moisture stress is mild in November and December, there is possibility of saving water and energy by light irrigations. The irrigation requirement is maximum (154 mm) during March. During this period, heavier irrigation are required to alleviate the effect of severe drought and to obtain good yield. Since growth and reproductive phases proceed simultaneously, coconut requires readily available soil moisture throughout the year. This is also evident from the findings of Gopalasundaram (1985) that for higher production coconut palms need irrigation at IW/CPE ratio of 1.00 i.e. water requirement is equal to the evaporative demand of the atmosphere.

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Moisture depletion patterns in coconut plantation under rainfed and irrigated conditions

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ABSTRACT

Under rainfed conditions, the evapotranspiration was about 4mm/day during the first two days of receipt of rains. The values changed to 2.4mm/day and 2.1 mm/day, respectively, when calculated for the first week and first two weeks after rains. 0-70 cm layer had the maximum contributron to the water needs of coconut. Water loss from the interspaces was higher than from basins. Under irrigated conditions, the maximum evapotranspiration (6.6mm/day) and water loss from interspaces (5.6 mm/day) were recorded with 20 mm water at IW/CPE ratio of 1.00. Decreasing frequency gradually decreased the rates to 4.0mm and 2.3 mm/day at IW/CPE=0.75 and 0.50, respectively from 0-90 cm soil depth. It is concluded that irrigation with 20 mm of water at IW/CPE ratio=1.00 is adequate to meet the water needs of coconut for optimum growth. A higher quantity is not desirable as it leads to deep percolation losses.

Introduction

Evapotranspiration is one of the most important factors affecting the frequency of irrigation. It is the sum total of water lost by evaporation from soil and transpiration from plants. It is directly related to solar radiation, temperature, wind velocity, saturation deficit, level of soil moisture and plant cover. An increase in these factors causes an increase in evapotranspiration. Under identical climatic conditions, the rate of evapotranspiration depends on the availability of soil moisture. Therefore, studies were undertaken to determine soil moisture depletion under rainfed and irrigated conditions.

Materials and Methods

Soil moisture studies were carried out at the Central Plantation Crops Research Institute, Kasaragod during the summer seasons of 1984 and 1985 in an irrigation cum fertility experiment started in 1968. The treatments consisted of all combinations of three depths of irrigation water viz., 20 mm (q1), 40 mm (q2) and 60 mm (q3) of water per irrigation, three frequencies of irrigation viz. IW/CPE ratio of 1.00 (f1), 0.75 (f2) and 0.50 (f3) and three levels of fertilizers viz. 500 gN+ 330g P_2O_5+ 750g K_2O+170g MgO (m_1), 750g N+670g P_2O_5+1500g K_2O+ 170g MgO (m_2) and 1000g N+1000g P_2O_5+2250g K_2O+170g MgO (m_3) per palm per year. The experiment was laid out in a 3^3 factorial confounded design with two replications. There were four side treatments including a rainfed control. Soil moisture studies were conducted under different depths and frequencies of irrigation at the m_2 level of fertilizers.

The soil of the experimental field was sandy loam in texture, deep, highly permeable and non calcarious. The values of field capacity (FC) and permanent wilting point (PWD) were 10 0% and 5.2% (W/W), respectively and bulk density 1.4g/cc.

The soil moisture measurements were carried out by using a Troxler Neutron Probe, Model 3222. Access tubes were fixed at about 1 m distance from the bole in the basins and in the centre of the interspaces. Under rainfed condition, measurements were taken at an interval of 7 to 10 days whereas in irrigated treatments one day before and one day after each irrigation and also between two irrigations at suitable intervals. Perfo spray system was used for irrigation. The results are discussed under rainfed and irrigated conditions separately.

Results and Discussion

The rainfed treatment showed an increase in water content of the profile (0-130 cm) with the occurrence of rainfall. A drop in water content occurred with the cessation of rainfall obviously due to the poor WHC of the sandy loam soil that imbibe water quickly and releases most of it under the influence of gravity. A comparison of integrated water contents of basin and interspace revealed that the latter had higher water content in the profile as well as in different layers. This might be due to involvement of crop factors and receipt of more rain water in the interspaces because of less interception by the leaves.

In general, fluctuation of moisture was found to be more sharp in interspaces than in basins (Table-1). This might be because of the *in situ* enrichment of the basin soil with organic matter. The results indicated that the water content of the soil profile was higher as a result of NE monsoon (upto May) than the moisture at the time of first measurement (25th January, 1984) and the moisture change remained positive till the end of SW monsoon (upto September, 1984). The highest integrated water content of the profile was recorded on 6th June, 1985 when positive balance was 80 mm and 86 mm for basins and interspaces, respectively. Moisture changes on 31st January, 1985 was negative and higher indicating higher evaporative demand of the climate. Interspaces recorded higher values indicating relatively higher exposure to radiation (Table-1).

The actual evapotranspiration (Et) for rainfed treatment was 4 mm/day during the first two days of receipt of rain. The Et values after one and two weeks of rain were 2.4 and 2.1 mm/day, respectively. This was because of the higher initial moisture content which decreased gradually in the absence of rains. The layer-wise Et data indicated that 0—70 cm layer had the maximum contribution (2.83 mm/day) to the water need of the coconut palm (Table–2).

Table 1: Rainfall and moisture changes in basins and interspaces.

Soil depth cm	25.1.84 to 4.4.84	4.4.84 to 26.5.84	26.6.84 to 18.9.84	18 9.84 to 31.11.85	25.1.84 to 31.11.85	25.1.84 to 2.3.85	21.1.84 to 6.6.85	27.2.84 to 15.2.85
				RAINFALL				
	122.3	190.7	2352.7	598.7	3264.4	3264.4	4481.4	3261.6
			Moisture changes (mm) in basins					
0—130	3.2	14.0	12.2	—33.8	—4.5	—7.3	79.6	2.8
0—90	1.1	9.9	12.2	—25.2	—1.6	—3.5	68.7	4.8
0—70	0.6	9.2	9.2	—20.2	—0.8	—1.8	59.9	5.3
0—30	2.0	4.4	4.0	— 8.3	+2.1	2.5	27.5	—4.0
			Moisture changes (mm) in interspaces					
0—130	1.1	12.1	13.5	—35.7	—9.0	—15.9	86.2	2.5
0—90	0.8	12.4	8.4	—27.6	—6.0	—10.4	71.2	3.7
0—70	1.3	11.0	6.2	—20.9	—2.3	—5.8	61.3	4.8
0—30	2.2	7.0	3.3	— 8.3	4.1	2.3	31.2	5.7

The water loss data from the interspaces (Table-3) revealed the same trend as that of Et from the basins. However, the water loss from the interspaces was higher than the Et from the basins. This might be due to the receipt of higher amount of water and more exposure of soil to solar radiation.

Table 2: Actual evapotranspiration (mm/day) by coconut.

Soil layers cm	1st week *10—17 March,84	2nd week 17—24 March,84	2 weeks 10—24 March,84	1st 2 days 10—11 March,84	Next 5 days 12—17 March,84
0—30	1.34	0.62	0.98	2.38	0.92
0—70	2.83	1.14	1.99	5.04	1.95
0—90	2.78	1.55	2.17	5.20	1.82
0—130	2.35	2.07	2.21	4.08	1.66

* Data on which profile was close to FC.

Table 3: Water losses (mm/day) from interspaces of coconut palm

Soil layers cm	1st week 10—17 March,84	2nd week 17—24 March,84	2 weeks 10—24 March,84	1st 2 days 10—11 March,84	Next 5 days 12—17 March,84
0—30	0.76	0.41	0.58	1.22	0.57
0—70	2.23	0.93	1.58	3.81	1.65
0—90	3.00	1.19	2.10	5.22	2.12
0—130	5.41	1.72	2.90	7.28	2.82

The evapotranspiration and water loss data for q1 (20 mm) and q2 (40 mm) with different frequencies are presented in Table 4. The data revealed that frequency of irrigation had great influence on Et as well as water loss from the interspaces. Within each quantity of water higher frequency recorded higher Et and water loss. A decrease in the frequency of irrigation gradually decreased the Et and water loss rates.

The maximum Et (6.6 mm/day) and water loss (5.6 mm/day) from interspaces were recorded under q1f1 (20 mm water IW/CPE=1.00) treatment from 0-90 cm soil layer. Decreasing the irrigation frequency to IW/CPE=0.75 and 0.50 gradually reduced the Et to 4.0 and 2.3 mm/day and water loss to 4.2 and 1.9 mm/day, respectively.

Table 4: Actual evapotranspiration (mm/day) from basis and interspacing coconut palm

Treatment	Soil depth (cm)	Basin	Interspaces
q1f1	0—30	3.2	3.7
	0—70	6.3	5.6
	0—90	6.6	5.6
	0—130	6.4	4.8
q1f2	0—30	2.7	3.0
	0—70	4.4	4.2
	0—90	4.0	4.2
	0—130	2.5	4.3
q1f3	0—30	1.3	1.8
	0—70	2.3	2.2
	0—90	2.3	1.9
	0—130	2.3	1.8
q2f1	0—30	2.0	1.8
	0—70	3.9	4.6
	0—90	4.2	5.7
	0—130	4.4	6.9
q2f2	0—30	2.2	1.5
	0—70	4.3	3.3
	0—90	4.5	3.9
	0—130	4.3	3.5
q2f3	0—30	1.1	0.9
	0—70	2.6	2.1
	0—90	3.0	2.5
	0—130	3.1	2.6

A comparison between 20 and 40 mm irrigation water at different frequencies indicated higher Et as well as water loss from the interspaces with 20 mm irrigation at IW/CPE=1.00. At IW/CPE ratios of 0.75 and 0.50 the trend was reversed and higher rates of Et and water loss were found under 40 mm of irrigation water.

Such a trend is expected because in well watered fields the Et rate is directly related to the moisture content in soils. Irrigation with 20 mm water at IW/CPE of 1.00 maintained higher moisture (Table-5) and unsequently the Et and water loss were higher. The same was the case with 40 mm water at IW/CPE ration 0.75 and 0.50.

Table 5: Soil moisture (%v/v) and integrated water content in basins one day after and one day before irrigation

	After irrigation			Before irrigation			
Depth cm	q1f1 (7)	q2f1 (7)	q3f1 (2)	q1f1 (11)	q2f1 (8)	q3f1 (6)	FC.
10	12.7	12.7	12.3	12.1	10.5	8.3	13
30	15.3	15.5	14.0	11.3	11.0	8.4	14
50	15.6	17.1	16.6	13.3	12.6	11.2	15
70	14.4	17.0	16.7	13.8	13.4	11.2	15
90	14.8	17.0	16.6	14.7	13.7	12.2	15
110	14.7	16.3	17.4	14.8	13.6	13.5	16
130	14.4	16.2	17.7	14.4	14.5	14.1	15
Integrated soil water content (mm)							
0–30	49.8	50.2	44.1	39.9	36.7	32.7	42
0–70	118.5	127.0	120.8	100.8	84.6	83.6	98
0-90	148.1	160.9	153.7	130.2	121.9	108.0	126
0–130	191.1	209.6	216.2	174.3	163.7	149.0	182

Figures in paranthesis are number of observations

Soil moisture and integrated water contents in the basins with 20, 40 and 60 mm irrigation water at the frequency of IW/CPE=1.00 one day after irrigation indicated that 20 mm irrigation water was just sufficient to recharge diferent layers to field capacity whereas 40 and 60 mm water raised the water content above the level of field capacity (Table-5). As the availability of water is 100% at FC level, excess water will go as deep percolation and therefore, irrigation higher than 20mm is not desirable under sandy loam conditions.

The moisture content before next irrigation indicated that 20 mm irrigation water maintained soil moisture almost near to FC. In the case of 40 and 60mm irrigation water, soil water content was less than the FC level in all the layers. The deficit was more with 60mm water. This was owing to wide intervals of irrigation i. e. 8 and 12 days, respectively, with 40 and 60 mm of water. Further, the results point out that application of higher quantities of irrigation water is not advantageous in the sandyloam soil.

Water requirement of young TxG coconut hybrids

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ABSTRACT

Irrigation at IW/CPE ratio of 1.00 significantly increased the seedling height, collar girth and total number of leaves in 1985. Also, it recorded the maximum consumptive use (794 mm) of water followed by irrigation at IW/CPE=0.75 (716mm) and 0.50 (643.4mm). The ratio between crop evapotranspiration and open pan evaporation was 0.75.

Introduction

Summer irrigation is essential for increasing the unit production of coconut gardens in the northern region of Kerala. Under scarcity conditions, of water, a rational approach in irrigation is essential to economise water use. For scientific water management in any crop, the water requirement of that particular crop should be known. Water requirement includes evapotranspiration or consumptive use plus unavoidable losses. The former will vary depending upon the climate under a given soil type. Even under similar climatic conditions, the consumptive use will depend on the soil moisture status. Keeping these in view, a field experiment was conducted to determine the consumptive use of water based on soil moisture depletion approach.

Materials and Methods

An irrigation cum fertilizer experiment on young TxG coconut hybrids was laid out during 1980 at the Regional Agricultural Research Station, Pilicode. The treatments comprised of three levels of irrigation at IW/CPE ratios 0.50, 0.75 and 1.00 at 30mm CPE) and four fertiliser doses (500 g N+500 g P_2O_5+1500 g K_2O (f_1), 500 g N+500 g N+500 g P_2O_5+2000 g K_2O (f_2), 500 g N+1000 g P_2O_5+ 2000 g K_2O (f_3) and 1000 g N+500 g P_2O_5+2000 g K_2O (f_4). During 1984 and 1985, soil moisture studies were carried out.

The experimental area was red sandy loam in texture. The field capacity and permanent wilting point values were 10.0% and 5.3% (W/W), respectively and bulk density 1.4 g/cc.

Soil samples were drawn before and 24 hours after irrigation using a soil auger at about 1 m away from the bole of the seedlings. The moisture content of the soil was estimated gravimetrically. The consumptive use and the moisture extraction pattern were worked out according to the method suggested by Ray *et al.* (1977). The crop coefficient was worked out as per the method of Hargreaves (1968).

Results and Discussion

Table 1 gives the consumptive use of water in different soil depths. It could be seen that 0-30 cm layer recorded the maximum consumptive use irrespective of the treatments. Irrigation at IW/CPE ratio of 1.00 recorded the maximum consumptive use of water.

Table. 1 Consumptive use of water of young coconut seedlings

Treatment IW/CPE	Soil depth			Total (mm)
	0-30 cm	30-60 cm	60-90 cm	
0.50	367	173	100	640
0.75	317	183	216	716
1.00	278	242	274	794

The higher consumptive use in the upper layer is attributable to the rapid evaporation of moisture from the soil surface. The increase in consumptive use with an increase in the IW/CPE ratio might be due to frequent wetting of the soil surface. The result is in confirmity with the findings of Gopalasundaram (1985).

The moisture extraction pattern (%) under different irrigation regimes are presented in fig. 1 The moisture extraction was high in the upper (0-30 cm) layer and it was relatively uniform in the middle (30—60 cm) layer. The moisture content was relatively low at the depth (60-90 cm) under the irrigation treatment IW/CPE of 0.50

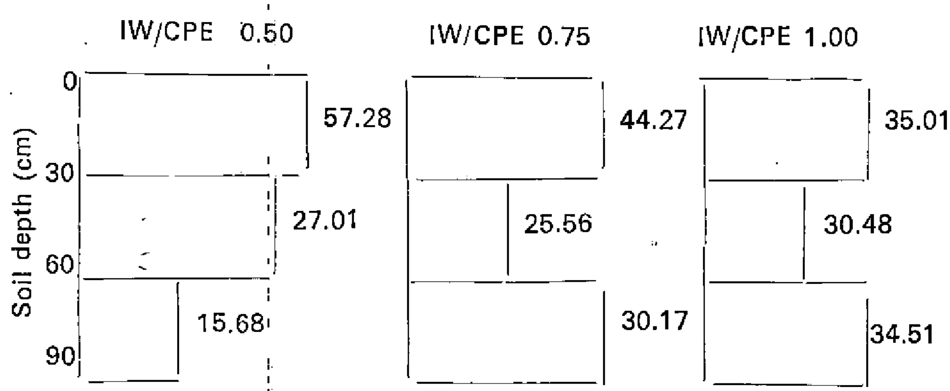

Fig. 1. Moisture extraction pattern (%) of coconut seedlings under different irrigation regimes.

The ratio of consumptive use to pan evaporation (crop coefficient) was computed under different irrigation treatments and the mean worked out to 0.75. The water requirement of coconut seedlings can be estimated using the crop coefficient if pan evaporation values are known.

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Discussion

R. C. Mandal (NRCC, Puttur): IW/CPE ratio of 1.00 recorded the maximum consumptive use in seedlings at Pilicode; While in case of adult palms at Kasaragod it has only 0.75. This is not true in practice because adult palm is likely to absorb more moisture. This needs a thorough analysis by both the workers.

A. Rajagopalan: The test variety at Pilicode is T x G hybrid. The variety tested at Kasaragod was WCT. Moreover, the response to irrigation at Pilcode is linear; hence we can not fix irrigation at the IW/CPE ratio of 1.00 as the optimum. As suggested, treatments can be modified after analysing the effect of irrigation on yield and other attributes.

Rainfall Acceptance in Eucalyptus based Taungya systems

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ABSTRCT

The cultivated bare fallow plot produced the maximum run-off and accepted only 47% of the rainfall. Though the ridge farming of cassava helped to harvest 93% of the rainfall, grass farming, consequent to better establishment.— substantially increased its acceptance ability and even overtook ridging by accepting almost 96% of the total. Rice taungya was more effective than mound method of cassava cultivation. Grass interstripping also showed positive tendency in reducing run-off. The results indicated viable agroforestry measures for increasing rainfall acceptance and water storing capacity of hill slopes where plantation crops are widely cultivated.

Introduction

Soil erosion by water is the most severe problem in many of the taungya plantations. Run-off, the overflowing water from precipitation after and infiltration, has got strong positive correlation with soil loss (Hudson, 1984). So, any attempt to increase the rainfall acceptance, will inevitably result in reduced soil loss and non-point source of environmental pollution. Further, the increased rainfall acceptance of a system, is a direct indication of its water harvesting ability and hence very much desirable for hill slopes, where plantation crops are widely cultivated. But correct quantification of run-off and rainfall acceptance in various taungya systems practiced in Kerala, based on clearly laid field studies are practically absent (Nair, 1984). This still remains a lacuna in conservation planning and watershed management. Moreover, agroforestry measures are accepted as viable conservation techniques especially for the fragile and brittle ecosystems of tropical developing world. But the absence of situation specific recommendations restricts their wide-spread adoption. Hence the present investigation was taken up to determine the run-off and rainfall acceptance in eucalyptus based taungya systems of Kerala. The efficiency of cassava planting on ridges, grass farming and grass stripping was also investigated.

Materials and Methods

The experiment was undertaken at the College of Horticulture, Vellanikkara, for a period of two years from May 1984 to April 1986. The area had a slope of 25% facing north. The soil of the experimental area was shallow, well drained, moderately acidic oxisol with a sandy clay loam surface texture. The steady-state infiltrability of the soil was 11.40 cm/hr with an initial infiltration rate of 82.80 cm/hr for the first first five minutes. Cumulative infiltration was 81.70 cm over a period of 300 minutes.

The following seven treatments were replicated thrice in RBD. Eucalyptus alone (T_1); Eucalyptus+five cassava on mounds in between for trees (T_2); Eucalyptus+four cassava on ridge across the slope in between four trees (T_3); Eucalyptus+one cassava on mound as laid down in the taungya contract regulations (T_4); Eucalyptus+congosignal grass (T_5); Eucalyptus+*modan* rice (T_6) and cultivated fallow (T_7). In the second year of the experiment, cultivated fallow plot was changed to Eucalyptus+cassava on mounds as in T_2+10% area interstripped with congosignal grass.

The plots of size 24x4m² were demarkated by mud-plastered round topped earthen bunds of 60 cm width and 30 cm height. A run-off collection assembly with 47 slot multi-slot device specifically designed for this purpose was made use of for collecting the run-off. Run-off was measured once in 24 hours at 8.30 AM. Rainfall acceptance, was determined by the equation,

$$1 - \frac{\text{Total run-off}}{\text{Total rainfall}} \times 100 \text{ (Uriyo, 1979)}$$

The daily data were pooled to get the corresponding monthly and annual values. With treatments as main-plots and months as sub-plots, the data on run-off were analysed in a split-plot design.

Results and Discussion

The monthly run-off observed in different treatment are presented in Table 1.

The data showed that in the first year, all the treatments differed significantly barring T_4 and T_2, which were on par. Run-off between months also showed significant variations. T_7 gave the highest value and T_3 the lowest throughout the months, except in September, where T_5 gave the lowest value. Among the months, June recorded the highest run-off and August the lowest with significant difference between them. Within each treatment too, the trend, in general, was the same between months. In the second year also T_7 recorded the maximum value. But instead of T_1, T_5 gave significantly lower run-off than all the other treatments. As against the first year, T_5 gave significantly lower values in June and July. T_1, which closely followed T_7 in the first year, started producing lesser run-off than T_6 in the above months. All the treatments recorded notable reduction in run-off in the second year.

The highest quantity of run-off produced in cultivated fallow plot (T_7) in all the months of first year may mainly be due to the decreased rate of infiltration consequent to direct continuous and uninterrupted hitting of raindrops which will puddle the soil surface and plug the macro-pores with fine soil particles (Hudson,

Table 1. Month-wise run-off (mm)

Year/month	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
1984								
May	117.22	114.07	8.25	117.50	84.30	93.32	119.41	93.43
June	434.94	422.67	81.53	426.58	270.77	320.94	453.48	344.48
July	375.73	381.32	41.86	375.59	260.55	305.61	417.63	308.33
August	53.69	47.12	9.31	46.36	14.03	35.54	63.09	38.45
September	61.77	56.09	9.29	61.45	8.77	14.57	68.56	40.07
October	126.63	100.98	16.35	109.38	18.36	45.07	136.88	79.09
Mean	195.00	187.04	27.77	189.48	109.46	135.84	209.84	
CD (0.05)	a = 2.58		b = 1.86		c = 5.03		d = 4.91	
1985								
June	260.09	352 24	58.60	356.31	48.64	263.92	423.40	251.89
July	222.66	306.50	53.06	276.72	36.20	228.76	324.11	206.86
August	42.31	63.69	17 32	63.00	15.18	15.12	74,47	41.59
September	0.81	1.30	0 40	1.14	0.81	0.79	1.29	0.93
October	18.71	42.37	10.28	52.07	9.98	21.62	44.33	28.48
December	2.82	2.26	0.87	2.42	0.99	1.69	2.22	1.90
Mean	91.23	128.06	23.42	125.28	18.63	88.65	144.97	
CD (0.05)	a = 2.95		b = 3.24		c = 7.51		d = 7.64	

a = CD for treatments
b = CD for months
C = CD for months between treatments
d = CD for months within the treatment

Table 2. Annual run-off (mm) and rainfall acceptance (%)

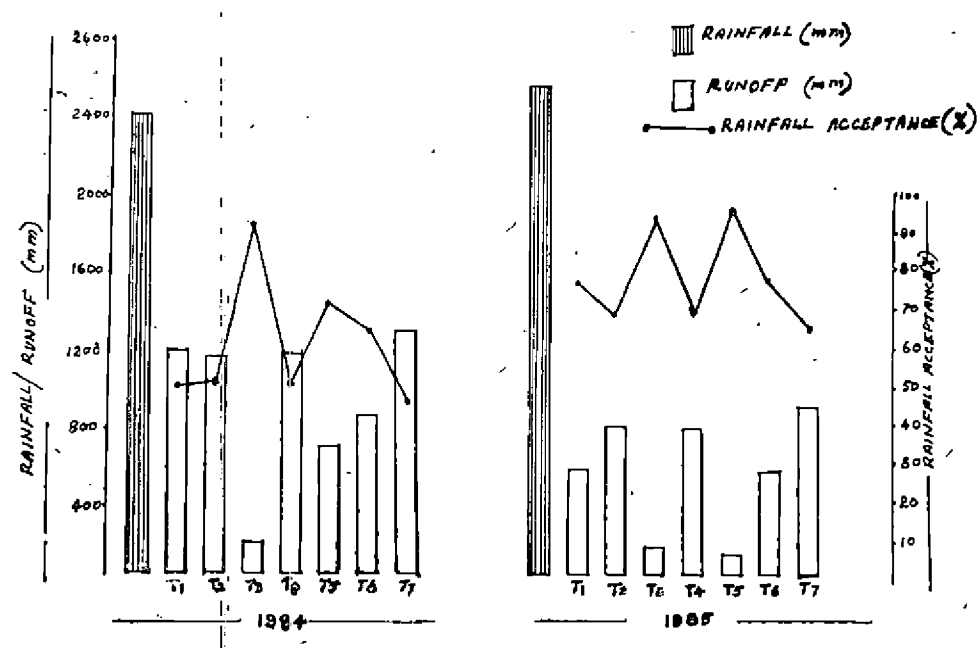
	Treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1984							
Run-off (%)	42.10	47.10	6.99	47.69	27.56	34.21	52.84
Run-off amount (mm)	1170.00	1122.24	166.62	1136.38	656.76	815.04	1259.04
Rainfall acceptance (%)	50.90	52.90	93.01	52.31	72.44	65.79	47.16
Rainfall amount (mm)	1212.75	1260.51	2216.13	1246.37	1726.00	1567.71	1123.71
1985							
Run-off (%)	21.75	30.53	5.58	29.87	4.44	21.14	34.56
Run-off amount (mm)	547.38	768.36	140.52	751.68	117.78	531.90	869.82
Rainfall acceptance (%)	78.25	69.47	94.42	70.13	95.56	78.86	65.44
Rainfall amount (mm)	1969.17	1748.19	2376.03	1764.87	2404.77	1984.65	1646.73

1984). This became clear by realizing the possible effects of vegetation/ground cover in dessipating 'rainfall energy' (Hudson, 1977 and Venkataraman, 1978) and from the observed reduction of run-off in all other treatments where varying levels of vegetation were maintained. In grassed plot (T_5) high initial infiltration rate, and increased moisture storage capacity of soil provided by the transpiratory withdrawal of dense grass cover might have contributed to the decreased run-off. Rice crop (T_6) was also effective in controlling run-off to a significant extent, which in effect behaved almost similarly as that of congosignal. Mound methods of cassava cultivation (T_2 and T_4) produced almost comparable values in the initial months. But reduced run-off in the maximum cassava treated plot (T_2) towards the end can probably be attributed to the rainfall interception ability of dense canopy cover due to high cassava population. Ridge farming of cassava (T_3) effectively prevented run-off by retaining it in-between the ridges.

Though, there was higher rainfall than the first year, all the treatments recorded comparatively lesser run-off in the second year because of the stabilization effects of the treatments. T_5, giving the lower values in all the months suggests that, grass once established, is better than ridging in controlling run-off. Grass interstripping as in T_7 also started showing positive tendency in controlling run-off. The data on total rainfall, run-off and rainfall acceptance are presented in Table 2 and Fig. 1.

When cultivated fallow plot (T_7) could accept only 47% of the rainfall, ridge farming of cassava (T_3) helped to harvest 93% in the first year. All other

Fig.1. ANNUAL RAINFALL, RUNOFF AND RAINFALL ACCEPTANCE



treatments recorded values in-between. In the second year, all the treatments substantially increased their acceptance ability and grass cultivation even overtook ridging, a costly and laborious method, by accepting almost 96% of the total rainfall. The efficiency of grass farming was manifested measurably even when 10% of the area was interstripped with congosignal as in T_7 of the second year. This treatment could harvest about 65% of rainfall, a comparable value, with that of the first year rice taungya.

Rainfall acceptance is a measure of the effectiveness of each treatment in harvesting the rainfall and infiltrating it into the soil matrix. Hence, factors responsible for reducing run-off will also hold good for explaining the rainfall acceptance.

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Discussion

R. C. Mandal (NRCC, Puttur): The particular paper dose not fit into this session since it pertains to run-off studies, soil moisture conservation and system of planting. To justify its inclusion weather parameters and effect of rainfall on "Taungya systems" could have been thoroughly studied.

R. Gopinathan: I am doubtful whether Dr. Mandal is fully aware of the scope of the first session on Radiation, Energy and Moisture balance. In this study. I tried to work out the rainfall acceptance as influenced by various agroforestry practices. It is the accepted rainfall which will form the available moisture later. Hence this particular paper fits exactly and only to the Session I. Rainfall parameters and their influence on rainfall acceptance have been studied in detail. For want of time, I could not discuss here,

Effective rainfall in coconut based land use of Kerala

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ABSTRACT

An attempt was made to study the water requirement of coconut plantations in different months using several climatological methods. Penman's method was found to be more agreeable for estimating crop water requirement. The mean annual water requirement of coconut was 1126 mm and the effective rainfall was 27 per cent of the annual rainfall. The mean annual irrigation requirement of coconut was found to be 388 mm spread from November to May.

Introduction

The different characteristics of rainfall of a place like its amount, frequency, intensity etc. are we studied and information on these aspects of any place is readily available. Inspite of all these data, informations on "effective rainfall" in agriculture is lacking because of the complexity involved in its quantification to any reliable extent.

Knowledge of effective rainfall in agriculture is essential for planning the effective utilisation of available rainfall potential of a place and for irrigation scheduling and water management.

Studies on effective rainfall in India are very few. Pharande and Dastane (1964) touched upon the subject of effective rainfall. Kushlani (1956) suggested that rainfall during the life cycle of the crop in a bad year should be considered as effective rainfall. Sastry (1956) suggested an empirical formula for evaluation of effective rainfall. Hayes and Buel (1955), Ogrosky and Mockus (1964), Hershfield (1964), Miller and Thompson (1970) Chow (1964), add Stamm (1967) discussed mainly on the concepts of effective rainfall.

The term crop water requirement (consumptive use of crop) can be interpreted as "the depth of water needed to meet the water loss through evapotranspiration (ET_{crop}) of disease free crop, growing in large fields under unrestricted soil moisture conditions including soil water and fertility and achieving full production potential under the given growing environment the water requirements of crops are mainly controlled by the climate of the place. The climatological or atmospheric demand for water for evapotranspiration is termed as reference crop evapotranspiration (ET_0) or potential evapotranspiration, which is the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the round and not short of water.

The maximum or potential rate of crop evapotranspiration is determined by the prevailing weather. However, plant physiological control over evapotranspiration often results in actual evapotranspiration or consumptive use (ET_{crop}) being less than the potential rate of ET_0. The recognition of this has led to evaluation of factors like root constants and crop coefficients (Kc), to represent the relationship between the two viz. $ET_{crop} = ET_0 \times Kc$. The value of Kc are found to vary with the crop, its stage of growth, growing season and prevailing weather conditions.

In view of the concepts of water requirements of crops, the term effective rainfall can be defined as the portion of rainfall, which is useful directly or indirectly for meeting crop water requirements at the site where it falls without pumping.

Materials and Methods

The five climatological stations in Kerala for which long period climatological data are available viz., Calicut, Palghat, Cochin, Alleppey and Trivandrum were selected for the study. Normal values of meteorological parameters such as temperature, surface pressure, vapour pressure, total cloud amount, wind speed and rainfall were taken from the climatological tables (IMD, 1970) for the different months of the year. The methods formulated by Penman (1948) modified by Rao *et al.* (1971), Thornthwaite (1948), Khosla (1949) and Leeper (1950) were used for estimation of potential evapotranspiration (reference crop evapotranspiration).

The reference crop evapotranspiration and consumptive (ET_{crop}) use of crops are related by the equation:

$$ET_{crop} = ET_0 \times Kc$$

Where, Kc is the crop coefficient for the particular crop. A crop coefficient of 0.75 was adopted for coconut plantations. The monthly ET_{crop} values were calculated for different months of the year and for all the stations selected for the study. For estimating the effective rainfall from the mean monthly consumptive use and rainfall, the table prepared by the United States Department of Agriculture, Soil Conservation Service (USDA, SCS, 1967) was used (Table 1).

Results and Discussion

A comparison of the consumptive use values computed for different months of the year and for different stations are presented in Figs. 1–5. The results of Penman's method was found to show maximum variations in estimated monthly consumptive use in a year, having maximum in March minimum in June–July. Khosla's and Leeper's formulae gave the least variations in monthly consumptive use. Thornthwaite formula under estimated in the months of January, February and March and overestimated in the rest of the months when compared to that of Penman.

The mean annual consumptive use estimated by the different methods are given in Table 2.

It was observed from Figs. 1-5 that the estimated values of water requirement (consumptive use) of coconut by the Penman's method show better agree-

Table 1: Average monthly effective rainfall as related to mean monthly rainfall and mean monthly consumptive use (USDA, SCS)

Monthly mean rain-fall mm	Mean monthly consumptive use (mm) 25	50	75	100	125	150	175	200	225	250	275	300	325	351
	Mean monthly effective rainfall (mm)													
12.5	7.5	8.0	8.7	9.0	9.2	10.0	10.5	11.2	11.7	12.5	12.5	12.5	12.5	12.5
25.0	15.0	16 2	17.5	18.0	18.5	19.7	20.5	22.0	24.5	25.0	25.0	25.0	25.0	25.0
37.5	22.5	24.0	26 2	27.5	28.2	29.2	30.5	33.0	36.2	37.5	37.5	37.5	37.5	37.5
50.0	*25*	32.2	34.5	35.7	36.7	39.0	40.5	43.7	47.0	50.0	50.0	50.0	50.0	50.0
62.5	at41.7	39.7	42.5	44.5	46.0	48.5	50.5	53.7	57.5	62.5	62.5	62.5	62.5	62.5
75.0		46.2	49.7	52.7	55.0	57.5	60.2	63.7	67.5	73.7	75.0	75.0	75.0	75.0
87.5		*50.0*	56.7	60.2	63.7	66.0	69 7	73.7	77.7	84.5	87.5	87.5	87.5	87.5
100.0		at80.7	63.7	67.7	72.0	74.2	78.7	83 0	87.7	95.0	100	100	100	100
112.5			70.5	75.0	80.1	82.5	87.2	92.7	98.0	105	111	112	112	102
125.0			*75.0*	81.5	87.7	90.5	95.7	102	108	115	121	125	125	125
137.5			at122	88.7	95.2	98.7	104	111	118	126	132	137	137	137
150.0				95.2	192.2	106	116	100	120	136	143	150	150	150
162.5				*100*	109	113	120	128	135	145	153	160	162	162
175.0				at160	115	120	127	135	143	154	164	170	175	175
187.5					121	126	134	142	151	161	170	179	185	187
200.0					*125*	133	140	148	158	168	178	188	196	200
225					at197	144	151	160	171	182				
250						*150*	161	170	183	194				
275						at240	171	181	194	205				
300							*175*	190	203	215				
325							at287	198	213	224				
350								*200*	220	232				
375								at331	*225*	240				
400									at373	247				
425										*250*				
										at412				
450	25	50	75	100	125	150	175	200	225	250				

Table 2: Mean annual consumptive use of coconut

	Method			
Station name	Penman's (mm)	Thornthwaite (mm)	Khosla's (mm)	Leeper's (mm)
Calicut	1126.1	1290.0	1178.0	1081.1
Palghat	1247.2	1316.8	1201.9	1156.3
Cochin	1068.1	1170.6	1171.9	1070.0
Alleppey	1072.8	1292.1	1179.4	1081.7
Trivandrum	1113.1	1279.0	1170.3	1067.0

Table 3: Mean monthly rainfall, effective rainfall and effective rainfall as percentage of the seasonal rainfall for different location in the state.

	SW Monsoon (June–Sept.) mm	NE Monsoon (Oct.–Dec.) mm	Winter (Jan. Feb.) mm	Hot weather (March–May) mm
	CALICUT			
Rainfall (R)	2351	460	17	455
Effective rainfall (ER)	304	267	17	197
ER as % of R	13%	58%	100%	43%
	PALGHAT			
Rainfall (R)	1360	373	93	253
Effective rainfall (ER)	320	173	93	177
ER as % of R	24%	46%	100%	70%
	COCHIN			
Rainfall (R)	1948	553	44	554
Effective rainfall (ER)	298	187	35	219
ER as % R	15%	34%	79%	40%
	ALLEPPEY			
Rainfall (R)	1887	641	46	690
Effective rainfall (ER)	327	187	33	242
ER as % of R	17%	29%	72%	35%
	TRIVANDRUM			
Rainfall (R)	834	551	40	414
Effective rainfall (ER)	326	214	29	206
ER as % cf R	39%	39%	72%	50%

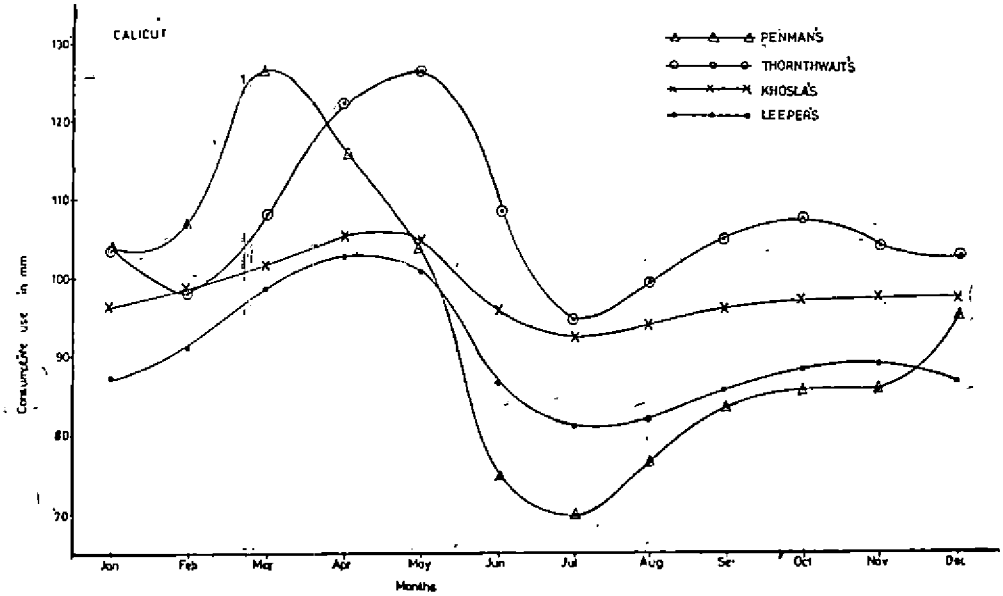

FIG 1 CONSUMPTIVE USE OF COCONUT

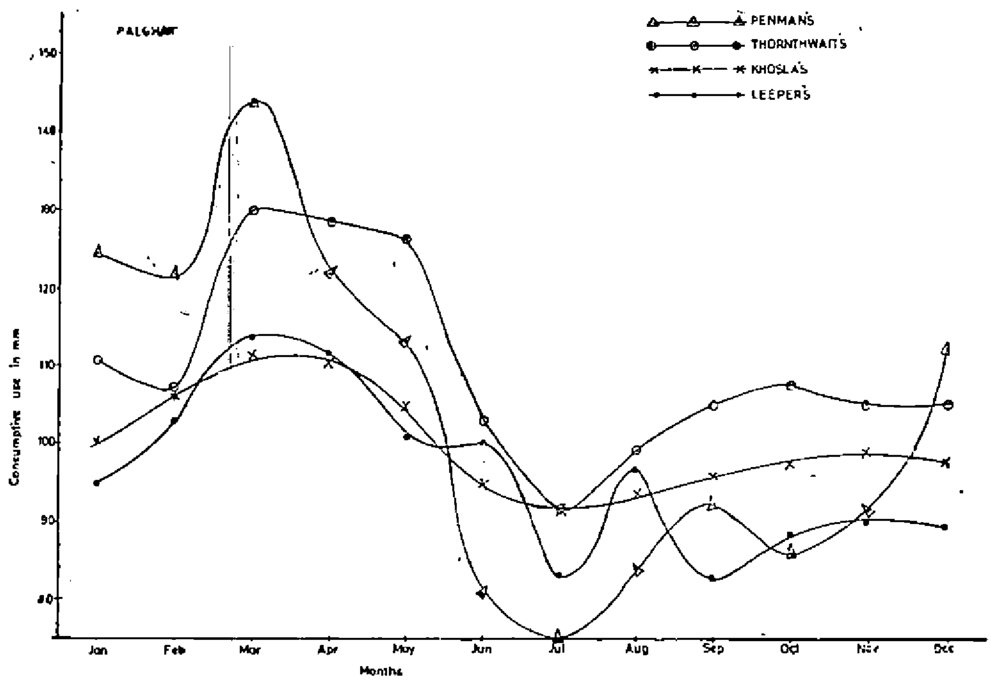

FIG 2 CONSUMPTIVE USE OF COCONUT

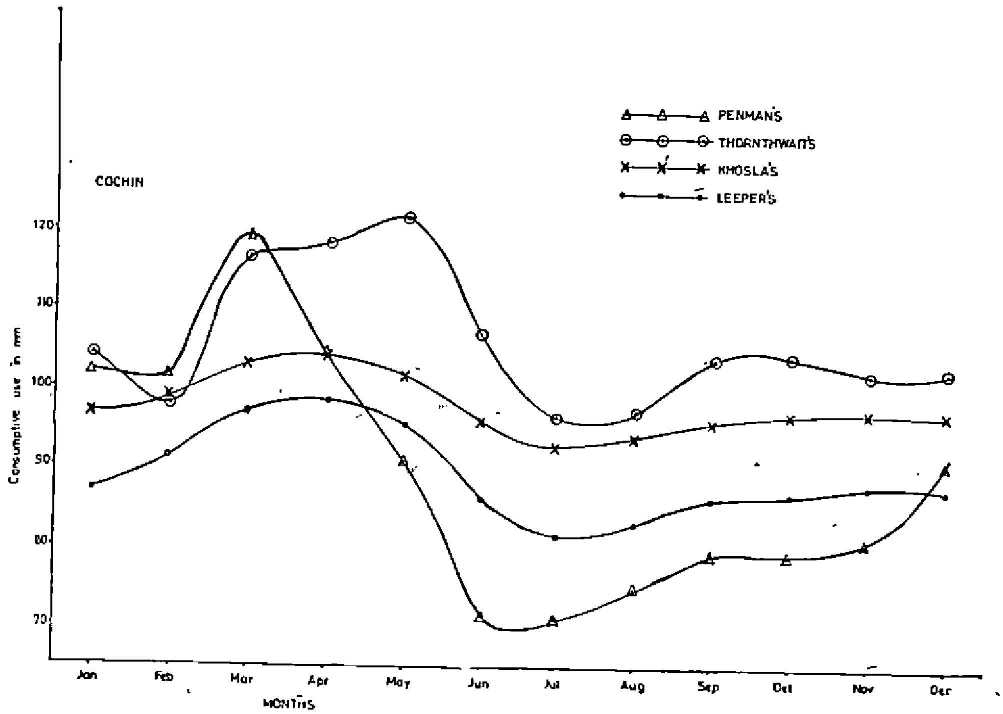

FIG 3 CONSUMPTIVE USE OF COCONUT

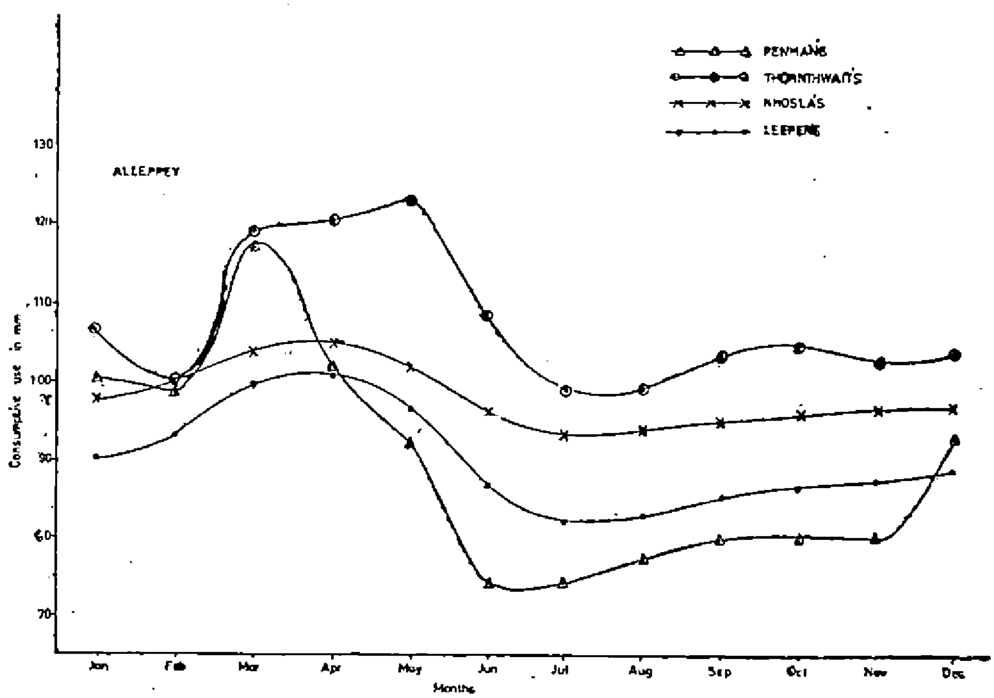

FIG 4 CONSUMPTIVE USE OF COCONUT

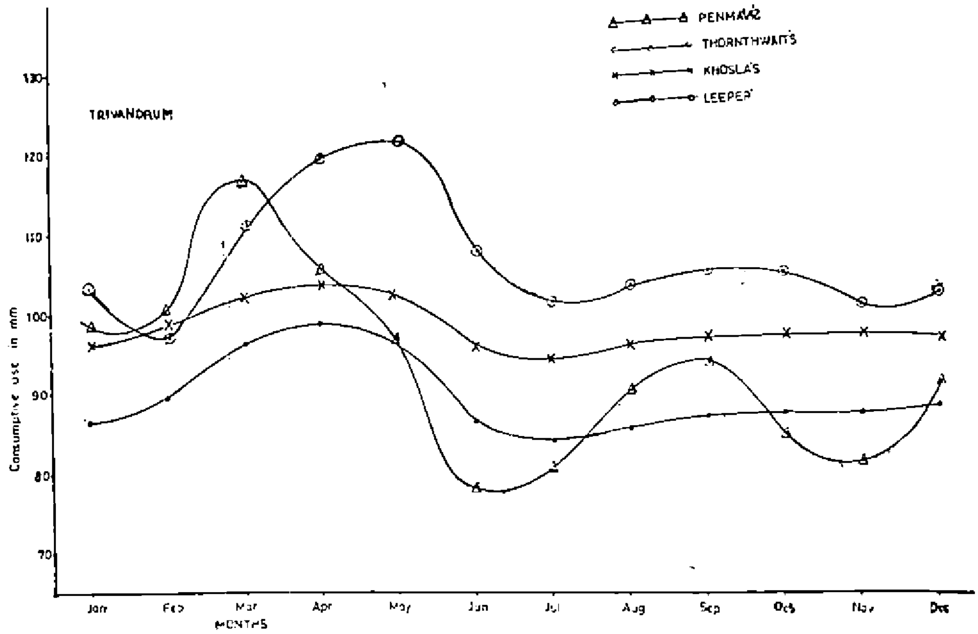

FIG 5 CONSUMPTIVE USE OF COCONUT

ment with the atmospheric demand for evapotranspiration loss of water with the change of seasons. The result of Penman's method was hence used for computations of effective rainfall in this study.

The mean monthly rainfall, effective rainfall in coconut based land use and consumptive use of coconut for the different stations are presented in Figs. 6–10. The effective rainfall was found to vary from 42% (Trivandrum) to 22% (Calicut) of mean annual rainfall. The mean seasonal rainfall, effective rainfall and effective rainfall as a percentage of the seasonal rainfall are presented in Table 3. On an average for the state as a whole, the effective rainfall with respect to coconut during the SW monsoon season (June–September) was of the order of 22% of the seasonal rainfall. The effective rainfall was of the order of 41%, 85% and 48% during the NE monsoon (October–December), Winter (January–February) and hot weather period (March-May), respectively.

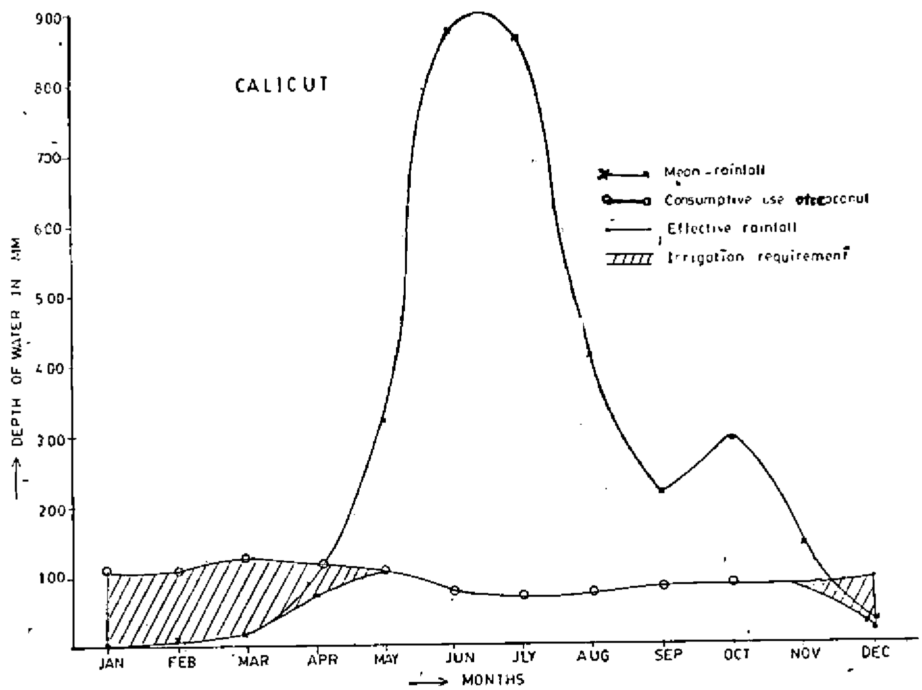

FIG:6. MEAN RAINFALL, CONSUMPTIVE USE AND EFFECTIVE RAINFALL

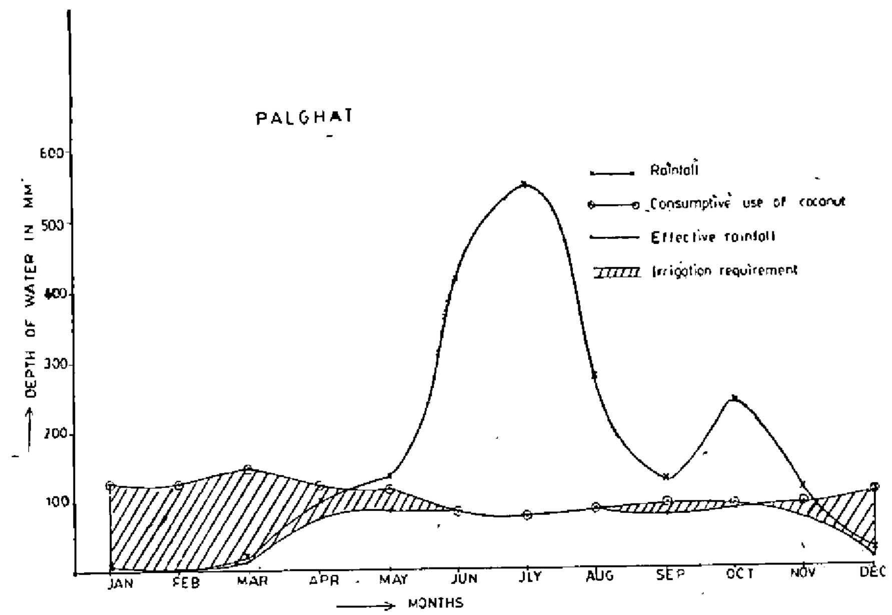

FIG.7 MEAN RAINFALL, CONSUMPTIVE USE AND EFFECTIVE RAINFALL

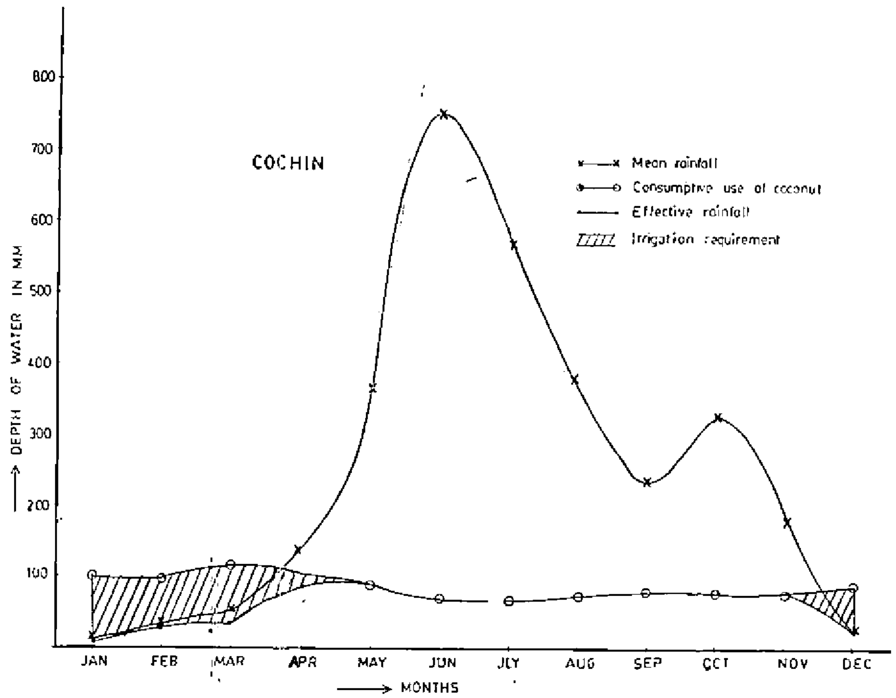

FIG.8. MEAN RAINFALL, CONSUMPTIVE USE AND EFFECTIVE RAINFALL.

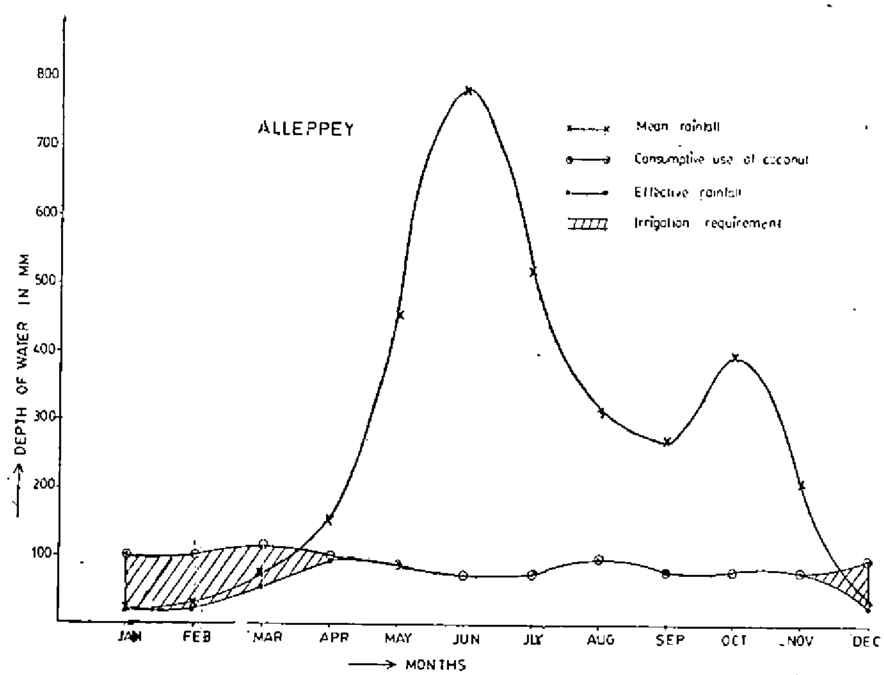

FIG.9. MEAN RAINFALL, CONSUMPTIVE USE AND EFFECTIVE RAINFALL

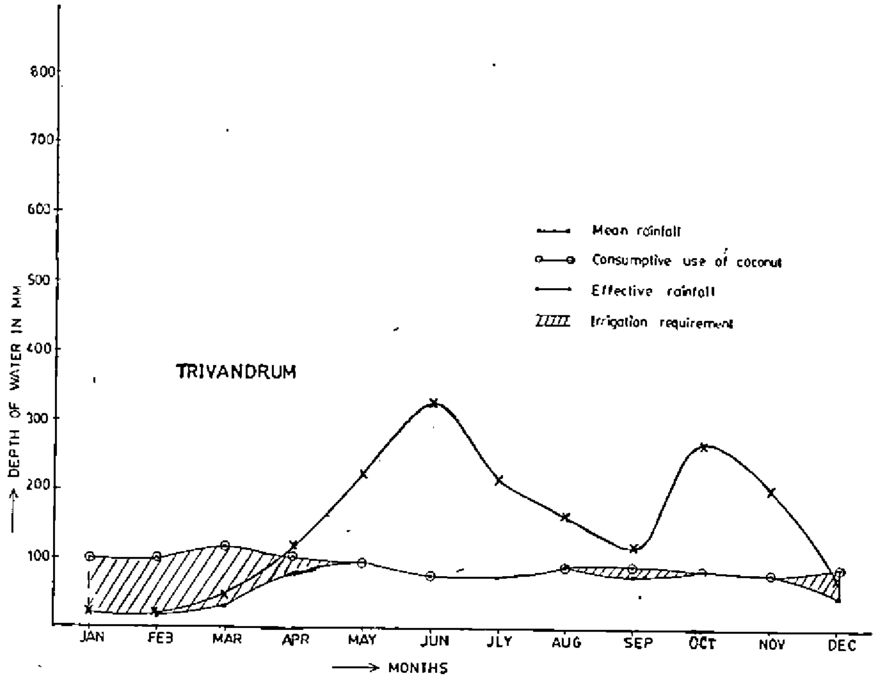

FIG 10 MEAN RAINFALL, CONSUMPTIVE USE AND EFFECTIVE RAINFALL

Acknowledgement

The authors are thankful to Dr. V. K. Vamadevan for encouraging discussions for the study. We wish to show our gratitude to Dr. P. Basak, Executive Director-i/c, Centre for Water Resources Development and Management for his keen interest in agrometeorological studies.

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Discussion

O. P. Bishnoi (HAU, Hisar): 1. The effective rainfall may be computed at different locations for different water holding capacity of the root zone of different crops.

2. Why not you use actual ET values with soil moisture measurement data than using consumptive use from climatological methods because the evaporative demand of atmosphere and the AET are quite different?

S. A. Saseendran: The suggestions are appreciated. A detailed study will be taken up in the future based on the suggestions.

M. R. C. Pillai (KAU, Vellayani): Has the contribution of ground water table been accounted in this study?

S. A. Saseendran: Contribution of ground water or effect of ground water fluctuation on rainfall acceptability of the soil was taken care of indirectly in the method of computations of effective rainfall (USDA, SCS 1867).

Relative degradation of chlorophyll content in black pepper (*Piper nigrum L.*) varieties during moisture stress

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ABSTRACT

The percentage degradation of chlorophyll in moisture stressed plants as that of the control was assessed in seven pepper varieties. The varieties were found to exhibit significant difference in the degradation of chlorophyll 'a' which is the prime pigment that donates energy directly to the photosynthetic reaction. The variety Kottanadan showed significantly less degradation. (19.38 per cent) as compared to the other varieties studied. Panniyur–1 was also found to be on par with Kottanadan (20.58 per cent). With regard to total chlorophyll content, Arakluamunda showed the least reduction (20.71 per cent) which was on par with Kottanadan (22.26 per cent), Panniyur–1 (22.28 per cent) and Punjarmunda (29.95 per cent). However, there was no significant difference with respect to chlorophyll 'b' pigment.

Introduction

Plants exhibit various physiological and biochemical changes in response to moisture stress. The specific characters that enable the plant to withstand drought should be identified and such characters utilised for efficient screening of drought resistant varieties. It hs been reported that extremity of drought, affect the plant carbohydrate composition directly and that certain carbohydrates might be involved in drought tolerance (Vaadia *et al.*, 1962). One of the selected constituents associated with the synthesis of carbohydrate content in plants is chlorophyll. The severity of drought stress primarly affects the photosynthetic efficiency of plant (Schneider and Childers, 1941 Brix, 1961). Though all the chlorophyll pigments participate fundamentally in photosynthesis, it has been suggested that chlorophyll 'a' is the only pigment that donates energy directly to the photosynthetic reaction. The other pigments transfer their absorbed energy to Chlorophyll-a (Davies *et al.*, 1964). Mathew and Ramadasan (1973) indicated that chlorophyll stability is an ideal indicator of drought resistance with reference to coconut. In the present investigation, the relative degradation of chlorophyll pigments in 7 cultivars of black pepper during moisture stress was assessed.

Meterials and Methods

Three-year-old vines of black pepper *(Piper nigrum, L)* varieties Panniyur–1, Narayakkodi, Karimunda, Kuthiravally, Kottanadan, Arakulamunda and Punjaramunda grown in the interspaces of 40-year-old coconut palms of the Regional Agricultural Research Station, Pilicode, Kerala were utilised for the investigation. Three uniform plants per variety were selected at random and subjected to sustained moisture stress for a period of about 90 days by with holding irrigation. The nonstressed plants which represented the control treatment were maintained by regularly irrigating them with uniform quantity of water. Sampling of leaves was done by selecting the first two leaves of the fruited twig arising from the middle portion of the plant. The samples so collected from each variety were further resampled into three groups and chlorophyll estimation carried out separately. The mean value of the three observations were treated as a replication and three such replication were considered for the analysis of variance.

The leaves ware collected and kept in between ice pack to minimise chlorophyll degradation. The middle portion of the leaf blade was used to avoid possible variations of chlorophyll within the leaf. The chlorophyll content was estimated using the method of Arnon (1949). Chlorophyll was extracted from the leaves by homogenizing 0.10 g fresh blade tissue in 20 ml of cold (2°C) 80 per cent acetone. After homogenization, it was filtered into test tubes covered with black paper and stored at 1°C to avoid possible degradation of chlorophyll. The density of chlorophyll in the extracts was determined at two wave lengths, 645 and 663 nm in Spectronic-20. The formulae for determining the concentration of chlorophyll–a and chlorophyll-b in mg/g dry weight was based on the absorbancy index values given by Mac Kinney (1941).

The moisture stress was monitored by assessing the plant water status using relative water content.

Results and Discussion

Table 1 gives the relative water content (%) in different varieties of black pepper under control and stress situations. It can be seen that the percentage

Table 1: Relative water content (%) in different varieties of black pepper under controlled and stress situations.

Variety	RWC		
	Controlled	Stress	% Reduction
Narayakkodi	77.84	52.56	32.48
Karimunda	69.68	45.31	34.97
Kuthiravally	71.71	52.15	27.28
Arakulamunda	72.48	52.05	28.19
Punjarmunda	81:72	61.14	25.18
Kottanadan	79.39	65.43	17.58
Panniyur–1	80.02	62.14	22.34

reduction in relative water content (R W C) was high in Karimunda (34.97) followed by Narayakkodi (32.48) while less in Kottanadan (17.58). The percentage reduction in chlorophyll pigments under moisture stress is given in Table 2.

Table 2: Percentage reduction in chlorophyll pigments upon indnction of moisture stress.

Variety	Chlorophyll-a	Chlorophyll-b	Total Chlorophyll
Panniyur-1	20.58	23.45	22.28
	(26.98)	(28.96)	(28.17)
Narayakkodi	33.97	24.57	30.31
	(35.65)	(29.71)	(33.41)
Karimunda	44.39	39.98	42.12
	(41.78)	(39.22)	(40.47)
Kuthiravally	31.20	38.57	37.14
	(33.96)	(38.39)	(37.55)
Kottanadan	19.38	24.08	22.26
	(26.12)	(29.39)	(28.15)
Arakulamunda	25.71	16.01	20.71
	(30.47)	(23.59)	(27.07)
Punjarmunda	27.67	24.33	25.95
	(31.74)	29.55)	(30.63)
S. Em±	2.76	3.80	2.41
C. D. at 1%	8.51	NS	7.42

Transformed values in paranthesis

The variety Kottanadan showed superiority over other varieties in withstanding stress situation by lesser degradation of the chlorophyll pigment-a (19.83) when compared to that of Narayakkodi (33.97) and Karimunda (44.39). The varieties did not differ significantly with respect to the degradation of the chlorophyll pigment-b. However, Arakulamunda showed the least reduction (16.01 per cent) followed by Panniyur-1 and Kottanadan (23.45 and 24.08 respectively). Karimunda exhibited the maximum degradation of the pigment, 39.98 per cent, followed by Kuthiravally with 38.57 per cent.

With regard to the reduction in total chlorophyll, it was observed that the variety Arakulamunda showed the least reduction (20.71 per cent) followed by Kottanadan (22.26 per cent). These varieties were found to be significantly superior to Karimunda with 42.12 per cent and Kuthiravally with 37.14 per cent which showed the highest degradation from among the varieties studied. The other varieties viz., Panniyur-1, Punjarmunda and Narayakkodi were found to be on par with Arakulamunda.

The chlorophyll content in the different varieties of black pepper was found to decrease upon induction of moisture stress. On a similar observation in corn, Virgin (1965) and Maranville and Paulsen (1970) visualised that the effect of moisture stress was on protoporphyrin molecule which is the prosthetic group of chlorophyll-a, rather than directly on chlorophyll-b. The above view has further been elucidated with the reported impairment in the uptake process during stress which limits the availability of certain elements like calcium, magnesium, iron etc. in which magnesium is an essential component of protoporphyrin molecule system. The observation in the present study also confirms the above finding since the break down of the chlorophyll-a was found to be more pronounced as compared to chlorophll-b pigment, which ranged from 19.38 to 44.39 per cent. That in three of the varieties studied pigment b registered a higher degree of degradation do not seem to be antithetic to the above because of the fact that the difference was only marginal and also that in such situations the stress effect may be acting on the chlorophyll-b already present in the leaf tissue. It is worth recalling the report of Albert *et al.* (1977) on the oxidative break down of chloroplast pigments during moisture stress. The loss of chlorophyll-a is very vital and might lead to the decreased rate of photosynthesis during moisture stress since it is the prime pigment that donates energy directly for photosynthetic reaction. The other pigments involved in this reaction are known to transfer their absorbed energy to chlorophyll-a (Davis *et al.*, 1964).

The reduction in total chlorophyll content in the moisture stressed leaves is in conformity with the results of Umarov *et al.* (1973) where a decreased chlorophyll content was noticed in depleted soil moisture situation. It may be possible that the reduction in total chlorophyll content may also possibly be due to the impairment in the activity of cytochrome oxidase, an iron perphyrin enzymes which regulates the chlorophyll synthesis. The reported decrease in the activity of other enzymes viz.,Peroxidase and Catalase during moisture stress by Albert *et al.* (1977) strongly favours the view of the possible enzyme inactivation.

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Discussion

R. C. Mandal (NRCC, Puttur): 1. Is it indicative that Kottanadan and Panniyur-1 varieties are drought tolerant.

2. Kottanadan is likely to be tolerant, but 'Panniyur-1' may not

Shyam S. Kurup : 1. This particular aspect of chlorophyll stability is only a part of many specific reactions that take place in the plant system during moisture stress. This has already been confirmed as a drought resistance character.

2. This study gave a positive indication in both Kottanadan and Panniyur-1.

Seasonal variation in the population of the diazotroph, Azospirillum

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ABSTRACT

The population of *Azospirillum* in the root environment of black pepper during the rainy and summer seasons was enumerated using the MPN technique. During the summer season, their population was considerably reduced. Among the different factors influencing the population of *Azospirillum*, soil moisture may be a predominant one. Hence to study the effect of soil moisture, an *in vitro* experiment was also conducted.

Introduction

In recent years, the associative N_2 fixing bacteria particularly the *Azospirillum* is gaining greater importance in the agricultural ecosystem because of their association with the roots of grasses and cereals (Uan Berkum and Bohlool, 1980; Neyra and Dobereiner, 1977). Black pepper, the most important spice crop of Kerala was believed to have no potential for biological nitrogen fixation till recently. This concept was thrashed down by the discovery that *Azospirillum* harbour the root environment of black pepper in large numbers (Govindan and Purushothaman, 1985) and that inoculation of pepper cuttings with the microbe enhances rooting and improves shoot and root growth (Govindan and Chandy, 1985). The survival of *Azospirillum* biocoenosis in different seasons has not been studied. Hence, a preliminary study was carried out to find out the seasonal variations in the population of *Azospirillum*.

Meterials and Methods

Six year old black pepper *(Piper nigrum* L.*)* vines growing in the degraded oxisols at the Regional Agricultural Research Station, Pilicode was selected for the study. Samples were collected during the rainy season (July 1986) and the summer (February 1987). The population of total bacteria and total diazotrophs in the rhizosphere were enumerated. Total bacteria was estimated using the nutrient glucose agar. Total diazotroph was enumerated following the procedure of Watanabe and Barraquio (1979).

The MPN technique was used for enumeration of *Azospirillum* employing the semisolid malate medium in test tubes. Population of *Azopirillum* in the histosphere, rhizoplane, rhizosphere and non rhizosphere soil were enumerated.

200 gram of sieved garden soil were incubated at different levels of soil moisture (adjusted using sterile distilled water). Malic acid (@ 1% level) was also added. The sample were drawn after 7 days of incubation and the population of *Azospirillum* was enumerated.

Results and Discussions

The results reveal that population of *Azospirillum* was more in the rainy season than in the summer period (Table 1). However, its influence was more in the rhizosphere and non rhizophere soil. In rhizoplane and histosphere the seasonal variation was comparatively less. The population of total bacteria and diazotroph was also high during the rainy season. The population of total bacteria was 45.08 x 10^6 during July while it was 10.19 x 10^6 during February. Similarly, diazotrophs recorded 16.99 x 10^4 and 3.49 x 10^4 during July and February, respectively. An interesting observation was that *Azospirillum* constituted 21.42% of the total diazotrophs in July and 28.22% in February. It may be due to its inherent resistance to adverse conditions. Formation of cyst (Lamm and Neyra, 1981) may also help the bacteria to tide over such situations. The net influence created by season is not simple, but compounded by rainfall, temperature, crop remains, direct and indirect effect of plant roots etc. The climatic factors may in part operate indirectly through the surface vegetation which is the source of the carbonaceous nutrients reaching the microflora as root excretions, sloughed off subterranean tissues or as crop debris, whereas the alterations in moisture and temperature influence the bacteria directly (Alexander, 1981).

Table 1. Seasonal variation in the population of *Azospirillum* in the root environment of black pepper

Particulars	Period		% reduction
	July	February	
Surface soil in the basin*	0.75	0.0825	89.00
Rhizosphere soil*	3.64	0.963	73.54
Rhizoplane**	47.00	40.510	13.81
Histosphere**	23.31	21.080	9.56

Population expressed as $10^4.g^{-1}$ soil on dry wt. basis.

Population expressed as $10^4.g^{-1}$ root tissue on dry wt. basis

The study conducted to determine the influence of moisture on the population of *Azospirillum* revealed that 50.4% to 73.5% of soil moisture was most favourable for the growth of *Azospirillum* (Table 2). Considerable reduction in the population was observed at 27.2% and 15.6% moisture level indicating the role of moisture in deciding the bacterial population. This is in conformity with the report that maximum bacterial density is found in regions of fairly high moisture content and that the optimum level for the activating of aerobic bacteria is at 50 to

75% of the soil moisture holding capacity (Alexander, 1981). From the present study, it can be expected that irrigation helps to enhance (the population of the diazotroph, *Azospirillum* which exerts a positive influence in plant growth by way of nitrogen fixation, production of phytohormones and enhancing nutrient uptake.

Table 2. Effect of different levels of soil moisture on *Azospirillum*

Moisture level	Population x 10^6
15.6%	0.872
27.2%	1.341
50.4%	4.511
73.5%	4.610

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Discussion

G. S. L. H. V. Prasada Rao (RARS, Pilicode): Is it sufficient to study the influence of season on *Azospirillum* with two months data.

Govindan, M. No. To fully understand the phenomena, samples have to be drawn at monthly intervals for a long time.

SESSION II

Phytoclimatology

Chairman : Dr. V. RANGANATHAN

Rapporteurs : Dr. P. K. N. NAMBIAR

Shri R. C. DUBEY

Influence of soil texture on the thermal regime of coconut root zone

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ABSTRACT

The soil temperatures in the coconut root zone in lateritic loam and sandy loam were compared based on the data collected at Pilicode and Nileswar during 1983-84. The mean annual soil temperature in the coconut root zone was higher (30.1–32.7°C) in sandy loam than in loam (27.9-30.6°C). Though the root zone temperature was high during summer in both the soils, the magnitude of difference between the two soils was high (1.9–5.9°C) in the post-monsoon season and low (0.9-2.0°C) in the South West monsoon. A marked difference in the thermal regime of coconut root zone was seen during the summer months of 1983 (drought year) and 1984 (normal year) in the same soil. Under mulched and exposed conditions in the loam soil, the difference in coconut root zone temperature was about 1°C in summer and about 0.3°C in the South West monsoon. The coconut root zone temperature in the loam soil was 28.6°C under coconut husk mulch and 29.2°C under no mulch at both 40 and 60 cm depths.

Introduction

The effect of soil temperature on root development has been studied by several workers (Shaw and Buchele, 1957; Burrows, 1963; and Mederski and Jones, 1963) in annual crops. However, such studies are lacking in perennial crops like coconut. Hence an attempt has been made in this study to understand the variations in soil temperature in the root zone of coconut grown in lateritic loam and sandy loam soils at the Regional Agricultural Research Station, Pilicode during the years 1983 and 1984.

Materials and Methods

Soil thermometers were installed in the coconut basins at a distance of 1 m from the bole of coconut palms in loam and sandy loam soils. Another set of soil thermometers were installed in the open in sandy loam soil for comparison. The soil temperatures were recorded at 2.5, 10, 40, 60 and 70 cm depths from the surface. The observations soil temperature were recorded daily twice in the morning (7–25 a. m.) as well as in the afternoon (2-25 p. m.) for two years 1983 (drought year) and 1984 (normal year). The soil temperature was also recorded in the effective root zone of coconut palm under mulched (coconut husk) conditions for comparison in the loam soil. The data on soil temperature were recorded daily

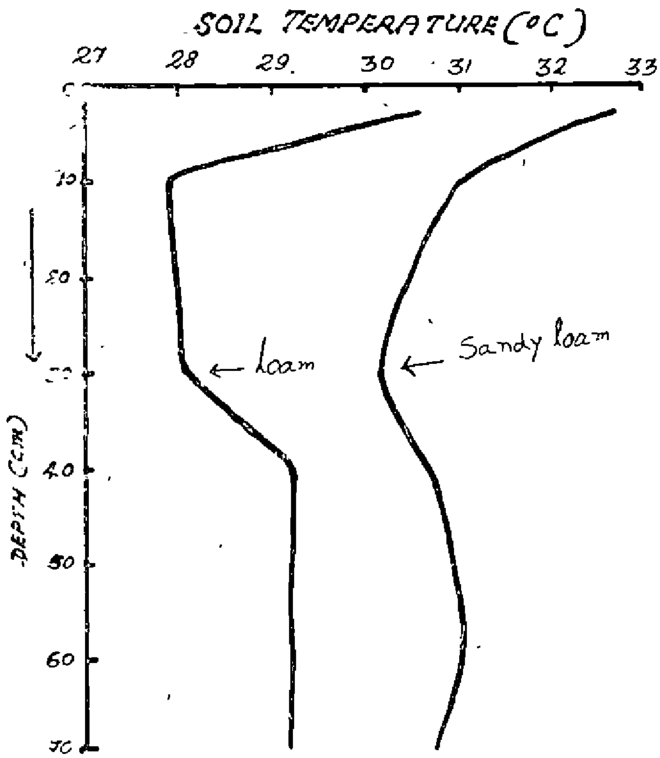
Results and Discussion

The data on the annual soil temperature (°C) in the coconut root zone and in the open in sandy loam soil during 1983-84 are given in Table I. It can be seen that the difference was conspicuous (3.0.-3.4°C) in the surface soil while it was not so in the deeper layers (30-70 cm). The range in soil temperature was high (32.8-36.1°C) in open and low (30.1-32.7°C) in the coconut root zone.

Table 1: Mean annual soil temperature (°C) in coconut root zone and open in sandy loam soils during 1983-84

Depth (cm)	Open (°C)	Coconut (°C)	Difference (°C)
2.5	36.1	32.7	3.4
10	34.0	31.0	3.0
30	32.3	30.1	2.2
40	32.8	30.6	2.2
60	33.0	30.9	2.1
70	32.8	30.6	2.2

FIG.: MEAN ANNUAL SOIL TEMPERATURE (°C) IN COCONUT ROOT ZONE IN LOAM AND SANDY LOAM.



The mean annual soil temperatures (°C) in the coconut root zone in loam and sandy loam soils during March 1983 to February 1984 are depicted in Fig. I. The mean annual soil temperature in coconut root zone wes higher (30.1-32.7 C) in sandy loam than in loam (27.9-30.6°C). The soil temperature inversion was noticed (temperature increases with depth) beyond 10 cm depth in the loam but onlp beyond 30 cm depth in the sandy loam. This was probably due to the presence of more roots in the loam at 10 cm depth when compared to that of sandy loam.

Table 2 gives the seasonal thermal regime (°C) of coconut root zone in two different soils. It can be seen that the root zone temperature was high throughout the year under sandy loam. A marked variation in the thermal regime of coconut root zone was seen from one season to the other. Though the root zone temperature was high during the summer in both the soils, the difference between the two soils was high (1.9–5.9°C) in the post-monsoon (October-November) period and low (0.9-2.0°C) in the South west monsoon. This was probably due to sudden depletion of moisture in the surface soil in the sandy loam immediately after the cessation of monsonal rains.

The thermal regime (°C) of coconut root zone during the summer under two different soils in two typical years, 1983 (drought year) and 1984 (normal year) are presented in Table 3. It is seen that the root zone temperature and its range were higher (30.1-34.1°C in the loam and 32.4-37.3°C in the sandy loam) in 1983 than in 1984. The difference between the two typical years varied from 0.3 to 3.2°C in the loam and from 0.5 to 4.1°C in the sandy loam. Even under mulched conditions, the difference in coconut root zone temperature was 0.5 to 0.8°C (Table 4).

The data on the mean annual thermal regime (°C) of coconut root zone under mulch (coconut husk) and exposed situations during 1983-84 in loam soils all furnished in Table 5. It can be noted that the root zone temperature was comparatively low under mulched conditions and the difference was 0.4 to 0 6°C.

Table 6 summarises the seasonal thermal regime (°C) in the coconut root zone under mulched and exposed conditions during 1983-84 in loam soil. The difference in coconut root zone temperature between mulch and no mulch was relatively more during summer than is the other seasons.

High soil temperatures (35-38°C) in the coconut root zone under unirrigated conditions may hamper root development. Though the mean soil temperature during the summer was around 34°C and 37°C in the loam and sandy loam soils, respectively, the diurnal fluctuations were very high shooting sometimes upto 60°C in the afternoon hours. Cooper (1973) revealed that the root temperature above 33°C drastically decreased the shoot dry weight in maize. Studies of this nature will be useful to understand the effect of soil temperature on the development of coconut roots.

Table 2. Seasonal thermal regime (°C) of coconut root zone in two differerent soils during 1983–84

Depth (cm)	Summer			SW monsoon			Post monsoon			Winter		
	SL	L	Diff.	SL	L	Diff.	SL	L	Diff.	SL	L	Diff.
10	32.4	30.1	2.3	29.2	27.2	2.0	32.4	26 5	5.9	31.1	27.7	3.4
30	32.4	30.3	2.1	28.8	27.7	1.1	30.4	26.8	3.6	29.3	27.4	1.9
40	32.9	31.4	1.5	29.5	28.6	0.9	30.4	28.0	2.4	30.6	28.7	1.9
60	32.6	31.1	1.5	30.0	28.8	1.2	30.6	28.0	2.6	30.5	28.7	1.8
70	32.8	30.9	1 9	29.9	28.9	1.0	30.0	28.1	1.9	30.0	28.8	1.2

SL—Sandy loam; L—Loam

Table 3. Thermal regime (°C) of coconut root zone during summer under two different soils in typical years (1983 and 1984)

Depth (cm)	Sandy loam			Loam		
	1983	1984	Diff.	1983	1984	Diff.
2.5	37.3	33.2	4.1	34.1	30.9	3.2
10	32.6	32.1	0.5	30.1	29.2	0.9
30	32.4	30.9	1.5	30.3	29.4	0.9
40	32.9	31.5	1.4	31.4	30.7	0.7
60	32.6	31.9	0.7	31.1	30.5	0.6
70	32.8	31.4	1.4	30.9	30.6	0.3

Table 4. Seasonal thermal regime (°C) in coconut root zone under mulch and no mulch during 1983-84 in loam soil

Depth (cm)	Summer			SW monsoon			Post monsoon			Winter		
	NM	M	Diff.	NM	M	Diff.	NM	M	Diff.	NM	M	Diff.
10	30.1	29.8	0.3	27.2	27.1	0.1	26.5	26.1	0.4	27.7	26.8	0.9
40	31.4	30.4	1.0	28.6	28.4	0.2	28.0	27.4	0.6	28.7	27.8	0.9
60	31.1	30.3	0.8	28 8	28.5	0.3	28.0	27.5	0.5	28.7	28.0	0.7

NM—No mulch, M—Mulched with coconut husk.

Table 5. Thermal regime (°C) in coconut root zone during summer (March-May) under mulch (coconut husk) in 1983 and 1984

Depth (cm)	1983	1984	Difference (°C)
10	29.8	29.0	0.8
40	30.4	29.8	0.6
60	30,3	29.8	0.5

Table 6. Thermal regime (°C) in coconut root zone under mulched and exposed situations

Depth (cm)	No mulch (°C)	Coconut husk (°C)	Difference (°C)
10	27.9	27.5	0.4
40	29.2	28.6	0.6
60	29.2	28.6	0.6

Acknowledgement

The authors are grateful to the Director of Research, Kerala Agricultural University tor providing necessary facilities during the course of this study.

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Discussion

Mohamed Kunju (RARS, Kumarakom):

1. Did you make any observation on water table in different soil types and correlate it with soil temperature?
2. In all cases, there is a reduction in the thermal values when the depth increases.

G. S. L. H. V. Prasada Rao: 1. No, the impact of water table on soil temperature does not arise at the experimental site as the ground water table is very low.

2. If you look the variations in soil temperature closely, you will not find conspicuous reduction in temperature till 60 cm depth.

P. S. Sreenivasan (Jyotinagar, Palghat): Have you tried different types of mulches other than coconut husk.

G. S. L. H. V. Prasada Rao: The soil temperatures have been recorded under tree leaf mulch also. No significant variation in temperature in the effective root zone was noticed when compared to the coconut husk mulch.

R. C. Mandal (NRCC, Puttur): 1. Studies on sandy loam and sandy soil during the last two years showed marginal variation in soil moisture.

2. Weather parameter studies should be correlated with the end-product either yield or growth parameters, otherwise the studies are not complete.

G. S. L. H. V. Prasada Rao: Your suggestions will be taken into consideration in future studies.

Vertical profiles of air temperature and vapour pressure in coconut gardens and open space

G. S. L. H. V. PRASADA RAO and R. R. NAIR

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Kerala Agricultural University,
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ABSTRACT

The mean monthly vertical profile of air temperature in December 1986 showed that the air temperature decreased with height in the open whereas no definite pattern was seen inside the the coconut garden due to its canopy structure. The difference in temperature between the open and inside the coconut garden was high (1.0°C) at 30 cm above the ground level and low (0.1°C) at 7m height. The differences were high in the afternoon when compared to the morning hours. The vapour pressure was high inside the crop and tended to increase in the afternoon. Higher amplitudes in air temperature were noticed at the lower levels when compared to the canopy level inside the coconut garden. The vertical profiles of air temperature at different time intervals during the day time on 5-2-1987 (clear day) one also presented.

Introduction

The success of any crop association in coconut gardens depends upon the phytoclimate produced by coconut palms due to its structure and stand. The canopy of coconut palm acts as a screen to the incoming solar radiation and develops its own climate. The India Meteorological Department, Government of India has studied the variations in microclimate within the annual crops and is the open at different Agricultural Research Stations in India. A strong inversion with great stability of the air layers is developed during the day inside the sugarcane field in contrast to the turbulent or unstable conditions in the open (Anon 1957). No such studies are seen in plantation crops like coconut. For understanding the phytoclimate in coconut, an attempt has been made to study the vertical profiles of air temperature and vapour pressure in coconut gardens.

Materials and Methods

A field experiment was taken up at the Regional Agricultural Research Station, Pilicode in order to study the variations in air temperature and vapour pressure inside the coconut garden and in the open. The crop stand had an average height of 7 m and the palms were 12 year-old. The plant density was 180 per ha (7.5 m x 7.5 m)

An Assmann psychrometer was used to record dry and wet bulb temperatures at different heights inside the crop and in the open for comparison. The observations were taken daily twice in the morning (7-25 a.m) as well as in the afternoon (2-25 pm) during December, 1986. Semi-diurnal observations on air temperature were also taken on 5-2-1987 to understand the vertical profiles at different time intervals during the day time.

Results and Discussion

The vertical profiles of air temperature and vapour pressure in the coconut garden and in the open are given in Tables 1, 2 and 3 during December 1986. The mean monthly air temperature decreased (27.6–26.8°C) with height in the open while on definite pattern was seen inside the coconut garden due to its canopy architexture. The difference in air temperature between the open and inside the coconut garden was highet at the ground level than at the crown level. The differences were marked in the afternoon (2–25 pm). The same vertical profile in air temperature was maintained (decreasing with height) in the afternoon but differed in the morning in the open space. Interestingly, the air temperature in coconut garden was high in the morning.

Table 1 Vertical profile of mean air temperature and vapour pressure in coconut garden and open during December, 1986

Height (cm)	Temperature (°C)			Vapour pressure (mm)		
	Open	Coconut	Difference	Open	Coconut	Difference
30	27.6	26.6	1.0	19.16	19.62	0.46
60	27.3	26.6	1·0	18.98	19.49	0.51
120	27.1	26.7	0.4	18.82	19.31	0.49
240	26.9	26.7	0.2	18.75	19.10	0.35
360	26.9	26.7	0.2	18.59	19.10	0.51
540	26.8	26.6	0.2	18.83	19.24	0.41
660	26.8	26.7	0.1	18.94	19.28	0.34

Table 2. Vertical profile of air temperature and vapour pressure in coconut garden and open at 7.25 a.m. during December, 1986

Height (cm)	Temperature (°C)			Vapour pressure (mm)		
	Open	Coconut	Difference	Open	Coconut	Difference
30	23.4	23.4	0.0	18.57	18.78	0.21
60	23.0	23.3	0.3	19.54	18.88	0.34
120	23.0	23.4	0.4	18.54	18.57	0.03
240	23.0	23.5	0.5	18.33	18.68	0.35
360	23.1	23.5	0.4	18.23	18.68	0.45
540	23.1	23.6	0.5	18.44	18.68	0.24
660	23.4	23.7	0.3	18.57	18.68	0.11

Though the vertical profile of vapour pressure decreased with height inside the coconut garden and the open, a second maxima was noticed after 120 cm height from the surface in both the cases. The second maxima of vapour pressure in the open may be due to the influence of surrounding coconut gardens. The vapour pressure was high inside the crop and tended to increase in the afternoon. This is probably due to high rate of transpiration in the afternoon hours.

Fig. 1a & 1b show the semi-diurnal variation of air temperature (°C) at different heights in the open and in the coconut gardens respectively. It can be

FIG: 1a: SEMI-DIURNAL VARIATION OF AIR TEMPERATURE (°C) AT DIFFERENT HEIGHTS IN THE OPEN ON 5.2.1987 (CLEAR DAY)

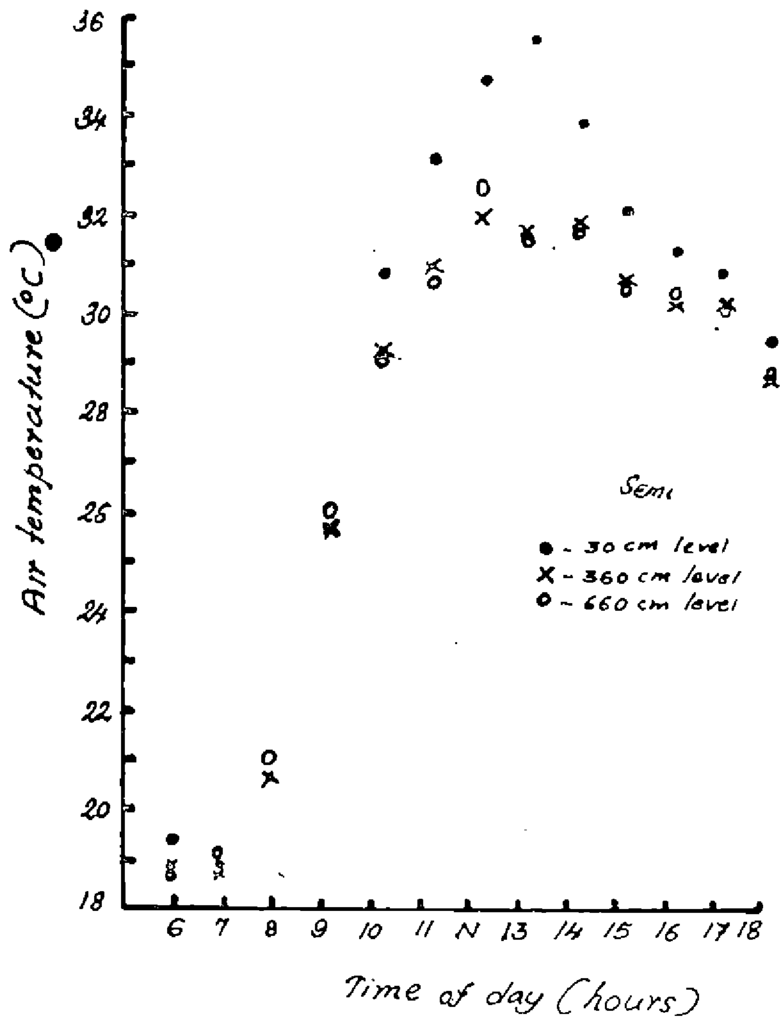


Table 3. Vertical profile of air temperature and vapour pressure in coconut gardens and open at 2.25 PM during December, 1985

Height (cm)	Temperature (°C)			Vapour pressure (mm)		
	Open	Coconut	Difference	Open	Coconut	Difference
30	31.8	29.8	2.0	19.75	20.46	0.71
60	31.5	29.9	1.6	19.42	20.10	0.68
120	31.2	30.0	1.2	19.09	20.05	0.96
240	30.8	29.8	1.0	19.16	16.51	0.35
360	30.6	29.8	0.8	18.95	19.51	0.56
542	30.4	29.5	0.9	19.22	19.80	0.58
660	30.3	29.7	0.6	19.10	19.87	0.77

FIG: 1 b. SEMI-DIURNAL VARIATION OF AIR TEMPERATURE (°C) AT DIFFERENT HEIGHTS IN COCONUT GARDEN ON 5.2.1987 (CLEAR DAY)

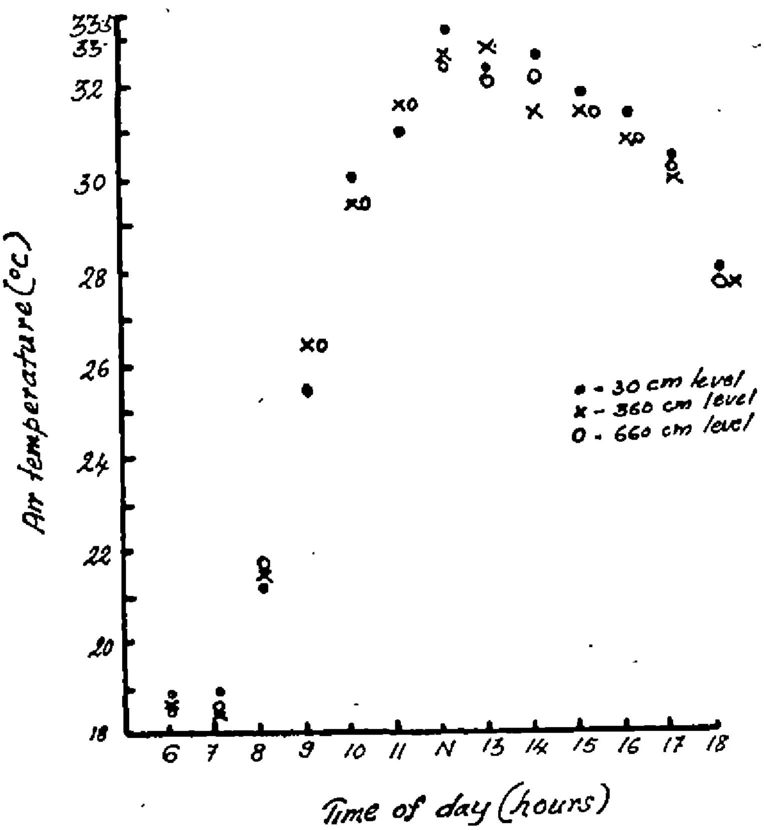


FIG. 2a. AIR TEMPERATURE PROFILE IN OPEN ON 5.2.1987

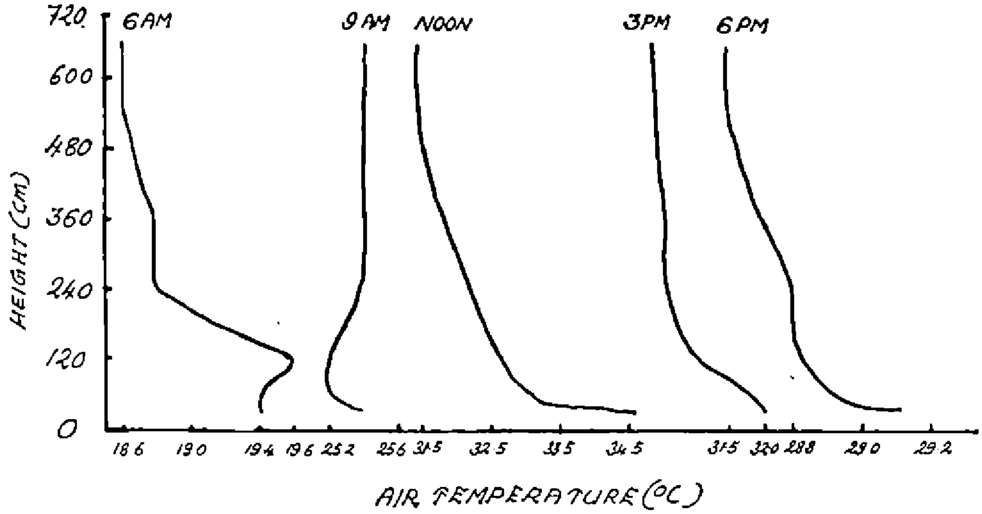
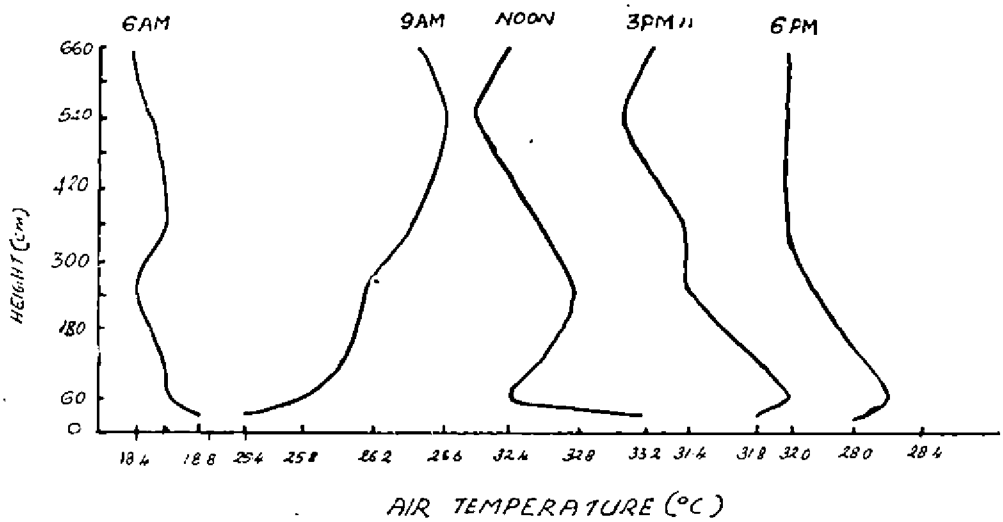


FIG 2b AIR TEMPERATURE PROFILE IN COCONUT ON 5.2.1987



seen that higher amplitudes in air temperature were noticed at the lower levels in the open as well as in the coconut gardens; but the magnitude of air temperature was high in the open.

The vertical profiles of air temperature at different time intervals during the day time on 5-2-87 in the open and in the coconut gardens are depicted in Figs 2 a and 2 b. It can be seen that air temperature in the open decreased with height when the time progressed from morning to evening except in the early morning hours (6-00 am). This was probably due to higher re-radiation cooling of the earth surface when compared to that of air layer just above the ground. In the coconut gardens such a definite pattern was not noticed. A complete air temperature inversion was noticed by 9-00 am inside the coconut garden which explains a quick rise in air temperature due to the presence of coconut leaves. By noon, there was a drastic decrease in air temperature from the ground leavel to 60 cm above the ground and then increased from 60 cm to 240 cm. A similar pattern was seen above the height of 240 cm. It shows that the middle whorl of crown acted as a surface. By evening, the temperatures were low at the ground level when compared to that of layer just above the ground and from there it decreased.

As these studies pinpoint the changes in phytoclimatic conditions with time, more and more studies of this nature must be taken up in all plantation crops.

Acknowledgement

The authors are grateful to the Director of Research, Kerala Agricultural University for providing necessary facilities to take up this study.

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Discussion

S. T. Nagaraj (UAS, Bangalore): Were the coconut palms in the garden of the same height, same age or of different, heights and ages.

G.S.L.H.V. Prasada Rao: The palms selected for the study were of the name age and height.

P. S. Sreenivasan (Jyothinagar, Palghat): Mention the location inside the coconut garden for making the observations on temperature profile.

G. S. L. H. V. Prasad Rao: In the middle of the coconut garden in N VI Block of R.A.R.S., Pilicode.

R. C. Dubey (I.M.D., Pune): While studying T & V. P. profiles, could you take wind profiles into consideration.

G.S.L.H.V. Prasada Rao: No

R. C. Mandal (NRCC, Puthur): 1. More data on temperature profile should be gathered at different periods.

2. Studies should be extended to multi-storeyed cropping and also cover-crops like *Mimosa*, Calapogonium etc. to gather more information.

G.S.L.H.V. Prasada Rao: I fully agree with your suggestions.

K. Subba Rao (A.U. Waltaire): Combining your two papers, is there an ideal condition in the atmosphere and soil that gives the maximum yield.

G.S.L.H.V. Prasada Rao: The authors have not studied this aspect.

SESSION III

Agrometeorological equivalents

Chairman : Dr. O. P. BISHNOI

Rapporteurs : Dr. (Mrs.) K. V. KASTURI BAI

Shri. N. N. RAMANKUTTY

Agrometeorology of productivity in tea in South India

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ABSTRACT

An equation for agroclimatic potential applicable to South Indian conditions is derived based on growth of tea plant as related to photosynthetic efficiency and weather parameters. A prediction value of around 50% is achieved by using agroclimatic potential of the previous month and that of the current month. The rest of prediction must come from crop husbandry and manuring practices which affect the per cent of total dry matter harvested as crop and availability of minerals.

Introduction

There were a number of attempts to correlate climatic parameters with productivity (Fisher, 1924; Wastson, 1963; Monteith, 1963; Carr, 1972) and also to develop classification systems of agroclimates (Miller, 1957; Thornthwaite, 1948; Sellers, 1967). The attempts so far made reveal that it is unlikely for any single meteorological factor to affect yield significantly. Since commercial crop is the culmination of a series of stages of growth differentiation and development, the first step should aim at establishing relation between growth of plant and climatic factors (Devanathan, 1975). Unfortunately all earlier works have centered on commercial yield and not on growth of plant. Keeping this in view, an attempt has been made for deriving an agroclimatic potential equation for estimating crop yield of tea.

Materials and Methods

Based on kinetics of photochemical reactions and theoritical considerations of the various factors that affect photosynthetic efficiency, Devenathan (1975) derived an equation of photoclimatic potential for crop.

$$\psi P = K f_t RS$$

Where ψP = Phytoclimatic potential

K = Constant for a particular crop or cultivar which includes transport mechanisms of CO_2 to mesophyll cells, transport resistance to water, photosynthetic sites per unit area, etc.

f_t = temperature coefficient of photosynthetic process. It is estimated from the measurements of Beldry, Buckel and Walker (1966) on the rate of photosynthesis on isolated chloroplasts under saturated light and high CO_2 concentration using labelled CO_2.

S = Sunshine hours/day above the limiting light saturation.

R = Rainfall in cm/month. It respresents the probability of the time the water supply system maintains the leaf water potential above the critical level (88% of the optimum level) during illumination. In a soil with unlimited water availability, the probability factor is related to rainfall and plant factors. The plant factors include water transport resistance within the plant and evapotranspiration required to dissipate heat. The plant and other factors are accounted by the constant, K, as mentioned earlier.

In tea, there is a time lag between the physiological function of tea bush and the vegetative harvest. It is about 5 weeks in the pruned year and 4 weeks in other years of the cycle (Devanathan, 1975). As such the climatic index of the previous month is generally correlated to the current month's harvest.

The equation as described above is found to predict monthly yield of tea fairly well in areas having a uniform distribution of monthly rainfall within a narrow range. The predictive value obtained in Malawi experimental plots in deep soils with water storage capacity of 80 cm under constant management and non-limiting fertilizer application is above 94%.

In non-ideal soil arising from extreme rainfall conditions, the excess rainfall above what the soil can accept is a waste. On the other hand, the water is drawn from the soil storage system during rainless months. A functional correction factor is therefore developed for non-ideal soils (Devanathan 1975).

$$\text{Correction factor} = \frac{F}{R}(1 - EXP(-R/F))$$

Where F is the finite storage capacity of the soil which is reported to be 80 cm for Malawi soils and 15 cm for Sri Lanka soils. The new equation gives the agroclimatic potential of area.

$$\psi A = f_t\, RS \times \frac{F}{R}(1 - EXP\,(-R/F))$$

Agroclimatic potential — Phytoclimatic potential — Soil correction factor

$$\therefore \quad \psi A = f_t\, F\,(1 - EXP\,(\frac{R}{F}))S$$

The predictive value up to 85% for monthly yield is obtained in Sri Lanka after introducing soil correction factor.

Under South Indian conditions, the agroclimatic potential as defined above fails to give meaningful prediction of monthly yields. The reasons are (i) extreme rainfall conditions and (ii) effect of atmospheric humidity and temperature on growth, besides the pruning and plucking practices, plant proection measures and manuring practices which are all tuned to get maximum benefits in the two growth periods (mid-March to mid-June; and mid-August to mid-November). For non-ideal,soils and weather conditions that prevail in South India, certain modifications are introduced and the proposed agroclimatic potential equation is as follows:

$$\psi A = Kf_t R (S+1) \quad \times \quad RT$$

(*Photosynthetic yield*) (*Growth index*)

$$\therefore \psi A = Kf_t R^2 (S+1) T$$

where A = Agroclimatic potential

K = Constant which includes plants factors as described earlier

f_t = the temperature coefficient of photosynthetic process (estimated from the work of Baldry, Buckel and Walker, 1966)

$$R = 1 - EXP\,(-(F_m + R_m)/F)$$

F_m is the actual soil water storage available at the end of the month, R_m rainfall in cm and F the effective water storage capacity of the soil F, is taken as 36 cm for 1 m depth of soil in Anamallais. It will vary with the water holding capacity of soils, effective root penetration and soil depth. F_m is calculated by deducting 6 cm for the loss by evapotranspiration after giving correction for return by dew from the previous month's F_m. The evapotranspirational loss, also, varies with yield, mean temperature and atmospheric humidity. F_m value is limited to effective water storage capacity. This gives a parameter for rainfall efficiency in maintaining leaf water potential at optimum value and (S+1). A correction is given to diffused light and unrecorded sunshine at the boundaries below light saturation value.

The first part of the equation, viz. f_t R (S+1) describes the conditions for getting photosynthetic yield. The second part of the equation gives correction for atmospheric humidity and mean temperature which determine the growth of plant in the current month.

R : The mean atmospheric humidity is related to the rainfall efficiency factor and hence it is expressed by the same functional relation as R in the first part of the equation.

T : Night temperature below 14°C retards growth and the probability of night temperature falling below 14°C is related to monthly mean temperature. Moreover day degrees above the optimum 12.5°C determine the rate of growth but the increase is exponential reaching a maximum at 25 to 30°C.

Taking both these factors, the temperature factor (T) on growth is expressed by a functional relationship:

$$T = 1 - EXP\left(\frac{12.5 - \text{monthly mean temp.}}{17.5}\right)$$

Results and Discussion

The simple and multiple correlation coefficients of yield against agroclimatic potential of current and previous months are given in table 1. The coefficients of multiple regressions are given in Table 2. The multiple regressions

Table 1: Simple and multiple correlation coefficiegt of yield with agroclimatic potential of previous and current month (for yields of two locations)

Year	Simple correlation coefficient (r)				Multiple correlation coefficient R	
	U AP		U AP			
	UPASI	Estate	UPASI	Estate	UPASI	Estate
1978	0.39	0.54	0.59*	0.61*	0.60*	0.67*
1979	0.43	0.47	0.47	0.62*	0.66*	0.68*
1980	0 52	0.56*	0.83**	0.52	0.88**	0.67*
1981	0.63*	0.51	0.62*	0.52	0.76**	0.62*
1982	0.43	0.52	0.62*	0.46	0.63*	0.65*

*, ** Significant at P: 0.05 and P: 0.01 respectively.

Note;- U AP and U AP denote agroclimatic potential of previous and current month respectively.

Table 2 Coefficients of multiple regression of yield (U) with agroclimatic potential of previous (X_1) and current (X_2) month

Year	UPASI				Estate			
	a	b_1	b_2	R	a	b_1	b_2	R
1978	2.59	1.43	6.12	0.60*	0.40	4.21	6.21	0.67*
1979	4 98	1.31	0.66	0.66*	2.14	2.00	3.52	0.68*
1980	1.23	2.55	6.39	0.88**	2.62	3.81	3.37	0.67*
1981	0.12	5.84	5.51	0.76**	1.52	4.52	4.52	0.62*
1982	0.49	2.66	10.59	0.63*	1.72	1.72	10.38	0.65*

*,** Significance at P=0.05 and P=0.01 respectively

Note: Multiple regression equation $Y=a+b_1 x 1=b_2 x 2$

Table 3: Crop distribution at two locations in different months (mean of 5 years, 1978-1982)

Monthly	% Crop	
	UPASI*	Estate**
January	6.5	8,7
February	4.3	5.9
March	5.6	8.6
April	10.5	11.4
May	13.0	11.5
June	8.6	9.2
July	6.2	3.7
August	5.6	3.5
September	7.5	5 8
October	13.6	12.3
November	8 7	7.9
December.	9.9	11.5

* Area of about 30 ha ** Area of about 125 ha

Table 4: Mean climatic factors for various months (mean of 5 years, 1978 to 1982)

Month	f_t	R	S	T
January	0.72	0.54	8.3	0.31
February	0.75	0.48	8.7	0.34
March	0.81	0.50	8.5	0.39
April	0 86	0.60	7.4	0.43
May	0.86	0.71	5.8	0.43
June	0.76	0.96	1.3	0.35
July	0·73	0.97	1.2	0.32
August	0.71	0.96	1.6	0.31
September	0.76	0.84	3.8	0.35
October	0.79	0.80	5.0	0.37
November	0.77	0.77	4.7	0.36
December	0.74	0.61	6.2	0.32

are significantly superior to simple correlattons. The prediction value with the multiple regressions varies between 38 to 77% with a probability of occurrence around 50%.

The rest of prediction comes from (i) pruning and plucking practices (ii) manuring practices and plant protection measures. Pruning effect the monthly yield in as much as a greater portion of dry mater goes in for wood and new growth in early months after pruning. The plucking practices influence the monthly yield as they aim at putting out one or two tiers of new foliage during lean months (lower per cent of total dry matter formed is taken as crop) and level plucking during the growth periods to exploit the favourable weather conditions. (higher per cent of dry matter formed recovered as crop). Tha plant protection measures effect the crop to varying extent depending on the efficiency of control measures in different periods of the year undertaken to combat seasonal pests and diseases. The manuring practices are turned to maintain higher availability of nutrients during growth periods. High fertilizer inputs in high yielding fields carry a higher soil concentration of nutrients during drought months and hence in these fields there is an increase in dry months crop (Table 3).

The general eduation of yield (Y) is given below:

$$Y = (K_1 \psi AP + K_2 \psi AC) \times CF$$

K_1. K_2 are contents representing ratio of contribution ψ AP and ψ AC to yield.

ψAP = Agroclimatic potential of the previous month

ψAC = Agroclimatic potential of the current month

CF = Correlation factor for crop husbandry practices which may vary from month to month.

In south India, meteorological parameters are able to account for 50% of prediction value on commercial crop at estate leval and the other 50% comes from crop husbandry practices including manuring. Thus there is a scope to even out distribution to some extent by manipulating crop husbandry practices including manuring.

The monthwise average values of various parameters for anamallais conditions are given in Table 4. In tea, seasonal fluctuations are thus explained fairly by agroclimatic potential of different months.

In other exercise using path coefficient analysis, it has been shown that the significant contribution to rainfall comes from the temperature effect and also the appreciable contribution to temperature effect comes from the rainfall effect in tropical and sub-tropical zones. Therefore irrigation during cool dry season, mid-January to mid-March will not produce desired effect on production as the temperature is the limiting factor during the period. Irrigation during the hot and dry period (March to September) that occurs frequently in Nilgiris will be beneficial in crop production. However, the availability of water for such purposes, imposes limitation for extensive adoption.

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Discussion

G. S. L. H. V. Prasada Rao (RARS, Pilicode): How did you quantify the drought period in relation to tea plantation. Is it based on rainfall alone or soil moisture is also taken into consideration.

V. Ranganathan: The quantification is based on rainfall, effective water storage capacity of soil and evapotranspirational losses.

R. C. Mandal (NRCC, Puttur):1. Productivity model worked by Tea Institute is very informative. Similar model like crop-weather model and some simple models for infiltration of water into soil like rainfall intensity and duration, surface characteristics, vegetation cover, permeability etc. should be thoroughly studied.

2. Further, suitable climatological water budgeting techniques for different regions applicable to various crops and soils have to be developed.

Heat unit requirement for germination of coconut cultivar West Coast Tall—A preliminary study

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ABSTRACT

An attempt was made to study the heat unit requirement for germination of seed nuts of the coconut cultivar West Coast Tall at the Regional Agricultural Research Station, Pilicode during the year 1985. The heat unit requirements for 50 per cent germination, 70 per cent germination and 90 per cent germination of seed nuts were 1721 day°C, 1883 day°C and 2216 day°C, respectively.

Introduction

Several workers (Yogeswara Rao, 1983; Newman *et al.*, 1967 and 1968) have studied the heat unit requirements for maturity of annual crops, in particular, rice. The heat unit is a better yard stick for determining the duration of a crop when compared to the number of days required, as the former takes into account both time and temperature. The duration of different phenophages in annual crops has been worked out using the growing degree days concept. However, such studies in perennial crops like coconut are not seen. Hence an attempt was made to study the heat unit requirement for germination of seed nuts of the cultivar, West Coast Tall at the Regional Agricultural Research Station, Pilicode during the year 1985.

Materials and Methods

One hundred seeds nuts of the cultivar West Coast Tall were collected from 60 year-old palms having more or less similar morphological characters during January to February, 1985. The nuts were stored in sand under shade for about four months, before sowing in June. They were sown in five rows (20 nuts per row) at a spacing of 30 x 30 cm in the nursery bed keeping the stalk end up. The germination of seed nuts was noted at the time of emergence of the sprouts just above the husk. The daily maximum and minimum temperatures during the period from sowing to germination of nuts were collected from the agromet station which is stationed close to the nursery beds. The heat units were worked out using Newsman's method which is given below:

$$GDD = \frac{T\ maximum + T\ minimum}{2} - 10^{\circ}C$$

Where GDD = Growing degree days,

T maximum = Maximum temperature.

T minimum = Minimum temperature and 10°C is the minimum threshold temperature below which the germination will not take place (assumed). The heat unit requirement was worked out for 50 per cent, 70 per cent and 90 per cent germination of seed nuts.

Results and Discussion

Table I gives the heat unit requirement of West Coast Tall. seed nuts. It can be seen that the heat unit requirement for 50 per cent, 70 per cent and 90 per cent germination was 1721, 1883 and 2216 day °C, respectively.

Table I Heat unit requirement for germination of West Coast Tall seed nuts

Percentage of germination	Heat unit required (day°C)
50	1721
70	1883
90	2216

Normally, it takes 3 to 5 months for the germination of seed nuts. However in seasons characterised by prolonged and continuous rains, the time required for germination is more than 5 months. At higher altitudes where the ambient air temperature is low, the seed nuts take more time for germination. Hence the heat unit concept may be a better yard-stick to determine the duration of germination rather than the number of days required.

Acknowledgement

Authors are grateful to the Director of Research, Kerala Agricultural University for providing facilities for the study.

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SESSION IV

Forecasting insect pest and disease outbreak

Chairman	:	Dr. S. JAYARAJ
Rapporteurs	:	Dr. P. B. PILLAI
		Shri M. GOVINDAN

Influence of weather on the larval populations of Cockchafer beetle in coconut

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ABSTRACT

The abundance of white grubs in the root environment of coconut palms was under the influence of mean monthly rainfall and was negatively correlated with mean maximum temperature. The populations were higher during June and July than during February to May. The top 30 cm of the soil harboured the maximum number of larvae in all the months. The larval populations varied with depth. It is advocated that prophylactic insecticidal treatment of the top layer of soil during the periods of heavy rainfall will aid in reducing the pest build-up in endemic areas.

Introduction

The Cockchafer beetles commonly called as root grubs or white grubs, referring to their mode of attack or their whitish appearance as larvae, are one of the most menacing of root-feeding insects to almost all crops grown in light textured soils. The common species occurring in Kerala include *Leucapholis bermeistri*, *L. concophora* and *Holotrichia consanguinea*, all belonging to Melolonthidae and *Anomala* spp., belonging to Rutellidae, Scaraboidea, Coleoptera. The insect is univoltine and their development is seasonal. The larvae feed on the roots of a variety of crops like coconut, tapioca, yam, plantation and many grasses (Abraham and Kurian, 1970). *Holotrichia consanquinea* has sometimes been found to cause more than ninety per cent damage to groundnut (Yadava *et al.*, 1978). Severe attack by the white grubs has been reported by Rai *et al.* (1969) and Vora *et al.* (1985).

Though it is widely known that adults emerge during pre-monsoon showers, oviposit shortly thereafter and the grubs hatch out in the monsoon months, no concerted efforts have hitherto been made to correlate the population fluctuation of the larvae in the coconut rhizosphere with the weather factors. The present paper summarises the results of an experiment conducted at the Regional Agricultural Research Station, Pilicode during 1982-83 to 1984-85 with the above objective.

Materials and Methods

The root-zone of coconut palms in the sandy soil of Nileshwar was surveyed every month for the presence of white grubs. For this purpose, pits of 100 cm x 100 cm x 90 cm were taken, 80 cm away from the bole of the palms. Soil from the top 30 cm was examined first (denoted as D_1) and the total number of larvae available in the sample was counted. The soil from the depth range 30-60 cm (D_2) was examined subsequently and larval population assessed. Population in D_3 (60-90 cm depth) was assessed similarly. Every month, ten samples were drawn. The total rainfall, mean maximum temperature, mean minimum temperature and mean relative humidity for all the months were also recorded. Since keys for identification of the species in their larval stage were not available, the larval population currently expressed in these results indicate the population of all the species of white grubs put together. The data were analysed in a randomised block design. Correlations and regressions were also worked out.

Results and Discussion

The average larval population per month per palm during 1982–82, 1983—84 and 1984—85 corresponding to the depths D_1, D_2, D_3 and the total for the whole depth are furnished in Figs. 1, 2 and 3 respectively. The monthly rainfall during those periods are also indicated. When the correlations between the weather

Fig. 1 Population of whitegrubs in relation to mean monthly rainfall 1982-83

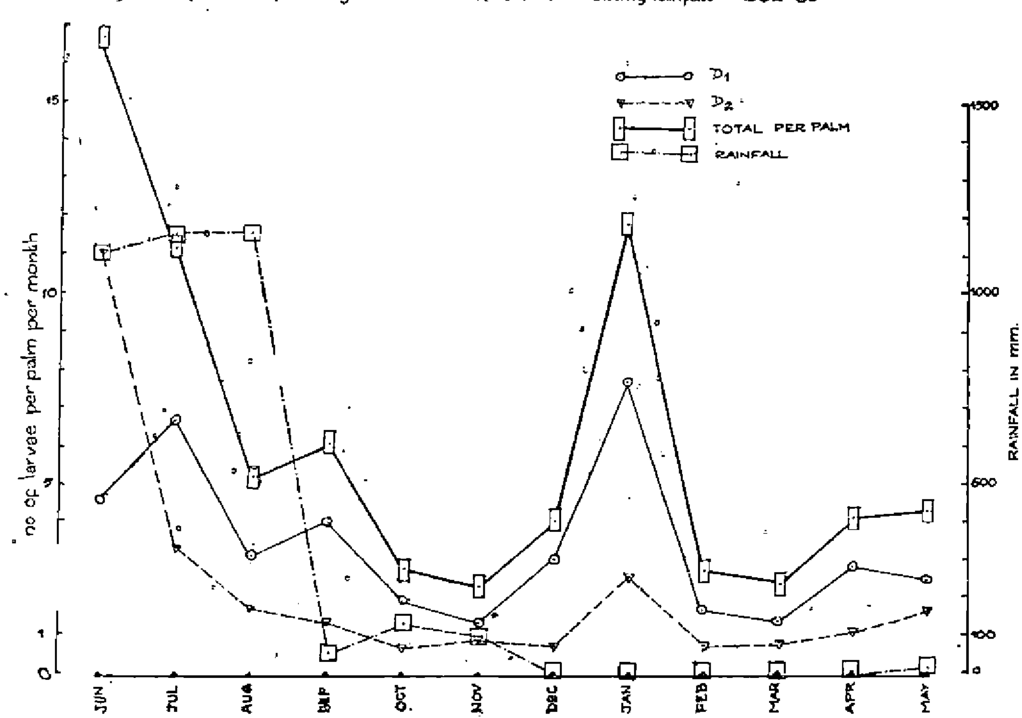
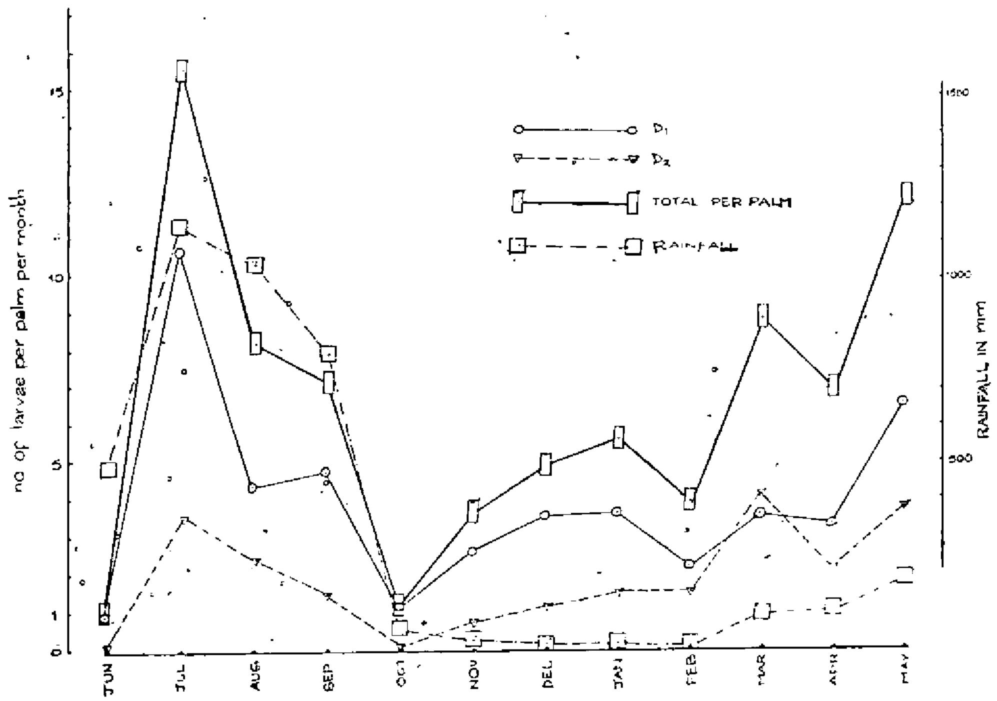


Fig 2 Population of whitegrubs in relation to mean monthly rainfall 1983 84



factors and the larval populations were worked out, it was seen that mean monthly rainfall was the most important factor contributing to the abundance of larvae. Populations of larvae in the depths D_1, D_2 and D_3 individually and when pooled together were affected by rainfall. The mean maximum temperature had a negative correlation on the larval populations at all the depths. But, at any of the depths, mean minimum temperature did not contribute to the larval abundance. Hence, it becomes apparent that the increase in temperature causes the larvae to move down further into cooler layer of the soil at the deeper zones and this aids in their survival. Those that fail to make it, eventually perish. This is further established by the positive correlation with relative humidity obtained from depths D_1 and D_2. Indeed, at depth D_3, more than 60 cm from the surface, changes in the relative humidity on the surface are too trivial to be felt by the larvae. Bakhetia *et al.* (1986) also found temperature and relative humidity as density independent mortality factors in the population of *H. consanguinea* on groundnut in Punjab.

Regression analysis was done to find out the extent of influence the different weather factors were having on the larval populations (Table 1). The notations b_1, b_2, b_3 and b_4 are the regression coefficients corresponding to mean monthly rainfall, mean maximum temperature, mean minimum temperature and per cent relative humidity, respectively, b_0 is a constant term.

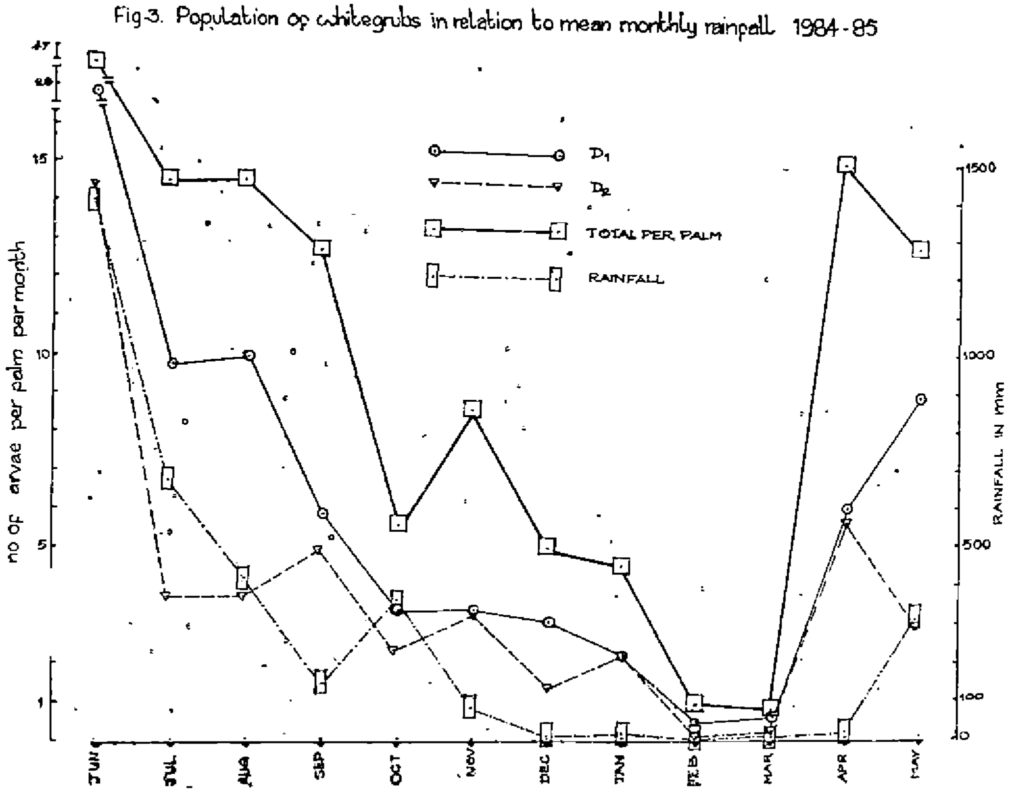


Table 1. Regression coefficient, standard error and 't' values for the total larval population

Regression coefficient	Value	SE	't' value
b_0	+ 91.9815	+ 137.7318	+ 0.6678
b_1	+ 0.0150	+ 0.0052	+ 2.9089*
b_2	— 1.5464	+ 3.1827	— 0.4859
b_3	+ 0.5448	+ 1.1338	+ 0.4805
b_4	— 0.6314	+ 0.7425	— 0.8503

The analysis of variance in respect of the above is presented in Table 2.

At all the depth ranges of the soils, the mean maximum and minimum temperatures and mean per cent relative humidity were not contributing to the larval abundance. Mean monthly rainfall was the most important factor influencing larval populations at depths D_1 and D_2. At depth D_3, the influence was much less pronounced. At this depth, drastic changes in the soil moisture content and other components of microclimate are not expected, which can have a deterimental effects on the larval population. The general level of population of the larvae is also too low at this depth range.

Table 2. Analysis of variance

Source	df	SS	MS	F
Regression	4	886.47	221.62	4.77
X_0	1	2386.16	2386.16	51.41
X_1	1	831.92	831.91	17.92
X_2	1	18.08	18.08	0.39
X_3	1	2.91	2.91	0.06
X_4	1	33.56	33.56	0.72
Error	31	1438.91	46.42	

Changes in the larval population during the different months of an year were further evaluated. The data for the three consecutive years 1982-83, 1983-84 and 1984–85 served as replications and the fluctuation in monthly population was analysed (Tables 3 and 4). Larval populations in the different months were found to differ significantly. The maximum larval population was seen in June. The least number of larvae was seen in February.

Table 3. ANOVA for monthly population changes of the larvae at different depths.

Source	df	SS	MS	F	CD (0.05)
Replications	2	85.79	42.89	4.90	
Months	11	311.31	28.30	3.24*	2.79
Depth	2	259.87	129.93	14.86*	1.39
Month x Depth	22	118.77	5.40	0.62	4.83 (NS)
Error	70	612.23	8.75	1.00	

* Significant at 5 per cent level. NS Not significant

Table 4 Larval populations at different depth during different months of an year

Month	Depth			Mean
	D_1	D_2	D_3	
June	11.01	8.43	2.10	7.18
July	9.02	3.48	1.24	4.58
August	5.78	2.62	0.87	3.09
September	4.81	2.56	1.23	2.87
October	2.12	1.00	0.37	1.16
November	2.43	1.63	0.74	1.60
December	3.19	1.08	0.31	1.53
January	4.46	2.09	0.56	2.37
February	1.44	0.95	0.07	0.82
March	1.81	1.70	0.46	1.33
April	4.02	2.97	1.67	2.89
May	5.99	2.81	0.93	3.24

A perusal of the rainfall data (the weather factor which contributes most to be larval population) clearly reveals appreciably high levels of rainfall in June and July. The biology of the beetle is also seasonal with the adult emergence during the premonsoon season. Eggs are laid immediately thereafter and larvae emerge in 7-10 days. During June and July, the larvae are in their first instar or early second instar and a numerical abundance is only expected. Since this is the stage at which the coconut palm puts forth new roots and rootlets, a very congenial environment is provided for the larvae to invade the roots and grow. The next higher population is in August which ranked third in total rain also. The results of the experiment thus strongly indicate the seasonal cyclic occurrence of the larvae, corresponding to the availability of rainfall. The larvae are soft bodied arthropods which prefer light textured sandy and sandy loam soils. Gravelly and lateritic soils hamper their movement and also cause physical injury. Good rainfall aids in better per cent hatching of the eggs and better survival of the larvae, probably due to better availability of soft, growing roots and also is of movement in the loosened soil. It is thus expected that a period of monsoon withdrawal after its onset, is due to hamper the pest build up by way of reduced survival.

The larvel populations at depths D_1, D_2 and D_3 differed significantly among themselves. D_1 registered the maximum population and D_2 and D_3 had the next higher populations in that order. Thus, a greater number of the larvae are available in the top 30 cm of the soil. Prophylactic application of insecticides at this zone is bound to reduce crop losses considerably. Since the periods of monsoon activity in this region (June and July) also registers the heaviest larval population, prophylaxis at this stage will evidently be the most beneficial control measures in endemic areas of attack by the white grubs.

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Discussion

G. S. L. H. V. Prasada Rao (RARS, Pilicode): Instead of taking atmospheric element, if you consider soil environment like soil moisture and soil temperature, it would have been more realistic since the grub population is highly dependent on soil factors.

A. M. Ranjith: The point is quite pertinent and will be borne in mind in future studies.

M. Gokuldas, Kumar (CCRI, Chikamagalur): How far chemical control is practicable against cock-chafers during rainy season.

A. M. Ranjith: When we get a lull phase in the monsoon or withdrawal for a short spell, it would be possible to apply chemicals.

Impact of drought on stem bleeding disease incidence of coconut

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ABSTRACT

The influence of soil moisture deficiency on stem bleeding disease of coconut was studied utilizing monthly aridity indices during the summer months. The disease incidence was more in 1978 (185 palms). 1979 (189 palms), and 1983 (188 palms) when the mean aridity indices were greater than 95 per cent while it was less in 1980 (37 palms) when the aridity index was 47.65 per cent A significant positive correlation between the mean aridity index during summer and the disease incidence was noticed. A multiple linear regression has been worked out for estimating the disease incidence based on monthly aridity indices during summer (January to May).

Introduction

Stem bleeding of coconut is a disease of unknown etiology. Some workers consider that the disease is caused by the fungus *Thelaviopsis paradoxa*. However, other fungi like *Phomopsis cocoina*: *Paecilomyces varotii* and *Schizophyllum commune* are also involved in the disease. The disease is believed to be caused by infection through growth cracks on the stem, which are vulnerable to the fungus. Cracks develop due to sudden changes in moisture content in the soil. Sampson (1923) has described an instance in which lack of soil drainage aggravated a condition of stem bleeding in palms. Briton Jones (1940) opined that to avoid the disease, all attempts should be made to mitigate drastic changes in soil moisture. Soil moisture is a highly complex and dynamic parameter whose depletion from the root zone is controlled by soil, plant and climatic factors (Malik *et al*., 1986). In order to understand the impact of soil moisture deficiency on the incidence of stem bleeding disease, this study was conducted.

Materials and Methods

The palms in different blocks of RARS, Pilicode constituted the material for the study. The observations on the incidence of stem bleeding disease in the years 1976 to 1983 were taken. The monthly aridity index (Ia) which is expressed as the ratio of water deficiency (WD) to water need (WN) in percentage $\left(\frac{WD}{WN} \times 100\right)$ was worked out using Thornthwaite and Mather (1955) book-keeping water balance procedure. Based on the monthly aridity index and the stem bleeding disease incidence, a multiple regression equation was developed for estimating the diseased incidence.

Results and Discussion

Table 1 gives the mean aridity index (Ia) and disease incidence during summer (March to May). It can be seen that the disease incidence was more in drought years 1978 (185 palms), 1979 (189 palms) and 1983 (188 palms) during which the mean aridity indices (Ia) for the summer months (March, April and May) were greater than 95%. The disease incidence in the year 1980 was less (37 palms) when the aridity index was also 47.66%. Also, there was a singificant positive correlation (at 0.01% level) between the aridity index and the disease incidence.

The monthly aridity index (Ia) during summer and the disease incidence are given in Table 2. It can be seen that the disease incidence was high in the years 1978 and 1979 when the aridity indices were high (98.94 in 1978 and 97.29 in 1979) in April and the incidence was low in 1980 when the aridity index was 23.98 though the aridity index till March did not vary much in both the cases. It indicated that the aridity index in April was critical in determining the disease incidence. It was probably due to continuous soil moisture stress over a longer period which caused production of cracks on the stem through which the fungi entered. The following equation is suggested for estimating the disease incidence based on the monthly aridity values

$$Y = 243.0155 + 2.4895\ x_1 - 8.8681\ x_2 + 3.7445\ x_3 + 1.6488\ x_4 + 0.2550\ x_5$$

Where x_1, x_2, x_3, x_4, and x_5 are the monthly aridity indices of January, February, March, April and May, respectively. The equation has a multiple correlation coefficient of 0.8995 accounting for 80% of the disease incidence.

Table 1. Mean aridity index (Ia) during summer (March—May) and disease incidence

Year	Average Ia	Disease incidence
1976	72.73	159
1977	70.41	157
1978	97.52	185
1979	96.1	189
1980	47.65	37
1981	72.11	120
1982	79.5	140
1983	97.5	188

Correlation coefficient (r) = 0.9142,
Significant at 0.01 level,

Table 2. Monthly aridity index during summer and disease incidence

Year	January	February	March	April	May	Disease incidence
1976	79.92	92.45	96.49	86.34	35.35	159
1977	70.63	76.03	84.15	56.67	0	157
1978	69.12	89.67	96.11	98.94	0	185
1979	34.97	75.52	91.53	97.27	99.5	189
1980	70.63	88.08	95.56	23.98	23.42	37
1981	76.42	89.78	96.77	95.31	24.26	120
1982	73.52	89.55	93.41	98.89	46.20	140
1983	81.54	92.76	97.89	98.89	95.26	180

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Discussion

G. P. Bishnoi (HAU, Hisar). What was the 'r' value between the aridity index during the summer and disease incidence.

T. C. Radhakrishnan It was 0.9142, significant at 0.01 level.

A study on the weather associated with the abnormal leaf fall disease of rubber (*Hevea brasiliensis*)

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ABSTRACT

The meteorological factors associated with the triggering of the abnormal leaf fall caused by *Phytophthora spp.* in rubber *(Hevea brasiliensis)* plantations are presented. An out break invariably follows a five-day rain spell with an overcast day. The epidemics can be expected within 9–15 days after the first overcast day, depending on the onset of South West monsoon.

Introduction

Abnormal leaf fall caused by different species of *Phytophthora* is the most serious disease of rubber, in which mature leaves drop while still green or turning coppery red. This disease causes considerable crop loss every year. In South India, severe defoliation occurs annually in June–July, coinciding with the South-west monsoon period. This disease incidence is closely correlated with pod infection which occurs in May-June just after the onset of monsoon. Sanitation with copper fungicide as prophylactic treatment has been found necessary (Radhakrishna Pillai, 1977) to retain a reasonable canopy and to avoid severe depression in yield.

Weather plays an important part in disease management (Fry, 1982), since the severity and timing of attack is often linked to certain sequences of weather events and the optimum timing of control measures may also be deduced from a combination of meteorological data and crop observations, Since every process of either the plant or the pathogen is influenced by micro-climate (Aust and Hvene, 1986; Waggoner, 1965), identification of optimum conditions are beneficial.

A careful study under field conditions would often indicate the reasons for the epidemic incidence of a plant disease and methods of reducing its intensity (Berger, 1977; Waggoner, 1965). Waiste (1973) and Perise (1969, 1973, 1979) studied the epidemiology of *Phytophthora* under the agroclimatic conditions of Malaysia and Sri Lanka respectively. However, under South Indian conditions Radhakrishna Pillai, *et al.* (1980 a) noticed that prolonged rains and cloudy weather are favourable for *Phytophthora*. The present study is attempted to critically examine the weather association with the abnormal leaf fall at Kottayam.

Materials and Methods

The biological symptoms of the triggering of the abnormal leaf fall in the unsprayed field of the Rubber Research Institute of India, Kottayam were observed during May-August, 1984 to 1986. The meteorological parameters such as, rainfall, temperature, humidity, sunshine and wind were recorded. The microclimate inside and also in the border of the plantation during 1985-86 was also recorded. The moving graphical technique was followed to identify the favourable weather conditions triggering the abnormal leaf fall.

Results and Discussion

The rainfall pattern indicates (Fig. 1 a) that the onset of South West monsoon was on 14th June. A continuous spell of rains provided the surface moisture on rubber trees which is essential to cause infection of the Hevea leaf petiole. This indicates the necessity of a minimum quantum of rainfall (112 mm) with at least 1.0 mm (light shower) per day for a period of five consecutive days

The fluctuation in minimum temperature (Fig, 1 a) was comparatively lesser than maximum temperature. The minimum temperature during the first five-day rainspell was 22.7°C and the mean temperature was 29.3°C. However, the lowest minimum temperature recorded was 21.8°C.

The fluctuation in relative humidity (Fig. 1c) shows that the maximum humidity level was below 90 per cent upto the onset of the monsoon. Then, it increased to above 98 per cent which favoured the pathogen, indicating the optimum for *Phytophthora* propagation. Low temperature together with high humidity are congenial for development of *Phytophthora*.

The overcast sky (Fig. 1 b) with moist weather promotes the fungal multiplication. It was further noticed that the severity of this fungus depends on the number of overcast days. This may be the probable reason for the severe attack in Trichur region and lesser incidence in Kanyakumari region. Further, with four consecutive overcast days, second attack was observed during the middle of August 1986.

Fig. 1 d indicates that the wind speeds of the order of 2-4 km ph occurred at the time of the triggering of the disease.

A combination of meteorological factors associated with the triggering of *Phytophthora* are indicated in Table-1. The meteorological factors were more specific at the beginning of the incubation period. The incubation period varies from 10 days (late onset, 1986) to 14 days (normal onset, 1984 and early onset, 1985) depending on the onset of South West monsoon. Moreover, the beginning of the incubation period coincided with the first appearance of overcast sky. A comparison with earlier schemes by Peeries (1979) and Radhakrishna Pillai, *et al*. (1980 a) indicates that the present study more clearly defines the weather association with the abnormal leaf fall

A comparison of microclimate inside and outside the plantation (Table-2) indicates that the low thermal and high moisture (Humidity) regimes which are

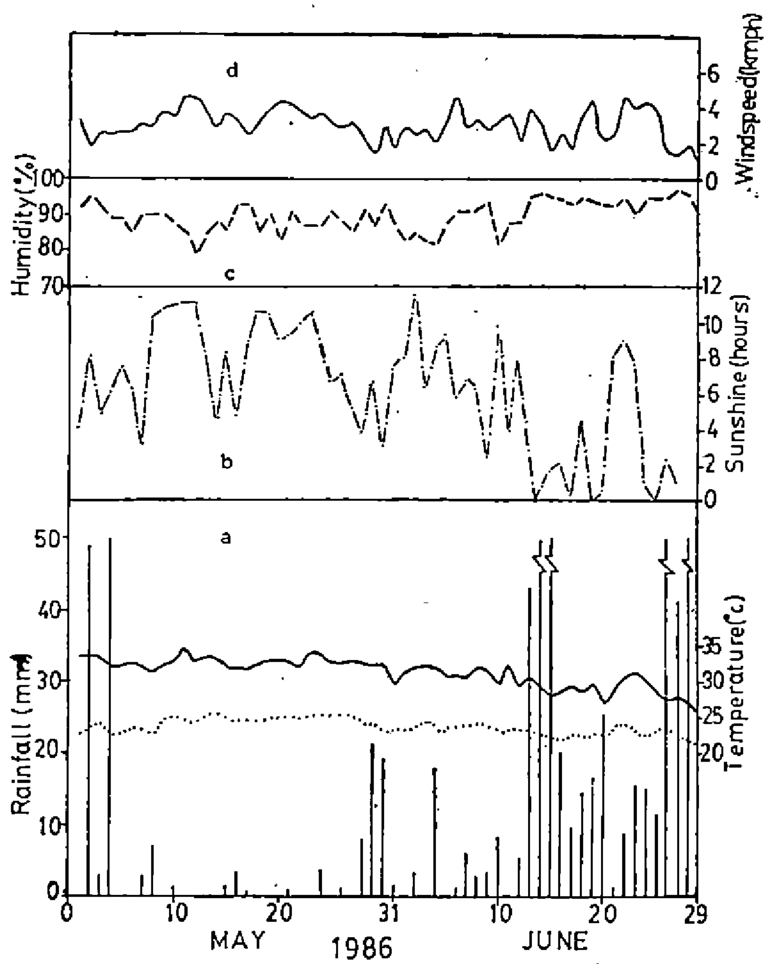

Fig. 1. METEOROLOGICAL FACTORS ASSOCIATED WITH THE TRIGGERING OF THE ABNORMAL LEAF FALL OF HEVEA CAUSED BY PHYTOPHTHORA spp.

a. RAINFALL AND TEMPERATURE (MAX. & MINI)
b. SUNSHINE DURATION
c. MORNING RELATIVE HUMIDITY
d. WINDSPEED

favourable conditions for disease establishment prevail inside the plantation. There was no appreciable difference in thermal and moisture conditions in the border of the estate and outside. Intense rain provided the pathogen from the overlying diseased pods and twigs and also underlying soil at a fast rate at the edge of the plantation. Whereas, the *Hevea* canopy intercepts the rain, reduces the intensity and thus causes low sporangia dissemination inside the plantation. Further, low wind speed which causes less spread of sporangia, seems to be the major factor influencing the outbreak of *Phytophthora*.

Table 1. Weather associated with the occurrence of abnormal leaf fall of *Hevea* caused by *Phytophthora*. The values in the parenthesis indicate the lowest observed value during the five day rainspell with 1 0 mm or more rainfall.

Year	First rainspell		Temperature (°C)		Humidity (%)		Sunshine (Hours)	Triggering on
	Date	Total (mm)	Max.	Mini.	Max.	Mini.		
1984	31 May 04 June	163.5	29.9 (28.7)	22.8 (22.0)	94	70	2.2 (0.0)	19 June
1985	23-27 May	112.0	30.7 (28.5)	22.7 (22.0)	93	71	3.8 (0.0)	5 June
1986	06-10 June	21.6	31.1 (29.9)	23.7 (22.9)	90	65	6.3 (2.5)	
	12-16 June	221.3	29.3 (27.8)	22.7 (21.8)	94	76	3.5 (0.1)	25 June

Table 2 Comparison of meteorological conditions within the *Hevea* plantation (a) to that of the open field (b)

Year	Period	Temperature (°C)		Humidity (%)	
		Max.	Mini.	Max.	Mini.
	A	28.8	21.7	96	78
1985	23–27 May				
	B	30.7	22.7	93	71
	A	30.8	23.2	94	70
1986	6-10 June				
	B	31.1	23.7	90	65
	A	28.2	22.2	95	83
	12–16 June				
	B	29.3	22.7	94	76

A. Rubber Plantation B. Open Field

Under the agroclimatic conditions of Kottayam, the weather associated with the initial triggering of the abnormal leaf fall are as follows: A rain spell of five consecutive days with at least 1.0 mm per day with a cumulative total of 112 mm or more accompanied with (a) the mean air temperature of 26.5 $\pm$ 0.5°C (b) the minimum temperature of 22.5 $\pm$ 0.5° (c) the mean relative humidity of greater than 80 per cent, in which it is more than 93 per cent in the morning and (d) at least one overcast day; then the epidemics can be expected to appear at the edge of the plantation after 9 to 15 days from the overcast day if the inoculum is present on the tree parts.

The critical weather parameters obtained in this study for triggering abnormal leaf fall disease will be useful for the control of this disease effectively and economically using systemic fungicides.

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Influence of weather on foot rot disease of black pepper

(Piper nigrum L.)

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ABSTRACT

The study revealed that 'Foot rot' disease incidence was high during the South West Monsoon period (June–September) and low in Summer (March–May). There was a drastic decrease in the disease incidence when the monsoon ceased. The weekly incidence of the disease was found to be positively correlated with relative humidity, rainfall and number of rainy days while the maximum temperature and bright sunshine hours had a significant negative correlation with the disease incidence. The study also indicated that high relative humidity favoured incidence of the disease under a continuous wet spell. A multiple linear regression equation using the different combinations of weather variables was developed for the prediction of 'Foot rot' disease incidence on pepper.

Introduction

Foot rot (Quick wilt) caused by *Phytophthora palmivora* (Butl.) is a dreaded and devastating disease of black pepper in all the countries where the crop is grown in an extensive scale. In India, Samraj and Jose (1966) recorded vine death upto 20 per cent in Cannanore district while Nambiar and Sarma (1976) reported 25–30 per cent loss in some of the gardens of Cannanore and Calicut districts of Kerala. About 26 per cent death of vines due to the disease was noticed in Cannanore district during 1985 (Anonymous. 1986).

Phytophthora palmivora (Butl,) which also causes the disease of bud rot of coconut, fruit rot or Mahali of arecanut, leaf fall of rubber etc. is noticed during the South-West monsoon season when the environmental factors are highly favourable. Radha and Joseph (1976) revealed that occurrence of bud rot disease of coconut was directly related to relative humidity and temperature in the leaf axils of palms. Studies of similar nature have not been attempted in pepper. Therefore, with a view to understand the influence of weather on the incidence of Foot rot disease of pepper, the present investigation was undertaken at the Pepper Research Station, Panniyur.

Materials and Methods

An experimental plot was selected at the Pepper Research Station, Panniyur in which 128 pepper vines grown as a pure plantation. Vines showing typical symptoms of foot rot either on leaf, branch or stem and complete wilting of the plants were recorded as diseased vine. The weekly incidence of foot rot (Y) was recorded. To understand the relationship between the incidence of disease and weather variables, weather, data such as maximum temperature (X_1) and minimum temperature (X_2), relative humidity in the morning (X_3), rainfall (X_4), number of rainy days (X_5) and sunshine hours (X_6) were also collected daily. The study period was 11 years from 1976 to 1986.

The weekly, monthly as well as seasonwise disease incidence was gathered for the study period. The correlation coefficients were worked out between the different mean weekly weather variables and disease incidence for assessing their associations and based on the relationship, a multiple linear regression equation was developed for estimating the disease incidence using the weather variables.

Results and Discussion

The mean weekly spread of the disease incidence during the study period from 1976 to 1986 showed that a gradual increase in the disease incidence occurred only after the onset of monsoon and reached its peak in the month of July which was the rainiest month. The decline in disease incidence was noticed when the monsoon ceased (Fig. 1). It indicates that the disease incidence due to

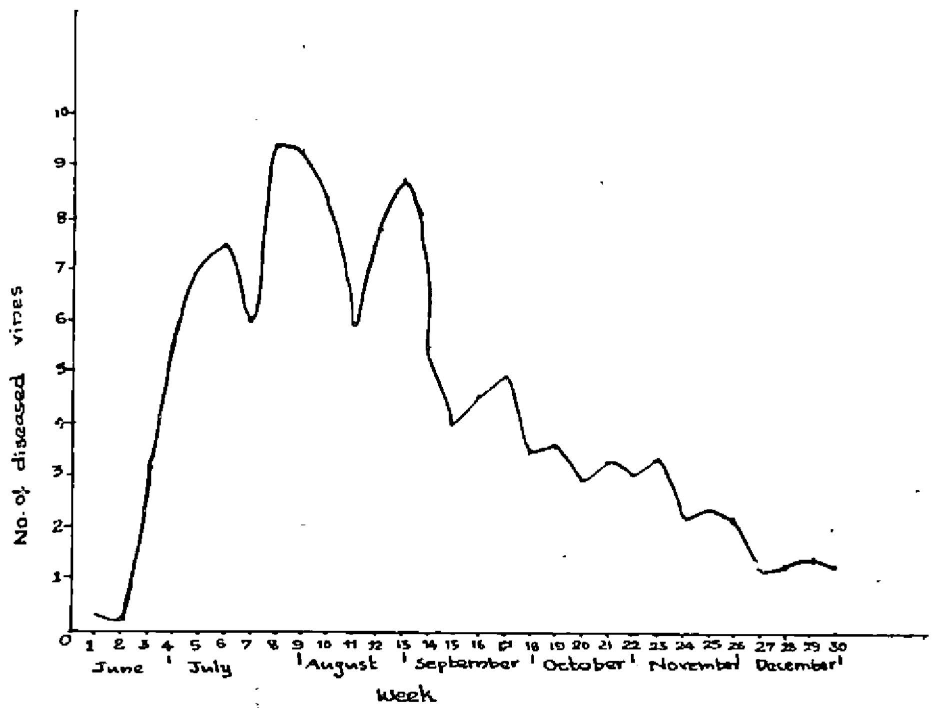

Fig. 1. Mean distribution of Foot rot disease incidence of Pepper during June to December.

foot rot of pepper vines follows the annual rainfall pattern. The maximum disease incidence (39.08%) was noticed in July and it declined thereafter. However, during the years when the monsoon was late, heavy incidence varied from middle of July to middle of August. Similar observations have been noticed with the abnormal disease of rubber caused by *Phytophthora* spp also (Radhakrishna Pillai, 1980).

During the month of July, weather variables such as rainfall, number of rainy days and the relative humidity were the highest for the whole year (Table 1). This agrees well with observations made by Butler (1910) in the case of bud rot disease of coconut caused by *Phytophthora palmivora* (Butl.) that the disease was related to the humid atmospheric conditions.

It can be seen that the maximum disease incidence (41.00) was during the South-West monsoon and the minimum (3.18) during summer. The highest (90) number of diseased vines was noticed in 1985 and the lowest (3) in 1980 (Table 2). This variation can be attributed to variations in inoculum potential of the pathogen in the field.

Correlation studies between the different weekly weather variables and the number of diseased vines indicated that a significant positive correlation existed between the disease incidence and weater parameters like weekly rainfall, number of rainy days and relative humidity. On the other hand, a negatively significant correlation existed in the case of maximum temperature and sunshine hours (Table 3). The increase in the amount of rainfall, number of rainy days and relative humidity aggrevated the incidence of the disease. It can also be seen that the maximum temperature tended to fall when the rainfall was high and continuous. So, the increase in disease incidence might possibly be due to the favourable conditions created by high rainfall and relative humidity for a longer period which favoured the development and spread of the foot rot pathogen.

Table 1: Monthly incidence of foot rot disease and weather variables from 1976 to 1986

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative humidity (%)	Rainfall (mm)	No of rainy days	Sunshine hours (per day)	No. of diseased pepper vines
June	30.28	24.05	91.85	895.4	22.24	2.52	9.35
July	24.24	23.54	93.56	1267.2	29.25	2.14	39.08
August	29 17	22.87	93.25	534.2	16.20	2.44	30.61
September	31.07	23.21	90.39	212.20	13.8	4.47	18.98
October	32.33	23.12	88.87	244.20	7.50	6.88	16.25
November	31.97	22.18	87.78	129.72	6.25	7.34	10.17
December	34.11	21.13	84.77	11.9	1.48	7.95	5.08

Table 2: Seasonwise diseased pepper vines from 1976 to 1986

Year	Summer March to May	South-West monsoon June to September	Post monsoon October to November	Winter December to February
1976	0	45	19	1
1977	0	70	25	3
1978	0	29	6	2
1979	5	11	0	5
1980	2	3	0	4
1981	8	6	5	9
1982	0	47	9	1
1983	5	49	6	3
1984	6	49	8	2
1985	5	90	15	3
1986	4	52	14	3
Mean	3.18	41.00	9.72	3.27

Table 3: Correlation matrix of foot rot disease incidence and weekly weather variables

	X_2	X_3	X_4	X_5	X_6	Y
X_1	−0.527**	−0.832**	−0.739**	−0.753**	+0.794**	−0.796**
X_2		+0.736**	+0.667**	+0.718**	−0.666**	+0.262
X_3			+0.817**	−0.823**	−0.854**	+0.741**
X_4				+0.900**	−0.841**	+0.538**
X_5					−0.892**	+0.558**
X_6						+0.660**

** Significant at 1% level

Based on above relationship, the following multiple linear regression equation was developed using all the weather variables for predicting the disease incidence.

$$Y = -3.5644 - 0.6545\,x_1 - 1.4342\,x_2 + 0.6946\,x_3 - 0.0069\,x_4 + 0.0085\,x_5 - 0.1742\,x_6$$

Where X_1 to X_6 are weather variables and Y, incidence of disease. The equation has a multiple correlation coefficient (R) of 0.8920 accounting for 79.57% of the variability in the disease incidence. It is significant at 1% level. The actual and estimated values of the disease incidence using the above equation are presented in Table 4.

Table 4: Actual and estimate values of foot rot disease incidence on pepper

Week (June to December)	Actual	Estimates
1	0.36	0.87
2	0.18	2.38
3	3.00	5.79
4	5.81	6.89
5	7.00	5.32
6	7.45	6.70
7	6.00	5.60
8	9.36	7.73
9	9.27	6.89
10	8.36	8.05
11	5 90	8.15
12	7.72	8.55
13	8.63	7.26
14	5.45	5.69
15	4.00	5.04
16	4.63	3.93
17	4.90	4.20
18	3.45	3.34
19	3.54	2.87
20	2.90	2.94
21	3.27	2.19
22	3.09	1.44
23	3.36	3.43
24	2.27	2.43
25	2.36	3.54
26	2.18	3.32
27	1.18	0.79
28	1.27	1.77
29	1.36	1.85
30	1.27	0.70

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SESSION V

Climate and crop production

Chairman : Dr. M. ARAVINDAKSHAN

Rapporteurs : Dr. V. RAJAGOPAL

Dr. K. V. SATHEESAN

Forecasting models for the yield of Coconut

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ABSTRACT

The yield data of 91 coconut palms maintained at the Regional Agricultural Research Station, Pilicode ahd the meteorological data for the region of Pilicode, collected from CPCRI Kasaragod were utilised in the present study with the objective of developing a reliable statistical methodology for the pre-harvest forecast of coconut crop yield by evolving different emperical, statistical and crop-weather models. Three models were fitted based on the data and their comparative efficiencies tested by means of four criteria and the models I & III were found to give the "best" fit.

Introduction

An attempt has been made in this study to develop crop-weather models for the pre-harvest forecast of agricultural crop yields with special references to coconut. As coconut is one of the most important agricultural crops in India, the importance of this study need not be over emphasised. The present investigation had the following broad objectives.

i) To develop a suitable and reliable statistical methodology for the pre-harvest forecast of coconut crop yields by evolving different emperical—statistical crop-weather models using the original and generated weather variables as predictor variables.

ii) To make a comparative study of relative efficiency, adequacy and performance of each of the crop forecasting models evolved and to select the 'best' for the purpose of predicting coconut crop yield reliably in advance of harvest.

Materials and Methods

The monthly nut yield of the coconut cultivar 'West Coast Tall' during the period from 1958 to 1980 was collected from the Regional Agricultural Research Station, Pilicode (91 palms having numbers 86 to 176 were selected from block I in an area of 1.19 ha.) along with the weekly meteorological variables such as rainfall, hours of bright sunshine, wind velocity, relative humidity and the maximum temperature recorded at CPCRI, Kasaragod. The average nut yield per palm during the first (January-June) and second half year (July–December) was computed and thus obtained 26 values of nut yield. The same was used as response (predicted) variable. The meteorological data were reduced to the following 3 month and 6 month periods having more uniformity in environmental effects on the crop.

1. 3 month-period (December-February, March-May, June-August and September-November)

2. 6 month-period (December—May and June–November)

The general form of the forecasting model employed in the present investigation is given by the equation.

$$Y = A_0 + \sum_{i=1}^{p} \sum_{k=0}^{m} a_{ik} Z_{ik} + \sum_{i=1}^{p} \sum_{k=0}^{m} b_{ik} Z_{ik} + \sum_{i,j=1}^{p} \sum_{k=0}^{m} g_{(ij)k} Q_{(ij)k} + h_0 T + e$$

This is the most general form of the crop-weather model from which many forecasting models for the yield of coconut can be derived and brought out for different values of parameters p, m, n and for different forms of the generated predicted variables depending upon the various functional forms H_1 (w), H_2 (w), H_3 (w), where 'p' is the number of weather variables, 'm' the degree of the polynomial.

$$Z_{ik} = \sum_{w=1}^{n} H^{k}(w) X_{iw} \text{ — 1st order generalised variable}$$

$$Z^1_{ik} = \sum_{w=1}^{n} H^{k}(w) X_{iw} \text{ — 2nd order generalised variable}$$

$$\text{and } Q_{(ij)k} = \sum_{w=1}^{n} H^{k}(w)\, X_{iw}\, X_{jw} \text{ — more generalised variable}$$

where 'n' is the number of divisions of the crop season period.

1) If we take H_1^k (w) = H_2^k (w) = H_3^k (w) = w^k, m = 2 and $b_{ik} = 0$ for all i and k, our forecasting model (1) reduces to the crop-weather models used by Hendricks and Scholl (1943), and Rao (1980).

2) If we take H_1^k (w) = H_2^k (w) = H_3^k (w) = w^k, m = 4 and $b_{ij} = 0$ for all i and k, our forecasting model (1) reduces to the forecasting models employed by Runge and Odel (1957), Rungi (1968)

3) If we take in model (1).

i) $H_1^k (w) = w^k / \sum_{w=1}^{n} w^k$ for y = 1,2,3

ii) $b_{ik} = 0$ for all i and k, then forecasting model (1) reduces to the forecasting model I of Agarwal *et al.* (1980).

4) If we take in our model (1)

i) $H_i^k (w) = r_{iw}^k (1) / \sum_{w=1}^{n} r^k_{iw} (1)$

ii) $b_{ik} = 0$ for i and k

iii) $H_3^k (w) = r^k_{(ij)} w\,(3) / \sum_{w=1}^{n} r^k_{(ij)} w\,(3)$

where r_{iw} (1) is correlation coefficient of y with X_{iw} $r_{(ij)}$ w (3) is correlation coefficient of y with the product of X_{iw} any X_{jw} at wth period, then the forecasting model (1) reduces to the forecasting model of Agarwal *et al.* (1980) and Jain *et al*. (1980). Hence the forecasting model (1) is more general than all the recently developed models and would render a wider scope and structure of the system of generated predictor variables which influence the yield of coconut.

Though the general form of the forecasting model employed in the present investigation is given by the equation (1), different forecasting models are derived for different values of parameters and predictor varibles contained in the model.

Model I

In this model we take the generated predictor variables in the general forecasting model I as follows.

$$Z_{ik} = \sum_{w=1}^{n} w^{k} X_{iw}$$

$$Z^{1}_{ik} = \sum_{w=1}^{n} w^{k} X^{2}_{iw}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} w^{k} X_{iw} X_{jw} \quad \text{for } i < j.$$

Model II

In this model we take the generated predictor variables in the general forecasting model I as follows.

$$Z_{ik} = \sum_{w=1}^{n} w^{k} X_{iw} \Big/ \sum_{w=1}^{n} w^{k}$$

$$Z^{1}_{ik} = \sum_{w=1}^{n} w^{k} X^{2}_{iw} \Big/ \sum_{w=1}^{n} w^{k}$$

$$Q_{(ij)k} = \sum_{w=1}^{n} w^{k} X_{iw} X_{jw} \Big/ \sum_{w=1}^{n} w^{k}$$

Model III

In this model we take the generated predictor variables in our general forecasting model (1) as follows.

$$Z_{ik} = \sum_{w=1}^{n} r^{k}_{iw}(1) X_{iw} \Big/ \sum_{w=1}^{n} r^{k}_{iw}(1)$$

$$Z^{1}_{jk} = \sum_{w=1}^{n} r^{k}_{iw}(2) X^{2}_{iw} \Big/ \sum_{w=1}^{n} r^{k}_{ik}(2)$$

$$Q_{(ij)k} = \sum_{w=1}^{n} r^{k}_{(ij)w}(3) X_{iw} X_{jw} \Big/ \sum_{w=1}^{n} r^{k}_{(ij)w}(3)$$

where $r_{iw,}$ (1), r_{iw} (2) and $r_{(ij)w}$ (3) are the correlation coefficients of coconut crop yield y with.

(1) $X_{iw,}$ (ii) X^{2}_{iw} and (iii) X_{iw} $X_{jw,}$, ($i < j$) respectively.

For these three different crop forecasting models proposed, the effective crop season is taken to be three years (36 months) This is in accordance with the findings of Patel and Anandan (1936) on the influenee of rainfall on the coconut crop yields. In order to suit the forecasting models, this effective crop season of 3 years is equally divided into 12 periods, each having an interval of three months which is in confirmity with the findings of Marar and Pandalai (1957). Hence for this effective crop season of three years with 12 equally divided periods, the three models mentioned above have been developed using five weather variables viz: total rainfall (X_1), duration of bright sunshine (X_2), wind velocity (X_3), transformed relative humidity (X_4) and maximum diurnal temperature (X_5) respectively.

Under the effective crop season of 3 years equally divided into 3 month periods, the value of the parameters in the crop forecasting models fitted are $P=5$, $m = 2$, $k = 0, 1, 2$ and

$w=1,2,3,4,5,6,7,8,9\ 10,11,12$ respectively.

The first and second order predictor variables denoted by Z_{ik}' Z'_{ik} and $Q_{(ij)k}$ for $i < j$ were generated for $i, j=1,2,3,4,5$, and $k=0,1,2$. There were 15 different predictor variables generated for Z_{ik}' 15 different predictor variables generated for Z'_{ik} and 30 different second order predictor variables generated for $Q_{(ij)k}$ for $i < j$. The time variable T is also included as a predictor variable for purpose of checking downward or upward trend in coconut production. Therefore, in all, 61 predictor variables are considered for each of the forecasting models proposed above. Then 61 correlation coefficients of yield response Y, average units per bearing tree per half year, with each of 61 predictor variables are worked out and twenty predictor variables having the highest correlation coefficient with yield response Y were selected as preliminary selected predictor variables. The most plausible variables to be included in the final crop forecasting models were selected from these 20 preliminary predictor variab es through the application of step wise regression technique using forward selection procedure as explained by Draper and Smith (1981), for each crop forecasting models proposed above.

For the selection of the most efficient and plausible crop forecasting model the following different criteria were used.

(i) $R^2=SSR/SST=1-SSE/SST$ (R^2—Multiple coefficient of determination)

(ii) Adjusted Multiple Coefficient of determination

$R^2_a=1-(1-R^2)\ (S-1)/(S-r)$ as proposed by Ezekiel and Fox (1959)

(iii) Amemiya prediction criterion (APC) due to Amemiya (1980)

$APC= [\ (S+r)/(S-r)]\ (1-R^2)\ SST/S$

(iv) Akaike information criterion (AIC) due to Akaike (1978)

$AIC=(S-r) \log [\ (1-R^2)/(S-r)*SST]+r \log [\ (R^2/r)*SST]$

where r—no. of parameters estimated in the model

S—no. of observations used for fitting the regression analysis of the model

RSS—SS due to regression of the ANOVA
ESS—Error SS ,,
TSS—Total SS ,,
(r—1) is the d. f. of RSS
(S—r) is the d. f. of ESS
(S—1) is the d. f. of TSS

Results and Discussion

The season-wise (3 months period) coverage of weather variables involved in the crop forecasting models for the span of 15 years from 1965-1980 along with standard deviation and coefficient of variation in percentage were given in Table 1.

Table 1: Weather variables involved in crop forecasting models and their mean s.d. and coefficient of variation (1965-80)

Weather variables	Mean	s. d.	C. V.
1. Total rainfall	88.0058	109.8703	124.4447
2. Sunshine hours	7.3087	2.1810	29.8411
3. Wind velocity	2.1237	0.9223	43.4289
4. Relative humidity	62.2885	5.1348	8.2436
5. Max. temperature	30.9065	1.4581	4.7178

Out of this 61, generated predictor variables of Z_{ik}, Z^1_{ik} and $Q_{(ij)k}$ (for $i<j$), 20 variables were preliminary selected on the basis of maximum absolute correlation with the yield for fitting the model-I. They were Z_{30} Z_{50} Z_{31} Z_{51} Z_{32} Z_{52} Z^1_{30} Z^1_{50} Z^1_{31} Z^1_{51} Z^1_{32} Z^1_{52} $Q_{(12)0}$, $Q_{(23)0}$, $Q_{(23)1}$, $Q_{(23)2}$, $Q_{(34)0}$, $Q_{(34)1}$, $Q_{(34)2}$ and $Q_{(35)1}$ respectively. Through the step-wise regression procedure, 11 predictor variables were selected to be included in the final crop forecasting model-I. They were $Z_{(30)}$ $Z_{(32)}$ $Z^1_{(50)}$ $Z^1_{(31)}$ $Q_{(12)0}$, $Q_{(23)0}$, $Q_{(23)1}$, $Q_{(23)2}$, $Q_{(34)0}$, $Q_{(34)2}$ and $Q_{(35)1}$. The estimated regression coefficients for these corresponding predictor variables along with their standard deviation and computed t-statistic for model-I are given in Table 2.

The final functional form of crop forecasting Model I developed through step-wise regression procedure was as shown

$$\begin{aligned} Y = {} & 116.7730+261.559 Z_{30} - 2.4406 Z_{32} - 0.0023 Z_{50} \\ & +0.1319 Z_{31} +0.0011 Q_{(12)0} - 5.2728 Q_{(23)0} - 1.1269 Q_{(23)1} \\ & +0.1543 Q_{(23)2} - 8.2513 Q_{(34)0} + 0.0297 Q_{(34)2} \\ & -0.0034 Q_{(35)1} \quad \text{———————————(2)} \end{aligned}$$

(20)

Table 2. Variables selected regression coefficients S. E. and Computed t—values for Model-I

Variables selected	Regression Coefficients	Estimate	Standard error	Computed t-value
Z_{30}	a_{30}	261.5590	25.2000	10 3793**
Z_{32}	a_{32}	—2.4406	0.2374	—10.2805**
Z^{1}_{50}	b_{50}	—0 0023	0.0037	— 0 6216 N S
Z^{1}_{31}	b_{31}	0.1319	0.0359	3.6741**
$Q_{(12)0}$	$g_{(12)0}$	0.0011	0.0002	5.5000**
$Q_{(23)0}$	$g_{(23)0}$	—5.2728	0.5148	—10.2424**
$Q_{(23)1}$	$g_{(23)1}$	—1.1269	0.1255	— 8.9793**
$Q_{(23)2}$	$g_{(23)2}$	0.1543	0.0161	9.5839**
$Q_{(34)0}$	$g_{(34)0}$	—3.2513	0.3113	—10.4427**
$Q_{(34)2}$	$g_{(34)2}$	0.0297	0.0029	10.2414**
$Q_{(35)1}$	$g_{(35)1}$	—0.0034	0.0008	—4.2500**

$S = 26$ $R^2 = 0.9482$ $R^2 a = 0.9075$ $A_0 = 116.7730$
$t_{(0.025,14)} = 2.145$ $t_{(0.005,14)} = 2.797$ * — Significant at 5%

** — Significant at 1% N. S.—Non-significant

For fitting the Model-II the preliminary variables were selected having the maximum absolute correlation coefficients with the yield Y were Z_{30}, Z_{50}, Z_{31}, Z_{51}, Z_{32}, Z_{52}, Z^1_{31}, Z^1_{51}, Z^1_{32}, Z^1_{52}, $Q_{(12)0}$, $Q_{(13)2}$, $Q_{23(0)}$, $Q_{(23)1}$, $Q_{(23)2}$, $Q_{(25)0}$, $Q_{(34)0}$, $Q_{(34)1}$, $Q_{(34)2}$, and $Q_{(35)1}$. The thirteen predictor variables included in the final crop forecasting model selected through step-wise regression techique were Z_{30}, Z_{52}, Z^1_{31}, Z^1_{51}, Z^1_{32}, $Q_{(12)0}$, $Q_{(23)1}$, $Q_{(23)2}$, $Q_{(25)0}$, $Q_{(34)0}$, $Q_{(34)1}$, $Q_{(34)2}$, and $Q_{(35)1}$. The estimated regression coefficients for these corresponding predictor variables, along with their S. E. and computed t— statistics are presented in Table 3. The final functional form of crop forcasting Model II developed through step-wise regression technique was as given below.

$$Y = -520.2540 - 562.5090\, Z_{30} + 90.1274\, Z_{52} + 98.0748\, Z^1_{31} - 2.6224\, Z^1_{51} - 63.3173\, Z^1_{32} + 0.0939\, Q_{(12)0} + 10.3116\, Q_{(23)1} - 12.5098\, Q_{(23)2} + 1.6880\, Q_{(25)0} + 9.0241\, Q_{(34)0} - 12.5740\, Q_{(34)1} + 5.6116\, Q_{(34)2} + 9.4322\, Q_{(35)1} \quad (3)$$

Table 3. Variables selected—regression coefficients, S. E. and computed t-values for Model—II

Variables selected	Regression Coefficients	Estimate	Standard error	Computed t-value
Z_{30}	a_{30}	—562.5092	229.3700	—2.4524*
Z_{52}	a_{52}	90.1274	21.5500	4.1822**
Z^1_{31}	b_{31}	98.0748	21.6630	4.5273**
Z^1_{51}	b_{51}	— 2.6224	0.5652	—4.6398**
Z^1_{32}	b_{32}	—63.3173	16.7600	—3.7779**
$Q_{(12)0}$	$g_{(12)0}$	0.0939	0.0407	2.3071*
$Q_{(23)1}$	$g_{(23)1}$	10.3116	14.4240	0.7149 N.S
$Q_{(23)2}$	$g_{(23)2}$	—12.5098	10.5550	—1.1852 N.S
$Q_{(25)0}$	$g_{(25)0}$	1.6880	0.6397	2.6387*
$Q_{(34)0}$	$g_{(34)0}$	9.0241	3.3847	2.6661*
$Q_{(34)1}$	$g_{(34)1}$	—12.5740	3.3075	—3.8017**
$Q_{(34)2}$	$g_{(34)2}$	5.6116	1.5149	3.7043**
$Q_{(35)1}$	$g_{(35)1}$	9.4322	3.4984	2.6961**

S=26 R^2=0.8320 R^2a=0.6500 A_0—520.2540

$t_{(0.025,12)} = 2.179$ $t_{(0.005,12)} = 3{\cdot}055$

* — Significant at 5% ** — Significant at 1%

N S—Non-significant

For fitting the model—III, the 20 preliminary variables were selected having maximum absolute correlation coefficients with yield Y were Z_{50}, Z_{31}, Z_{51}, Z_{22}, Z_{32}, Z_{52}, Z^1_{50}, Z^1_{31}, Z^1_{51}, Z^1_{12}, Z^1_{32}, Z^1_{52}, $Q_{(12)0}$, $Q_{(12)2}$, $Q_{(23)1}$, $Q_{(23)2}$, $Q_{(25)2}$, $Q_{(34)1}$, $Q_{(34)2}$ and T. The ten predictor variables included in the final crop forecasting model selected through step-wise regression technique were Z_{50}, Z_{22}, Z_{52}, Z^1_{50}, Z^1_{12}, Z^1_{52}, $Q_{(12)0}$, $Q_{(12)2}$, $Q_{(23)2}$, and T. The estimated predictor variables, along with their standard errors and computed t—statistics are presented in Table 4.

Table 4. Variables selected, Regression coefficients, S. E. and computed t—values for model—III

Variables selected	Regression Coefficients	Estimate	Standard error	Computed t—value
Z_{50}	a_{50}	65.8204	13.3980	4.9127**
Z_{22}	a_{22}	—29.7842	4.7072	—6.3275**
Z_{52}	a_{52}	609.0960	62.8640	9.6891**
Z^1_{50}	b_{50}	—2.2427	0.2985	—7.5132**
Z^1_{12}	b_{12}	—0.0008	0.0002	—4.0000**
Z^1_{52}	b_{52}	—9.5624	0.9701	—9.8571**
$Q_{(12)0}$	$g_{(12)0}$	—0.0322	0.0086	—3.7442**
$Q_{(12)2}$	$g_{(12)2}$	—0 0403	0.0114	—3.5351**
$Q_{(23)2}$	$g_{(23)2}$	—0.2084	0.0176	—11.8409**
T	h_0	—1.4025	0.2407	5.8257**

$S=26 \quad R^2=0.9408 \quad Ra^2=0.9013 \quad A_0 = -9239.4700$

$t_{(0.025,15)} = 2.131 \quad t_{(0.005,15)} = 2.947$

The final functional form of crop forecasting Model—III developed through step-wise regression techniques was as given below :

$$Y = -9239.4700 + 65.8204\,Z_{50} - 29.7842\,Z_{22} + 609.0960\,Z_{52} - 2.2427\,Z^1_{50} - 0.0008\,Z^1_{12} - 0.0322\,Q_{(12)0} - 0.0403\,Q_{(12)2} - 0.2084\,Q_{(23)2} - 1.4024\,T \qquad (4)$$

The ANOVA Tables for the three crop forecasting models are given in Table 5.

The most efficient crop forecasting model which would serve our purpose of predicting coconut crop yield in advance of harvest was selected on the basis of the four criteria discussed in the method—viz., R^2, adjusted R^2 (R^2a), Amemiya prediction criterion (APC) and Akaike information criterion (AIC). The values obtained for these different criteria under these three models are given in Table 6.

Three different crop forecasting models were developed under the effective crop season of 3 years with 3 months period by giving different weights to the weather effects on the crop yields. The forecasting models for the yields of coconut, developed so far, have taken into consideration linear effect of only one or two weather variables at a time, excluding the interaction effect of these weather variables on the crop. In the present study, not only the linear part, but also the quadratic and interaction effects of five weather variables on the crop yields were taken into consideration. Over and above this, a comparative study within the fitted forecasting models were also attempted.

Table 5 ANOVA Tables for Model I, II & III forecasting models

Model I

Source	d. f.	S. S.	M. S.	F
Due to Regression	11	1156 0147	105.0923	25.2973**
Error	14	63.1529	4.5109	
Total	25	1219.1676		

Model II

Source	d. f.	S. S.	M. S.	F
Due to Regression	13	1014.3474	78 0267	4.5714**
Error	12	204.8202	17.0683	
Total	25	1219.1676		

Model III

Source	d. f.	S. S.	M. S	F
Due to Regression	10	1146.9929	114.6993	23.8378**
Error	15	72 1747	4.0633	
Total	25	1219.1676		

Table 6 Computed criteria measures for the three crop forecasting models fitted through step-wise regression

Model	R^2	R^2a	APC	AIC
I	0.9482	0.9075	6.5929	75.9049
II	0.8320	0.6500	26.2590	94.0079
III	0.9408	0·9013	6.8474	74.6825

The crop-weather forecasting model—I produced R^2 value of 0.9482 and R^2a value of 0.9075. Therefore 94.82% of the total variance from the mean in the yield response Y was explained by the predictor variables in this model. Here R^2 value was also highly significant. Moreover, the crop forecasting model—I on the predictor variables was also highly significant. Similarly, the index APC and AIC were the minimum (for more efficient fitting, these two indices must be minimum) in comparison to other models. Hence model I should be considered as the best among the three.

Similarly the model—II produced R^2 and R^2_a values as 0.8320 and 0.6500, respectively. This showed only 83.2% of the total variance from the mean in the yield response Y. Again the APC and AIC criteria values were also high In comparison to the other two models. Hence this model cannot be considered as the best model.

The model—III gave R^2 aud R^2_a values as 0.9408 and 0.9013, respectively. This showed 94.08% of the total variance in the yield response Y similarly, the APC and AIC indices were also minimum. Hence the model—III can also be considered as the best and at par with model—I. Hence it can be reasonably concluded that models I and III can be considered as the "best" fitting and most efficient forecasting model for predicting coconut yield.

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Discussion

M. P. Abdurazak (RARS, Pilicode): 1. Is it justifiable to use the weather data of Kasaragod for predicting the yield data of Pilicode which is situated about 45 Km away from Kasaragod? 2. What is the minimum number of palms required to use the models suggested in this paper? In other words can we forecast the yield for a farmer.

K. C. George : 1. The pattern of rainfall was similar in these two stations based on the study conducted by Balasubramanian (1956). 2. The objective of this study is to find out a suitable prediction model for coconut yield and not to find the optimum number of palms required for such a study. This objective can be solved separately.

Influence of seasonal climatic factors on coconut yield

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ABSTRACT

To identify the seasonal effect of 18 climatic parameters representing three basic agro-climatic variables solar radiation, temperature and soil moisture (for evapotranspiration), a correlation study was undertaken using the above weather parameters and total annual coconut yield in 3 year lag periods.

The pattern of influence of climatic factors on yield shifted from season to season in different lag periods. The most important climatic factors influencing the annual yield were sunshine hours (SSH), evaporation (EV) and relative humidity (RH). SSH and EV showed a positive correlation with yield, while RH showed a negative one. Rainfall (RF) and number of rainy days (NORD) did not shed much light on the pattern of influence.

Most of the above variables were found to influence the yield during pre and post monsoon periods. Evaporation, however, showed influence during monsoon season also.

Introduction

The crop yield depends basically on three agroclimatic variables: solar radiation, temperature and soil moisture. The relationship between these weather variables and coconut yield is discussed in this paper.

Meterials and Methods

Yield data of coconut from 167 palms of WCT variety grown under rainfed condition receiving recommended doses of Fertilisers, from CPCRI farm records were obtained for the period 1955-83. The palms were of the age group 45-50 years in 1983.

As many as 18 weather parameters were selected with the assumption that crop yield depends basically on three agro-climatic variables viz., solar radiation, temperature and soil moisture (or evaporation), as listed below:

1.	Maximum Temperature MXT	10.	Relative humidity, afternoon RHAN
2.	Minimum Temperature MNT	11.	Wind velocity WV
3.	Soil temperature at 5 cm, forenoon STF5	12.	Sunshine hours SSH
4.	Soil temperature at 5 cm, afternoon STA5	13.	Rainfall RF
5.	Soil temperature at 15 cm, forenoon STF 15	14.	Evaporation EV
6.	Soil temperature at 15 cm, afternoon STA 15	15.	No. of rainy days NORD
7.	Vapour pressure, forenoon VPFN	16.	Range in temperature RT
8.	Vapour pressure, afternoon VPAN	17.	Soil temperature range, forernoon STR 5
9.	Relative humidity, forenoon RHFN	18.	Soil temperature range, afternoon STR 15

These variables were grouped into four seasons as follows, as per Pillai and Satyabalan (1960):

Season 1	March, April and May
Season 2	June, July and August
Season 3	Septemder, October and Novembar
Season 4	December, January and February

Weather variables of first, second and third year before the harvest year were treated as lagged variables. To study the effect of weather variable for for each season on annual yield, simple correlation coofficients were worked out between yield and weather variables. The weather variable having a coefficient of correlation significant at 5 percent level was identified to have significant association with yield.

Results and Discussion

The seesonal variation in six weather variable selected out of 18 weather parameters are presented in Table 1.

Seasonal fluctuations of weather variables may be studied based on CV% given along with mean values. SSH, EV and RT fluctuated least in the first, third and fourth seasons whereas RF and NORD showed heavy fluctuations during the same period. Fluctuation in RH in all seasons was considerably low.

Coefficient of correlation between season-wise weather variables and annual yield of coconut in three lag years for all seasons was worked out and presented in Table 2. Six variables viz., SSH, EV, RH, RF, RT and NORD appeared to show significant association with yield in various lag years to different seasons. Effect of weather variables in the four seasons are explained here.

Influence of first season (March, April and May)

SSH associated with yield positively on all the three lag years (r=0.53, 0.48, 0.52). RH, RF, NORD and EV showed association in the second lag year

Table 1. Seasonal variations in six weather variables (per day)

	SSH (hrs)	EV (mm)	RH (%)	RF (mm)	NORD (No.)	RT (°C)
First season	8.54	5.00	64.3	111.8	4.5	8.2
(MAM)	(7.2)	(14.6)	(3.9)	(64.2)	(53.3)	(6.6)
Second season	3.56	2.37	83.5	886.9	24.6	5.8
(JJA)	(24.4)	(35.9)	(2.6)	(18.4)	(6.9)	(10.5)
Third Season	6.97	3.27	71.8	190.0	9.9	8.0
(SON)	(9.6)	(20.8)	(5.2)	(40.5)	(37.0)	(8.4)
Fourth season	9.32	4.45	54.5	6.3	0.5	11.2
(DJF)	(3.21)	(7.0)	(5.3)	(134.9)	(140.0)	(4.9)

MAM—March, April and May; JJA—June, July and August
SON—September, October and November
DJF—December, January and February
Figuers in brackets are coefficient of variation (%)

with coefficients of correlation —0.63, —0.53, —0.62 and 0.44, respectively. RF, RH and NORD depreciated the yield, while SSH and EV beneficially affected the yield.

Influence of second season (June, July and August)

EV and RH associated with yield significantly in the second lag year (r=0.49, —0.48), but had opposite effects. RT and MNT showed significant association in the third year lag with coefficient of correlation 0.58, and —0.63, respectively. MNT showed a negative relationship.

Influence of third season (September, October and November)

SSH, EV and NORD associated significantly with yield in the first lag year (r=0.44, 0.48, —0.42). NORD had a negative association. Association of EV with yield was significant on all the three lag years (r=0.48, 0.44, 0.48). VPAN, RHAN, SSH and RT showed significant association in the third lag year with coefficient correlation —0.45, —0.49, 0.42 and 0.59, respectively.

Influence of fourth season (December, January and February)

STF 15 and RF showed significant association with yield in the first lag year (r=—0.41, 0.47). VPAN and RHAN negatively associated with yield in the second lag (r=—0.40, —0.40). None of the variables showed significant association with yield in the third lag year.

A pronounced association between yield and weather variables viz, SSH, EV and RH was observed in the second and third lag years. Important stages of spadix development occur during these periods. The effects of sunshine hours and evaporation appeared to be beneficial whereas the effect of relative humidity was detrimental to yield. The above results indicated that prolonged hours of sunshine during all the three lag years of first season and first and third lags of third season

Table 2. Coefficient of correlation between seasonal lagged variables and annual yield for 18 climatic factors

Factors	First lag year				Second lag year				Third lag year			
	S(1,1)	S(2,1)	S(3,1)	S(4,1)	S(1,2)	S(2,2)	S(3,2)	S(4,2)	S(1,3)	S(2,3)	S(3,3)	S(4,3)
MXT	—.34	0.089	0.28	—.385	0.06	—.119	—.363	—.211	—.02	—.357	0 221	—.30
MNT	—.20	—.273	0.039	0.203	0.159	—.043	—.179	—.311	—.273	—.635	—.358	0.028
STF5	0.099	0.038	0.292	—.032	0.519	0 264	0.074	—.02	0.193	0.095	0.002	0.041
STF15	—.175	0.125	—0.140	—.412*	0 042	0.052	—.056	—.178	0.062	—.032	—.212	—.237
STA5	—.184	—.118	0.059	—.280	0.241	0.094	—.214	—.299	—.139	—.176	—.196	—.218
STA15	0.157	—.279	0.087	—.055	0.225	—.121	— 284	—.030	—.035	—.150	—.207	—.177
VPFN	0.041	0.069	0.298	0.309	—.303	—.162	—.084	—.249	0.166	—.011	—.212	—.064
VPAN	—.100	—.025	—.106	0 155	—.099	—.133	—.232	—.396*	0.061	—.002	—.451*	—.132
RHFN	0.121	—.236	—.161	0.247	—.627*	—.479*	—.035	—.190	0.113	—.199	—.357	—.179
RHAN	—.171	—.326	—.379	0.293	—.476*	—.254	—.206	—.403*	—.207	—.155	—.492*	—.057
WV	—.151	—.057	—.126	—.251	—.149	—.015	—.121	—.233	—.261	—.190	—.233	—.208
SSH	0.533*	0.257	0.438*	—.258	0.483	0 200	0.163	0.171	0.524*	0.183	0.416*	0.236
RF	—.231	—.117	—.210	0.468	—.525*	0.088	—.132	0.182	—.113	—.065	0.176	0.061
EV	0.362	0.354	0.483*	0.035	0.439	0.485	0.431	0.128	0.341	0.148	0.482	0.232
NORD	—.212	—.095	0.424*	0.224	—.617*	0.019	0.021	—.008	—.055	—.005	—.103	—.113
RT	—.106	0.362	0.184	—.60*	—.118	—.060	—.113	0.168	0.279	0.576*	0.532*	—.309
STR5	—.157	—.129	—.099	—.184	—.034	0.181	—.234	0.160	—.203	—.230	—.178	—.171
STR15	0.235	—.303	0.216	0.298	0.155	0.127	—.278	0.124	—.067	—.111	—.060	0.049

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

* Significant at 5 per cent

had a dominant influence on annual yield of coconut. Similarly increased rate of evaporation during the third season of all lag years and second lag of first and third seasons had a predominant role in influencing coconut yield. Higher relative humidity in the forenoons of second lag year in the first and second seasons, higher relative humidity in the afternoons of the third lag year in the third season and the second lag year of the fourth season had adversely affected the coconut yield.

High rainfall in the second lag of first season had adverse effect on yield while higher amount of rainfall during first lag of the fourth season appeared to influence yield beneficially. Diurnal temperature range (RT) in the third lag year of the third season beneficially influenced yield.

In confirmation to the above result, Salgado (1955) reported that sunshine hours beneficially affected the maximum harvest of coconut in Sri Lanka. It is known that bright sunshine raises the temperature on the leaf surface, thereby promoting better activity in the palm which is reflected through higher yield. The evaporative demand of the atmosphere is also known to enhance the rate of transpiration thereby increasing the plant activity.

Although a hot humid weather is good for coconut palm, very high humidity throug out the year interferes with moisture and nutrient uptake (Copeland, 1931). Copeland (1931) also reported that though relative humidity (obviously related to temperature, rainfall and insolation) should be such as to permit most active transpiration without the palm suffering from loss of water. Since the present study was based on the observation obtained from garden situated on the sea coast, the relative humidity inside the garden was ovbiously higher than the open area. The increase in relative humidity inside the garden was much above the normal limit which might have adversely effected the yield.

Though it is well known that moisture status of a soil has a definite role in influencing coconut yield, the two important indication of soil moisture viz. rainfall and soil temperatures at 5 and 15 cm depth did not show predominant influence on yield. In such a situation, it is worthwhile to construct a soil moisture index involving all soil parameters rainfall, soil temperature at different depth etc. to arrive at a relationship with yied.

Since the spadix production is a continuous process within the palm weather factors at all seasons exert some proportional influence on the growth of the spadix. The cumulative effect of all these variables will determine the quantum of yield. Any adverse climatic condition during these stages will have adverse effect on yield. Therefore, studying the effect of a particular weather variable without considering the possibilities of overshadowing effects by other variables will only vitiate the result. Hence, it is necessary to study the cumulative effect of all those variables which affect the yield to make valuable inferences.

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Influence of weather on coconut yield

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ABSTRACT

Studies were conducted on the relationship between four weekly averages of 11 weather variables viz.; temperature (maximum and minimum), vapour pressure —VP (forenoon and afternoon), relative humidity—RH (FN and AN), wind velocity, hours of sunshine—HRS, rainfall, evaporation and rainy days and quarterly yield of coconut. The seven lag periods viz., 6-8, 10-12, 17–18, 22-23, 30–31, 35-36 and 44-46 months prior to the harvest of nuts were identified as important. Of these, the last five periods correspond to some of the important developmental phases of the inflorescence like differentiation of ovary and development of stamens, growth of branches of inflorescence and formation of primordia of male flower, process of beginning of the primary bract of the inflorescence, differentiation of the outer or second bract and initiation of primordium of inflorescence.

Introduction

Weather plays an important role in determining the yield of any crop. In a perennial crop like coconut, the influence of weather on the yield is cumulative since every bunch has to go through a long period of 44 months of development from the primordial stage till maturity. The variations in weather parameters during this period thus are bound to affect the yield. Studies conducted so far in this direction by earlier workers like Patel (1938), Balasubramanian (1956), Abeywardena (1968), Prasad Rao (1982), Jacob Mathew *et al.* (1986) and Vijayakumar *et al.* (1986) have established the importance of summer rains. Vijayakumar *et al.* (1986) further listed the important weather variables which had significant correlation with yield of one year ahead, two years ahead and three years ahead of harvest. However, in none of these studies the authors have indicated the critical phases of the development of nuts during which the weather factors play a crucial role. In the present study, an attempt is made to identify the important weather variables during the different critical phases of development of nuts starting from the primordial stage up to harvest of nuts.

Materials and Methods

At CPCRI, Kasaragode coconuts are generally harvested at an interval of about 30 days. Monthly harvest data for a group of 30 palms, growing under rainfed condition in Block RS 29, for the period 1961 to 85 were considered for this analysis. Since the harvest had been skipped in some of the months, the monthly harvest figures have been grouped on the basis of the following four seasons. viz. June to August (S. W. monsoon), September to November (N. E. monsoon), December to February (Winter) and March to May (Summer). The weekly data on 11 weather variables, Viz. temperature (maximum), vapour pressure—VP (forenoon and afternoon), relative humidity—RH (FN and AN), wind velocity, hours of sunshine—HRS, rainfall, evaporation and rainydays available at CPCRI, Kasaragod were made use of for finding out the influence of weather variables on yield. The data were further grouped into four-week-blocks and in the case of rainfall and rainydays, four week totals and in the case of other vatiables, block averages were considered for analysis. As the coconut primordium is formed about 44 months prior to harvest, for correlation analysis, not only current month's weather, but lag periods up to 208 weeks (4 years or 48 months) were used. Since weather data have been considered in four-week-blocks and yield data on quarterly basis, for working out the lag periods, it was assumed that the weather variables and yield correspond to the middle of each period. Lag periods were first calculated on weekly basis and then converted into months for easier interpretation. Hence the results and discussions are mainly based on monthly lag periods.

Results and Discussion

Table–1 gives an idea about the monthly variation of weather parameters at Kasaragod.

Based on significant correlations obtained and their concentration within a particular period, seven lag periods were identified as important (Table-2). These were 24-36 weeks (6–8 months), 41–52 weeks (10-12 months), 72-80 weeks (17-18 months), 92-100 weeks (22–23 months), 128-137 weeks (30-31 months), 152–160 weeks (35-36 months) and 187-200 weeks (44-46 months). All these lag periods, except the first one, coincide with some of the important developmental phases of inflorescence as described by Patel (1938).

During lag 6-8 months, two of the parameters, namely, temperature–(max.) and hours of sunshine had positive influence on yield whereas RH (AN), wind velocity and rainy days had negative influence. It appears from this that warm and sunny days during this period help retention of tender nuts in the bunch, while more humid days coupled with high wind velocity and rain are not good and may lead to premature nutfall.

During lag 10-12 months, that is during the process of opening of spathe and immediately there after, VP (FN&AN), RH (FN) and rainfall had positive influence on yield, while wind velocity and evaporation had negative influence.

During lag 17-18 months, that is when ovary is first differentiated and when anther lobes and stamens develop, temperature (max.), rainfall, rainy days and evaporation had positive influence, while RH (FN & AN) and wind velocity had negative effect.

Table 1. Monthly weather data at Kasaragod (Mean for the period 1960-81)

Month	Variables											
	Temperature		V P		R H		W V					
	Maximum	Minimum	F N	A N	F N	A N	Km/hr	HRS	Total Rainfall	Evapor-ation	Total Rainy-days
January	31.68	20.11	16.03	17.23	84.50	52.90	2.13	9.31	0.71	4.47	0.05
February	31.88	21.30	18.17	19.05	87.00	56.45	2.36	9.76	0.00	4.85	0.00
March	32.45	23.26	20.48	21.42	87.36	51.09	2.57	9.41	5.57	5.30	0.23
April	33.21	24.97	21.92	22.67	82 35	61.87	2 83	9.14	39.41	5.43	2.55
May	32.42	24.90	22.50	23.30	83.05	68.74	2.75	7.68	225.42	5.50	8.09
June	29.75	23.33	22.21	23.06	91.50	81.98	2.20	3.68	886.51	3.79	23.27
July	28.52	22.96	21.87	22.93	93.90	85.53	2.31	2.58	1105.93	2.62	27.73
August	28.50	22.82	21.77	22.75	94.64	82.84	2.13	3.77	689.50	2.79	23.95
September	29.22	22.76	21.55	22.62	93.82	78.63	1.81	5.97	317.64	3.56	14.77
October	30.60	22.77	21.49	22.56	88.39	72.00	1.71	6.98	175.29	3.66	10 01
November	31.82	22.07	19.08	20.09	88.32	61.09	1.70	7.97	88.50	3.94	5.22
December	32.35	20.81	16.59	17.73	83.36	52.91	1'87	8.46	21.50	4.15	1.22
Mean	31.03	22.67	20.31	21.28	88.19	67.17	2.20	7.06	3555.98*	4.26	117.09*

* Represents total for year

Table 2: Influence of weather variables on yield of nuts—Significant correlations

Lag period Months	Lag period weeks	Temperature (Max)	Temperature (Min)	VP (FN)	VP (AN)	RH (FN)	RH (AN)	Wind velocity	HRS	Total rainfall	Evaporation	Rainy days
		1	2	3	4	5	6	7	8	9	10	11
6-8	22							−0.429				
	23	0.441	0.481	0.434								
	24							0.443				
	25								0.454			0.451
	26								−0.477			
	27											
	28											
	29		−0.437	−0.507								
	30	0.705		−0.520		−0.621	0.529	−0.535	0.466	−0.442		−0.482
	31		0.417									
	32											
	33						−0.483		0.465			
	34							−0.496		0.448		
10-12	39		0.497	0.426	0.536							
	40											
	41											
	42		−0.482			0.449		−0.506			−0.628	
	43		0.447									
	44			0.449	0.458							
	45					0.440						
	46		−0.456					−0.561				
	47	0.535										
	48											
	49					0.461				0.442	−0.521	
	50							−0.500			−0.433	

		1	2	3	4	5	6	7	8	9	10	11
17–18	70							—0.426				
	71								0.455			
	72											
	73											
	74	0.497				—0.513		—0.479	—0.513			
	75									0.505		0.459
	76											
	77					—0.527					0.429	
	78						—0.424					
22-23	90								0.440	0.465	—0.462	0.486
	91											
	92											—0.429
	93					—0.427						
	94											
	95											
	96											
	97					—0.580						
	98						0.526			0.531		
30-31	126									0.522		0.522
	127						—0.479					—0.524
	128						0.534			0.515		0.782
	129			—0.480								
	130								—0.467			
	131											
	132										0.502	—0.423
	133											
	134	0.448										
	135									0.458		0.458

		1	2	3	4	5	6	7	8	9	10	1.1
35-36	150											
	151					0.437				0.453		
	152	—0.493	—0.470				0.421					
	153					0.449						
	154				0.485							
	155		—0.431			0.469						
	156											
	157											
	158			0.469								
44-46	185								0.438	—0.534		—0.510
	186											
	187											
	188	—0.455	—0.562			0.579						
	189											
	190					—0.452						
	191					0.536						
	192											
	193											
	194										—0.452	
	195											
	196											
	197											
	198	0.602					—2.439			—0.581		—0.622

Note: All the coefficients listed above are significant at 1% or level of significance.

Lag 22-23 months brought out the importance of HRS, rainfall and RH(AN) which had positive correlation with yield and evaporation which had negative correlation. During this period, growth of rachille or branches of the inflorescence takes place and primordium of male flowers are formed.

During lag 30-31 months, that is during the process of beginning of fourth bract or the primary bract of the inflorescence temperature (max.), rainfall, evaporation and rainy days had positive influence while VP (FN) and HRS had negative influence.

During lag 35-36 months, VP (FN&AN), RH(FN&AN) and rainfall had a positive influence and temperature (max. and min.) had a negative influence. During this period differentiation of the outer or second bract takes place.

During lag 44-46 months, that is during initiation of primordium and before RH (FN) and HRS had positive influence while temperature (min.), RH(AN) evaporation and rainy days had negative influence.

The results thus show (Table 3) that temperature (max) had a positive influence towards the later part of development (lag 6-8, lag 10-12 and lag 17-18 months) of the inflorescence. Towards the early part (lag 35-36 months) it had a negative influence. Temperature (min) showed its influence which is negative, towards early part of development of the inflorescence. These suggest that towards initiation of primordium and early part of development of the inflorescence, cooler days and nights are preferable. VP (FN&AN) exhibited it's influence which is positive, towards the early period (lag 35-36 months) and the last period (lag 10-12 months). During the middle period its effect was not observed.

Table 3: Influence of weather at the difference stages of the development of nuts—Summary of results

Variables	Lag period in months						
	6-8	10–12	17–18	22-23	30–31	35-36	44–46
Temp (Max)	+	+	+		+	—	
Temp (Min)						—	—
VP (FN)		+			—	+	
VP (AN)		+				+	
RH (FN)	—	+	—	—		+	+
RH (AN)	—		—	+		+	—
WV	—	—	—				
HRS	+			+	—		+
Rainfall		+	+	+	+	+	—
Evaporation		—	+	—	+		—
Rainydays	—		+				—

\+ Indicates significant positive correlation at 1% or 5% level
— indicates significant negative correlation —do—

RH (FN) exhibited a positive influence during the early period of develoment (lag 44–46 and lag 35-36 months), while it had a negative influence during middle period. RH (FN) showed a negative influence during the formation of primordium (lag 44-46 months), thereafter its influence was positive till lag 22-23 months and then again negative towards the later periods. Wind velocity had only a negative influence that too towards the later periods of development (from lag 17–18 months). HRS generally had a positive influence except during lag 30-31 months when it had negative influence. Rainfall had positive influence throughout except during the initiation of primordium (lag 44-46 months) when it was negative. Rainy days however did not show the same trend. But, like rainfall, it had a negative influence at the time of initiation of primordium. The trend of evaporation was alternatively negative and positive during the development of inflorescence and at the time of the primordium initiation it's effect was negative.

Acknowledgement

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Discussion

N. Mohankumaran (KAU, Vellayani): Weather data and correlation 46 to 48 months prior to harvest may also be examined (since according to Patel, the flower bud initiation in coconut take place about 44 months prior to harvest of a particular bunch). Detailed studies will have to be conducted on the influence of the weather parameters (i) during the pre-initiation period (ii) during the period between initation and spathe opening and (iii) during post-spathe opening period.

K. Vijayakumar: The suggestions will be taken care of in our future studies.

O. P. Bishnoi (HAU, Hisar): Use of weather variables during different phenon-phases may be better correlated and utilised to improve yield prediction regression rather than using calender month meteoro-logical data.

K. Vijayakumar: Agreed. The same will be attempted in future studies.

Influence of weather parameters on the yield of coconut in the backwater areas of Kuttanad

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ABSTRACT

The relationship between weather parameters and nut yield of coconut was explained based on correlations. An increase in the maximum temperature adversely affected the coconut yield during the third year; low humidity during pre-monsoon was favourable for good nut yield in the same year; an increase in total rainfall was less beneficial to the second year yield, but increased yield in the same and the third years.

Introduction

In the backwater areas of Kuttanad where coconut is grown on bunds, the intervening channels are filled with water throughout the year and the water table is very high. Earlier workers like Menon and Pandalai (1958) and Mathai and Panicker (1978) could not notice any significant influence of rainfall on yield of coconut in the backwater areas of Kuttanad. On the other hand, it was observed at Pilicode that the absence of post and pre-monsoon showers and the occurrence of high rainfall during June to August adversely affected the second year's yield (Anon. 1986). Keeping this in view, an attempt has been made to study the influence of weather parameters on the yield of coconut palms grown in the backwater areas of Kuttanad under rainfed conditions using the data on nut yield and weather parameters gathered at the Regional Agricultural Research Station, Kumarakom, Kottayam district.

Materials and Methods

Fifty West Coast Tall coconut palms of the same age which received uniform management for the past ten years were selected for the purpose. The yield data of the above trees were collected for six years from 1981 to 1986 and the average annual yield per palm was worked out. The weather parameters recorded at the station were collected for seven years (1980 to 1986). The data were grouped into pre-monsoon (February-May), monsoon (June-September), post-monsoon (October-January) and total for the year. Weather parameters such as the maximum and minimum temperatures, relative humidity, rainfall, number of rainy days and average rain per rainy day were considered for this study. Correlations were worked out with each of the above weather elements and the average annual nut yield for the current year and for the two subsequent years.

Results and Discussion

The mean maximum temperature during the period from 1980 to 1986 (Table 1) ranged from 32.48°C in the pre-monsoon season to 28.83°C in the monsoon while the minimum temperature ranged from 26.24°C to 24.2°C. The rainfall recorded was high (1657.8 mm) in the monsoon when compared to that of the pre-monsoon (324.5 mm) and post-monsoon (359.6 mm).

Table 2 gives the average yield of nuts per palm during the different seasons. The highest number of nuts was recorded (76.6 nuts per palm) in 1983 while the lowest (41.9 nuts per palm) in 1982. Among the seasons' nut yield, the pre-monsoon season recorded the mean maximum yield of 25 nuts and the minimum of 15.6 nuts was noticed in the monsoon.

The correlation coefficients between rainfall and yield of nuts are given in Table 3. It can be seen that a significant positive correlation existed between the monsoon rainfall and the first and third annual nut yields. The average rainfall per rainy day during the year and the monsoon season had a significant negative correlation with the second year's nut yield. A positive correlation between the average rainfall per rainy day during the monsoon season and the third year's nut yield was also observed.

The significant correlations between the different weather elements and nut yield and their regression models are given in Table 4. It can be seen that there was a significant negative correlation between yield of nuts during the 3rd year and annual mean maximum temperature (r= —0.9212). However, the values of correlations were not significant during monsoon but significant during pre-monsoon (r= —0.7794) and post-monsoon periods (r= —0.8947). Differentiation of inflorescence primordia takes place 32 months before opening of the spathe and that of female flower 12 months before opening of spathe (Menon and Pandalai, 1958). The reason for significant decline in yield during the third year due to the fact that the high temperature might have affected the developing inflorescence adversely its early stages.

The increased yield during the third year due to increase in annual rainfall may be due to increased producton of female flowers since the number of female flowers is determined 2 years prior to harvest of nuts (Menon and Pandalai, 1958). The correlation between monsoon rains with yield also followed the above pattern of response and the 'r' values were still higher, indicating the importance of the monsoon rains in determining the yield of coconut palms in the backwater areas.

Table 1. Weather parameters recorded from 1980 to 1986 at Kumarakom

Season	Max. Temp. °C	Min. Tem. °C	R. H. (%)	Rainfall (mm)	No. of Rainy days	Rainfall per rainy day (mm)
Pre-monsoon	32.48	26.24	79.94	324.5	19.42	15.33
Monsoon	28.83	24.20	87.16	1657.8	78.00	21.26
Post-monsoon	30.64	24.36	80.78	359.6	27.00	18.27
Total	30.64	24.92	81.63	2341.9	118.43	19.74

The reason for the low yield during the second year may be attributed to poor fertilization resulting from poor pollination and poor setting of buttons due to excess rainfall. This is in conformity with the observations made at Pilicode where the maximum shedding of buttons was observed during South West monsoon (Anon, 1986).

There was a significant negative correlation between average rainfall per rainy day and second year nut yield (r= —0.8365). The monsoon rainfall per rainy day was significant only at 5% level on the second years' nut yield (r= —0.7344). On the other hand, the average rainfall per rainy day during the monsoon and third years' yield was correlated positively (r= +0.9135).

Thus an increase in rainfall during monsoon is not so beneficial to the second years' yield, but it encourages yield during the current year and the third year.

Table 2. Average yield of nuts per palm at RARS, Kumarakom

Year	Pre-monsoon	Monsoon	Post-monsoon	Total
1981	21.9	16.2	14.9	53.1
1982	17.8	14.3	9.8	41 9
1983	38.1	20 1	18.4	76.6
1984	20.1	14.1	15.2	49.4
1985	25.8	17.4	18.8	61.9
1986	25.9	11.5	10.5	47.9
Mean	25.00	15.6	14.6	55.12

Table 3. Values of correlation-coefficients between rainfall and yield of nuts

	Current year	Second year	Third year
Total rainfall and yield	+0.4362	—0.4686	+0.6590
Monsoon rainfall and yield	+0.8069*	—0.7034	+0.8352*
Total number of rainy days and yield	+0.1585	+0.0360	+0.1708
Monsoon rainy days and yield	+0.8174*	—0.6250	+0.7225
Average rainfall per rainy day during the year and yield.	+0.4817	—0.8365**	+0.7356
Average rainfall per rainy day during monsoon and yield.	+0.0941	—0.7344*	+0.9135**

* Significant at 5% level.
** „ 1% level

Acknowledements

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Table 4. Significant correlations and their regression models

Sl. No.	Characters correlated	'r' value	Regression model	Coefficient of determination (%)
1	Pre-monsoon mean maximum temperature x 3rd year yield	—0.7794*	— —	—
2	Post-monsoon mean maximum temperature x 3rd year yield	—0.8947**	435.8519 — 12.4996 X_1	80.00
3	Annual mean maximum temperature x 3rd year yield	—0.9212**	613.1817 — 18.4479 X_2	84.85
4	Monsoon rainfall x current year yield	+0.8069*	— —	—
5	Monsoon rainfall x 3rd year yield	+0.8352*	— —	—
6	Number of rainy days in monsoon x current year yield	+0.8174*	—29.47516 — 1.07755 X_3	66.81
7	Annual average rainfall per rainy day x second year yield	—0.8365**	169.106 — 5.8110 X_4	69.96
8	Average rainfall/rainy day during monsoon x second year yield	—0.7344*	— —	—
9	Average monsoon rainfall/rainy day x third year yield	+0.9135**	—186.4062 — 11.6209 X_6	83.45
10	Pre-monsoon mean relative humidity x current year yield	—0.8462**	— —	—

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

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Forecasting coconut yield using monthly distribution of rainfal

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ABSTRACT

Taking the monthly distribution of the rainfall of the preceding year as the factor influencing the productivity of the crop in the succeeding year, a crop forecasting formula based on the monthly distribution of rainfall was developed. The high values of the coefficient of determination estimated from the multiple liner regression of yield of coconut on monthly distribution of rainfall showed the usefulness of this formula for predicting the productivity of coconut.

Introduction

Coconut is cultivated in about 6.98 lakh ha in Kerala. The crop is highly adaptable to the climate of the state. In Kerala, the atmospheric temperature is uniform over comparatively large areas but the rainfall shows considerable variation even within short distances. Among the climatic parameters. rainfall appears to be the most important. The palm requires heavy and well distributed rainfall ranging from 1000 mm to 2500 mm. The presence of sufficient moisture in the soil is essential for crop development and better productivity. However, the distribution of rainfall is more important than the quantum of rainfall received during an year. Abeywardena (1968) tried to forecast coconut yield using rainfall data. The concept of effective rainfall was utilised by him to predict the yield. Abeywardena (1971) showed that the relationship between effective rainfall and yield was more pronounced than that between total rainfall and yield.

Materials and Methods

The district-wise data on the monthly distribution of rainfall (in mm) for a period of fifteen years from 1969-'70 to 1983-'84 and the average yield of coconut per ha (in nuts) for the succeeding periods 1970-,71 to 1984-'85 were collected from the Directorate of Economics and Statistics, Government of Kerala and utilised for the present study.

The female flowers will take twelve months to develop into mature nuts and every bunch of coconut is subjected to a full weather cycle of twelve months and the final yield will bear the cumulative effect of the weather of this period. The rainfall during this critical period was considered as the effective rainfall affecting the productivity of this crop. So the possibility of predicting the yield of coconut in a particular agricultural year using the monthly distribution of rainfall of the immediately preceding year was tried using multiple regression techniques, as given below.

$$Y = b_0 + b_1x_1 + b_2x_2 + ——— + b_kx_k,\ k = 1,\ 2,\ ——,—12$$

where b_1, b_2,———, b_k are the partial regression coefficients,

x_k; k = 1, 2———12

the independent variable viz. monthly rainfall and Y, the dependent variable 'yield' of coconut per hectare was fitted to the data.

Results and Discussion

The data on the average monthly rainfall received from nine districts of Kerala along with the normal rainfall (1901-1951) and the average yield (per hectare) of coconut for the 15-year-period under study presented in Table 1. The rainfall was very low in Trivandrum district compared to the other districts, the average rainfall pèr month being 140 mm with coefficient of variation of 60 per cent. On the West Coast, the rain increases in quantity from the south to the north but its distribution becomes less and less even. The rainfall during the period December to March was comparatively good in southern districts than in the northern districts.

Correlation coefficients were worked out between monthly rainfall and yield and are presented in Table 2. Significant positive correlation was observed between January rains and yield in Trivandrum, Alleppy, Ernakulam and Cannanore districts. Correlation between February rains and yield was observed only in Ernakulam district. March rains in Trivandrum and Cannanore districts, April rains in Trivandrum, Palghat, Quilon, Kottayam, Cannanore and Calicut showed significant correlations at 10 to 20 per cent level of significance. Rains in June and September had correlation with yield in Ernakulam district. A significant negative correlation was observed with November rains in Kottayam district. November rains were found to have a negative influence on yield in the southern districts of Kerala. In general the rains during January to April were found to be helpful for increased productivity.

Multiple linear regression equations were fitted to the data and the results are presented in Table 3. The significance of the multiple linear regression implies that some portion of the variability in Y is indeed explained by the fitted regression model and the value of the coefficient of determination (R^2) provides information on the size of that portion. The large values of R^2 indicate that the estimated multiple linear regression equations characterise the character 'yield'. However, the large number of terms included in the regression reduced the chance of detecting significance of individual regression terms and also of the multiple regression. The inclusion of twelve terms in the multiple regression provided only two (n-k-1) degrees of freedom to estimate the variation due to deviation from regression. Even with such large K = 12 and small n-k-1 = 2 for carrying out proper test of significance the fitted multiple linear regression for Trivandrum district was found to be

Table 1. Monthly distribution of average rainfall, normal rainfall and annual yield per hectare

Rainfall : in mm
Yield : in nuts

Months	Districts									Normal
	Trivandrum	Quilon	Alleppey	Kottayam	Ernakulam	Trichur	Palghat	Calicut	Cannanore	
July	210	472	512	524	706	765	595	874	972	703
August	157	306	358	394	431	484	373	602	613	427
September	134	262	261	262	321	258	177	256	235	240
October	229	314	302	270	332	247	285	237	166	306
November	196	245	177	187	178	167	159	165	98	187
December	69	47	50	49	44	33	53	25	23	49
January	22	7	10	9	20	0.5	1	1	6	17
February	24	34	22	29	25	4	7	3	2	18
March	39	53	33	31	23	12	16	10	24	42
April	120	179	131	136	118	59	81	118	41	112
May	201	232	257	220	237	236	144	230	201	245
June	283	498	521	525	625	678	481	757	775	641
Average rainfall	140	221	220	220	255	245	198	273	263	249
Yield	5214	4506	5502	4219	5332	6111	3400	5547	3820	—

Table 2. Correlation between rainfall and yield (District-wise)

Months	Districts								
	Trivandrum	Quilon	Alleppey	Kottayam	Ernakulam	Trichur	Palghat	Kozhikode	Cannanore
July	0.34	0.05	0.25	0.37	0.05	—0.05	0.21	0.03	0.25
August	0.38	0.08	0.25	0.38	0.43	—0.19	0.14	0.21	0.12
September	0.39	0.19	0.50	0.27	0.65x	—0.11	0.12	0.47	0.58
October	0.20	0.04	0.04	—0.26	—0.20	0.53x	0.19	—0.00	—0.12
November	—0.31	—0.29	—0 34	—0.52x	0.09	0.45	0.04	—0.45	0.37
December	0.18	0.40	0.11	0.40	0.13	—0.24	0.39	0.02	0.15
January	0.61x	0.42	0.58x	0.37	0.77x	—0.09	0.12	—0.22	0.63
February	0.34	0.02	0.41	0.07	0.67x	—0.22	0.15	0.29	0.32
March	0.60x	—0.10	0.16	—0 07	0.38	—0.27	0.24	0.03	0.61x
April	0.68	0.45	0.31	0.41	0.12	—0.24	0.75x	0.41	0.46
May	0.27	0.42	0.25	0.04	0.25	0.33	0.44	0.20	0.24
June	0.26	0.04	0.09	—0.20	0.56x	0.05	0.79x	0 11	0.28

x Significant at 5% level

Table 3 Regression of yield (nuts per ha) on monthly rainfall (mm)

Regression coefficient	District								
	Trivandrum	Quilon	Alleppey	Kottayam	Ernakulam	Trichur	Palghat	Calicut	Cannanore
b_1	5.114x	0.203	3.141	1.553	1.357	— 0 653	— 0.305	0 022	— 0.816
b_2	—1.944	— 0.698	—2.927	—0.593	1.128	1.394	0.622	0.176	0.022
b_3	0.314	— 1.970	4.547	2.666	0.218	— 0.291	0.265	2.488	0.311
b_4	3.741x	— 5.939	—1.635	—0.884	0.608	1.325	0.190	— 0.957	0.632
b_5	—6.706x	1.317	1.226	—4.234	— 0.013	3.174	0.512	— 0.287	3.593
b_6	7.880x	6.646	0.680	—7.052	—1.404	0.514	0.612	4.108	— 3.685
b_7	15.823x	47.414	37.834	3.407	20.006	44.570	0.765	—98.353	—14.787
b_8	49.524x	—21.128	—1.869	—8.021	—8.545	—58.672	—3.819	—47.304	38.303
b_9	—27.160	3.600	—4.732	—15.952	—17.758	3.167	—3.634	—15.075	9.101
b_{10}	— 5.139	11.438	2.062	7.975	4.348	— 2.354	4.281	2.242	7.512
b_{11}	2.148x	1.210	2.574	1.444	0.265	1.545	1.624	0.389	0.850
b_{12}	1.511	—0.996	—2.408	1.183	0.731	0.645	0.488	0.306	—0.264
b_0	3560	4722	4153	2994	2876	4664	2406	4766	3679
R^2 (%)	99.780	83.997	93.393	94.615	93.954	88.642	87.928	69.572	93.567
R	0.999	0.917	0.966	0.973	0.969	0.942	0.938	0.834	0.967

* Significant at 5% level

significant. Regression coefficients corresponding to July, October, November, December, January, February and May rainfall gave significant contribution to the variation in yield of which the November rainfall was found to have a negative effect.

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Influence of rainfall on coconut yield

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ABSTRACT

The total rainfall for five month periods and the annual nut yield of Kerala State were used to find out the relationship between them. The total rainfall for the five month periods of 16th to 20th and 4th to 9th months were found to be negatively correlated. A multiple regression was worked out using the rainfall series of the two periods for estimating annual coconut yield.

Introduction

It is well known that a considerable portion of the interannual variation in coconut production is due to the variation in climate. Of all the climatic factors that influence the yield, rainfall is perhaps the most important. As reliable crop yield forecasts are of paramount importance to planners, an attempt is made in this paper to study the association between rainfall and coconut yield with a view to develop some statistical relationship by which the yield could be predicted.

Materials and Methods

The data on cocount yield and monthly rainfall for the period 1960-61 to 1980-81 collected from the Bureau of Economics and Statistics were used for this study. These yield series give the total yield for the whole state for the 12 month-period from July to June, while the rainfall data are the monthly averages for the whole state preceeding the year of harvest.

Taking a month as unit of time, mean monthly rainfall for the state for 24 months preceding July of the harvest year was used. In other words, for the yield of the year 1961, the monthly rainfall from July 59 to June 61 was considered. Simple linear correlation coefficients between yield and monthly rainfall and also rainfall for overlapping periods of two to twenty four months were worked out. Based on the rainfall series of the two periods, a multiple regression equation was obtained for estimating the annual nut yield.

Results and Discussion

The total and average rainfall for five month-periods for 1954-'81 and annual coconut yield of Kerala are given in Table 1. It can be seen that the inter-annual variation in yield was of the order of 10%. The highest correlation coefficient between the yield and the average monthly rainfall for the state was —0.6272 and that was for the 20th month prior to harvest. The next highest was —0 5986 which was for the 8th month prior to the harvest year. Both happen to be the month of November. Of all the sets of correlations for the various periods, the one with highest magnitude was—0 6752 and the next highest one was —0.6732. The

Table 1. Total and average rainfall for five month—periods and annual coconut yield of Kerala, 1954—'81

Year	Yield in Mil. nuts.	Total rainfall		Average rainfall	
		Oct-Mar 4-9	Nov-Mar 16-20	Oct-Mar 4-9	Nov-Mar 16-20
1954	3042	744	242	124.0	48.4
1955	3076	569	319	94.8	63.8
1956	3099	684	250	114.0	50.0
1957	3182	614	325	102.3	65.0
1958	3199	630	249	105.0	49.8
1959	3248	468	329	78.0	65.8
1960	3365	465	258	77.5	51.6
1961	3220	712	259	118.7	51.8
1962	3247	519	468	86.5	93.6
1963	3305	722	257	120.3	51.4
1964	3262	513	239	85.5	47.8
1965	3273	602	235	110.3	47.0
1966	3293	588	266	98.0	49.2
1967	3425	754	396	125.7	79.2
1968	3593	434	346	72.3	69.2
1969	3834	381	247	63.5	49.0
1970	3956	478	192	79.7	38.4
1971	3981	432	239	72.0	47.8
1972	4054	327	152	54.5	30.4
1973	3921	646	120	107.7	24.0
1974	3703	452	277	75.3	55.4
1975	3712	295	175	49.2	35.0
1976	3439	680	159	113.3	31.8
1977	3348	616	278	102.7	55.6
1978	3053	884	390	147.3	78.0
1979	3211	653	421	108.8	84.0
1980	3032	589	488	98.2	97.6
1981	3008	514	387	85.7	77.4

first one is for the 5month-period from the 4th to the 9th (both inclusive month prior to harvest. Both these periods happen to be from November to March of the year prēvious to and in the year of harvest, respectively. It is seen that the years with larger amount of rainfall in November during the first period (ie. from November to March) prior to the harvest was closely associated with a reduction in yield. The reduction was more when the distribution was similar in the 2nd period also. Using the total rainfall series for the two periods, multiple regression equation was computed and is given below.

$$Y = 4225.6 - 1.204\ X_2 - 1.67\ X_3$$

Where, Y—is the yield of coconuts in millions,

X_2—is the total rainfall for the period 16th to 20th prior to harvest and

X_3—is the total rainfall for the period 4th to 9th month before harvest.

The multiple correlation coefficient is 0.8139 which accounts for about 66 per cent of the total variation in the yield. The standard error of the estimate worked out to be 204 million.

The deviations of the estimated yield from the actual one were not appreciable except in the years 1963, 1964, and 1965. Even in these the deviations were just about 10% of the actual.

Effect of weather parameters on the productivity of coffee and pepper in Wynad

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ABSTRACT

The intensity and distribution of summer showers in any year determined to a considerable extent the crop prospects of both coffee and pepper in that particular year. While coffee required adequate quantities of rainfall at the two critical periods of blossoming (February-March) and fruit set (March-April), a dry spell from February to April should prevail for satisfactory spiking in pepper. In an year of poor or no summer showers, coffee yield was considerably reduced whereas pepper yield was satisfactory (1981 and 1984). On the other hand, fairly high summer rains resulted in high yield of coffee and low yield of pepper (1982, 1083 and 1985). Satisfactory yield could be expected from both the crops in the event of receipt of moderate blossom and backing showers with a fairly long dry spell. Mixed cropping of coffee and pepper is, therefore, more suited to areas like Wynad in stead of mono-croping with coffee or pepper to ensure reasonable net returns from a unit area.

Introduction

Mixed cropping of coffee and pepper is widely prevalent in the sub-mountainous region of Wynad in Kerala. Both these crops are grown under rainfed conditions. Rainfall seems to be the most significant among the various factors influencing flowering and yield of these crops. Blossom showers of 20 to 40 mm during February-March and backing showers of 50 to 75 mm during March-April are considered to be critical for flowering and fruit set in Robusta coffee. Failure of any one of these two showers results in poor crop yield (Coffee Guide, 1985). Scanty blossom showers may give rise to 'Padding' or shanking of spikes resulting in crop loss according to Krishnamoorthy (1986). The beneficial effect of summer rains on the yield of coconut and oil palm have also been reported by Patel (1938), Gardner *et al.* (1952) and Prasad Rao (1984). On the contrary, pepper requires a short spell of drought during summer months preceding to flowering in June–July (Pillai, *et al.*, 1985). Ridley (1912) reports of profuse blooming and fruiting of pepper vines in Sumatra after a continuous drought period of eight months. With these in view, an attempt has been made on the distribution pattern of summer rains and its influence on the yield of coffee and pepper.

Materials and Methods

Yield data of a 37-year-old (planted in 1949) Robusta coffee garden for ten years and a 14-year-old (planted in 1972) Panniyur-1 pepper garden for 7 years recorded at the Regional Agricultural Research Station, Ambalavayal in the sub-mountainous region of Wynad, Kerala were analysed in relation to rainfall with particular reference to summer showers.

Results and Discussion

The monthly rainfall and number of rainy days from 1976 to 1985 are presented in Table 1. No blossom showers were received in 1976 and 1983 which resulted in low per hectare yield of 172 kg and 315 kg of cured coffee beans during the ensuing cropping season (Table 2). Comparatively higher yields of 684, 753 and 811 kg per ha were obtained in 1977, 1981 and 1984, respectively. In all these years, adequate quantities of blossom and backing showers at critical periods were received. In respect of other years, the rainfall was low and erratic which resulted in moderate yields.

With respect to pepper (Table 3) in 1984, no drought condition was experienced as rainfall was received in all the months from January to June. A total of 244.5 mm rainfall was received in 26 days in March-April. In May also 144.1 mm rainfall was received in 14 days. This resulted in very low per hectare yield of (185 kg) dry pepper in that year. As against this in 1982, there was no rainfall in January–February and the month of March was also practically dry since the rainfall was very scanty (40 mm in 6 days). After this drought period, good rains were obtained from third week of April to August and this resulted in the maximum yield of 3599 kg of dry pepper per hectare in that year. So also, the total rainfall recorded in March-April 1985 was only 168·8 mm in 16 days and the yield recorded was 2966 kg/ha. In 1983 also the rainfall was low in March-April and the yield was high (2372 kg/ha). As only partial drought conditions prevailed in March-April of 1980, 1981 and 1982 the yield was moderate.

The study revealed that the quantum and distribution of summer rains influenced the crop yield of both coffee and pepper to a considerable extent and their effect was antagonistic. The mean per hectare yield of coffee and pepper from 1979 to 1985 are given in Table 4. The maximum coffee yield was obtained in 1984 (811 kg/ha) whereas pepper yield was very low (185 kg/ha). The pepper yield was comparatively low (956 kg/ha) while coffee yield was high (753 kg/ha) in 1981 since no drought condition was experienced during the summer months. Similarly in 1982, a bumper pepper yield was obtained (3599 kg/ha) while the coffee yield was only 514 kg/ha.

The failure or excess of summer showers in a monocropping system will have disastrous effect on the economy of the farmer. In a situation where the crop prospects of coffee and pepper depend upon the vagaries of nature, it is advisable to go in for a mixed cropping system wherein a minimum return can be expected per unit area of land.

Table I. Monthly rainfall (mm) and number of rainy days/month from 1976 to 1985.

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual total (mm.)
1976	0	0	0	91.2 (19)	229.0 (4)	348.0 (16)	761.0 (28)	131.3 (24)	331.0 (11)	92.4 (11)	57.0 (10)	0.6 (1)	2041.5
1977	0	29.0 (2)	88.4 (3)	51.1 (11)	86.1 (16)	145.3 (21)	230.1 (23)	76.7 (18)	76.7 (16)	133.8 (16)	38.5 (11)	0	955.7
1978	0	13.0 (3)	24.0 (5)	31.6 (6)	95.1 (15)	205.3 (28)	217.4 (30)	169.0 (30)	30.6 (5)	47.5 (10)	83.2 (7)	30.7 (4)	947 4
1979	0	15.6 (5)	4.4 (2)	57.7 (10)	203.2 (11)	458.7 (20)	518.2 (24)	510.2 (17)	212.0 (21)	102.4 (12)	143.6 (13)	0	2226.0
1980	0	0	65.2 (7)	208.5 (14)	193.9 (18)	634.4 (29)	638.0 (31)	277.4 (31)	157.9 (19)	230.1 (16)	195.8 (11)	0.5 (1)	2601.7
1981	0	3.1 (2)	63.1 (11)	78.6 (10)	181.2 (14)	434.9 (27)	408 5 (22)	460.0 (30)	334.2 (28)	200.6 (17)	59.3 (11)	29.7 (2)	2253.2
1982	0	0	40.0 (6)	78 6 (9)	225.5 (15)	285.2 (21)	363.0 (26)	343.4 (25)	54.6 (13)	149.4 (11)	221.8 (14)	0	1761.5
1983	0	0	1.5 (1)	21.5 (3)	118.2 (12)	277.2 (20)	458.7 (20)	435 4 (24)	179.8 (25)	196.4 (13)	39.4 (4)	53.9 (6)	1782.0
1984	44.4 (7)	109.2 (8)	114.5 (11)	130.0 (15)	144.1 (14)	531.0 (26)	613.8 (27)	174 0 (25)	197.6 (20)	270.6 (14)	19.8 (2)	31.6 (1)	2380.6
1985	13.6 (1)	3.4 (1)	75.8 (3)	93.0 (13)	56.0 (10)	574.6 (27)	178.6 (28)	313.2 (27)	114.5 (20)	109.4 (12)	170.2 (6)	26.2 (5)	1728.5

( ) Indicates no. of rainy days

Table 2. Amount of blossom and backing showers and mean yield of coffee

Year	Blossom showers (February–March) in mm	Backing showers (April–May) in mm	Yield of beans. (kg/ha)
1976	Nil	320	172
1977	117.4	137	684
1978	37.0	126	535
1979	20.0	260	377
1980	65.2	402	368
1981	66.2	259	753
1982	50.0	304	585
1983	1.5	139	315
1984	223.7	274	811
1985	79.2	149	514

Table 3. Rainfall during March–April and mean yield of dry pepper

Year	Rainfall (mm)	Number of rainy days	Yield (kg/ha)
1979	62.1	12	1011
1980	273.7	21	1480
1981	141.7	21	956
1882	118.6	15	3599
1983	23.0	4	2372
1984	244.5	26	185
1985	168.8	16	2966

Table 4. Mean yield of coffee and pepper from 1979 to 1985

Year	Yield of coffee beans (kg/ha)	Yield of dry pepper (kg/ha)
1979	377	1011
1980	368	1480
1981	753	956
1982	585	3599
1983	315	2375
1984	811	185
1985	514	2966

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Effect of rainfall pattern on the yield of pepper (*Piper nigrum* L.)

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ABSTRACT

The rainfall pattern and pepper yields during the two extremely adverse years (1980-81 and 1986-87) were compared to that of a favourable year (1981–82) and it was found that during both the adverse years, there was a distinct break in the rainfall during the critical period following flower initiation. The break was experienced at two different times and therefore at different stages of the crop during the two years, but in both cases, the pepper yields were as low as 24.3% of the normal year's yield. On the contrary, during 1981-82, the favourable year, the precipitation remained steady without any break and the pepper yields were high.

So, it can be deduced that a break in the rainfall for even a few days at stretch occurring during any part of the critical period of reproductive phase of the pepper plant will affect pepper yields considerably.

Introduction

The pepper plant is very sensitive to climatic parameters especially the pattern of rainfall. The stand of the crop as well as the yields are highly dependant on the quantity and distribution of rains. The flowering and fruiting in the plant synchronise with the rainy season indicating the importance of rainfall in this process. Early work at Pepper Research Station, Panniyur has shown that flowering process in the pepper plant is initiated by the application of water equivalent to 70mm or more of rainfall within a period of three weeks, following a dry spell (Annual Report 1953–54). It has also been shown that rainwater is the chief pollen vector in the plant. Results from an irrigation experiment in progress at the station too indicate that a dry spell before the flowering season is advantageous -(Annual Report, 1984). Rema Menon (1981) and Nalini (1983) found that extension growth of plagiotropes started in April-May with the receipt of premonsoon showers and continued upto August-September. It was also found that 82.43% of the total annual growth of the fruiting branches was registered in June-July, coinciding with the peak period of the monsoon. Mathai (1983) found that maximum dry matter accumulation occurred in the branches in April-May ie. just before shoot elongation and flowering. He also found that the rate and quantity of photosynthesis was maximum during June. Studies conducted by Nalini (1983) have shown that during the period of new shoot growth, the total soluble carbohydrates, nitrogen content and C/N ratio in the shoots varied considerably. Rainfall was found to be positively correlated with flower bud differentiation process. Histological examinations conducted by her revealed that flower bud differentiation started in the shoots in April–May with the receipt of premonsoon showers and reached a peak in June-July, synchronising with maximum rainfall and vegetative growth in the plagiotropes. The period required for a flower bud to differentiate was found to be about 20 days. Keeping these in view, an attempt has been made to study the effect of rainfall distribution on pepper yield at the Pepper Research Station, Panniyur.

Materials and Methods

Pepper yields during the adverse years (1980–81 and 1986–87) were collected at Pepper Research Station, Panniyur along with the daily and weekly rainall and compared with the yield of pepper and rainfall distribution of the favourable year 1981-82. The varieties of pepper viz., Panniyur-1 Karimunda and Arakulam munda were selected to study the effect of rainfall distribution on the spike and yield characters. The spike and yield characters of five plants per variety were compared.

Results and Discussion

The stages of spike formation and development in the pepper plant with the time taken for each stage are depicted in Figures 1 and 2. It can be seen that the total time taken from the receipt of trigger of showers to early stages of fruit development is about 16 weeks, which is considered as the "critical period" in the reproductive phase of the plant. Therefore, the rainfall pattern during this critical period is of utmost importance in pepper production. The data on weekly rainfall of Panniyur from April to September for the years 1980, 1981 and 1986 are given in Table 1. It can be seen that during the year 1980, 77 mm of rains were received in the first week of April itself (Week No. 14) which triggered of the flowering process in the plants. But, during the next seven weeks, the rainfall was scanty and intermittant. Afterwards, the rainfall was quite sufficient and normal, but the damage done to the flowering process due to insufficient rains during the early stages was not redressed by the ample rains received later.

During 1986, sufficient rains to initiate flowering in the plants were received only by early June (Week No. 23). Then upto the second week of August (32nd week) the rainfall pattern was rather favourable with only two weeks (No.27 and 30) of low rainfall. But from the 33rd week onwards, a comparatively dry period with scanty rainfall persisted upto the end of the critical period. Thus, a period of stress with inadequate rainfall occurred during the critical period of both the years. However, the stress occurred at different stages of spike development during the two years.

Unlike the two years described above, the year 1981 was a normal or favourable one. Trigger off showers were received by the first week (Week No.18) of May and thereafter the rains grew stronger and continued to be so althroughout the critical period and even beyond. As a result, the flowering and fruit formation process progressed without any hindrance.

Fig. 1

Stages of spike development and berry formation in pepper

Summer/drought period — plants in resting stage

↓

70 mm or more rains within three weeks

↓

Lateral shoot growth and flower bud differentiation initiated

↓

20 days

↓

Shoot growth progress and flower bud differentiation completed/in progress

↓

12 days

↓

First few spikes emerge

↓

30 days

↓

Spike emergence continues, emerged spikes elongate flower opening fertilisation

↓

16 days

↓

Spike emergence and development, flower opening and fertilisation mostly completed. Berry formation and development started

↓

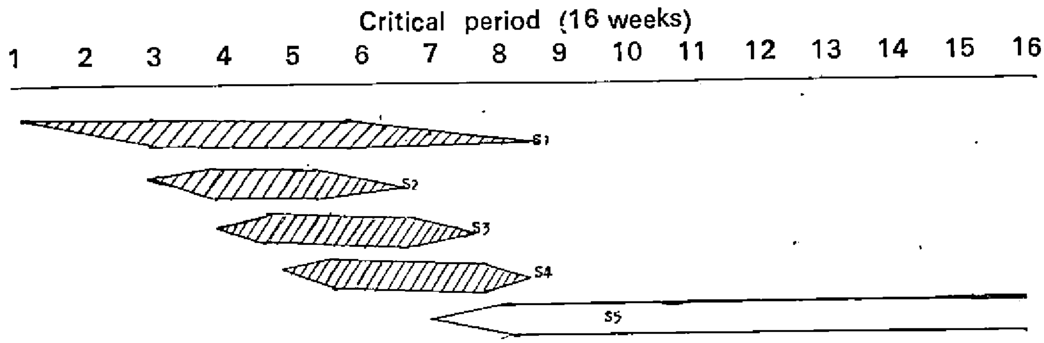
30 days

↓

Spike development, opening and fertilisation of flowers completed. Berry development in progress

108 days (16 weeks)

Fig. 2
Diagramatic representation of overlapping in the stages of
spike development in pepper



S1 — Lateral shoot growth and flower bud differentiation
S2 — Spike emergence
S3 — Spike development
S4 — Flower opening and fertilisation
S5 — Berry formation and development

The effect of the rainfall pattern during these three years is well reflected on the spike characters and yield of pepper plants as can be seen from Table 4. During both the unfavourable years, the number of spikes produced per plant and also the mean weight of a spike in all the three varieties of pepper were substantially low when compared to that of the normal year. Consequently, the pepper yields were also low during these two years. However, the reductions in yield and spike characters of the three varieties during the two abnormal years varied greatly, suggesting the season-variety interaction as reported by Ibrahim *et al.* (1986). The overall reduction in yield was 72.14% during both the abnormal years. This indicates that a stress situation of inadequate rainfall occurring at any time of the critical period can reduce the pepper yields substantially.

As is evident from the data, the contributing factors to this yield reduction were production of lesser number of spikes per plant and subnormal weight of the spikes; which in turn, was the result of shorter spike length and poor berry development as was observed during the unfavourable years. Abortion of undeveloped spikes due to unfavourable climatic conditions has been reported early (Chandy and Pillay, 1979).

During both the unfavourable years, the mean daily rainfall in the stress periods was less than 10 mm for any week. Probably this indicate that the mean rainfall should not be less than 10 mm per day if the stress is to be avoided. Also, the data show that stress occurring during early or late phases of the critical period can reduce crop production substantially. However, the number of days or weeks for which the stress condition should persist to affect crop production is not clearly brought out from the present study.

Table 1 Weekly rainfall data at Pepper Research Station, Panniyur, for three years (1980, 1981 and 1986)

Standard Week Nos.	Week days	1980 (Adverse)		1981 (Normal)		1986 (Adverse)	
		No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)
14	2/4 to 8/4	5	77.0	—	—	—	—
15	9/4 to 15/4	2	5.5	1	4.0	—	—
16	16/4 to 22/4	2	12.0	—	—	—	—
17	23/4 to 29/4	3	38.0	3	39.5	1	6.2
18	30/4 to 6/5	5	68.5	2	54.6	1	23.8
19	7/5 to 13/5	3	24.5	3	83.2	1	1.4
20	14/5 to 20/5	4	23.0	4	72.0	—	—
21	21/5 to 27/5	1	11.0	6	93.5	1	13.0
22	28/5 to 3/6	3	56.5	5	138.5	2	14.5
23	4/6 to 10/6	7	412.0	7	354.4	2	103.8
24	11/6 to 17/6	7	88.0	7	309.0	5	197.0
25	18/6 to 24/6	7	182.0	7	470.0	7	197.2
26	25/6 to 1/7	7	168.5	5	131.0	7	410.0
27	2/7 to 8/7	7	498.6	6	367.2	4	52.6
28	9/7 to 15/7	7	256.1	7	376.7	6	226.2
29	16/7 to 22/7	7	103.2	3	98.0	6	230.7
30	23/7 to 29/7	7	291.5	6	240.7	5	63.4
31	30/7 to 5/8	7	136.3	7	184.5	4	111.8
32	6/8 to 12/8	7	179.6	7	96.3	7	206.2
33	13/8 to 19/8	7	232.6	7	251.1	2	6.0
34	20/8 to 26/8	4	152.5	6	129.6	1	7.6
35	27/8 to 2/9	7	129.0	3	46.0	—	—
36	3/9 to 9/9	7	214.4	1	22.0	4	37.8
37	10/9 to 16/9	1	4.5	3	55.3	2	12.6
38	17/9 to 23/9	3	30.5	7	344.0	3	36.2
39	24/9 to 30/9	7	91.0	7	64.3	6	93.0
Total	(182 days)	134	3486.3	120	4031.4	77	2055.2

Other weather parameters during the critical period of flowering and fruit formation in all the three years are presented in Table 3. A comparison of weather parameters such as mean maximum temperature, mean minimum temperature, relative humidity and hours of sunshine during the stress period shows that mean maximum temperature and hours of sunshine were considerably high during the stress period than the nonstress period in both the unfavourable years. During the nonstress period of these years as well as the critical period of the normal year, the

Table 2. Mean daily rainfall during the weeks in 1980, 1981 and 1986

Std week Nos.	Mean rainfall per day during each week (mm) 1980			1981		1986		
14	11.0		Critical Period	—		—		
15	0.8	Stress Period		0.6		—		
16	1.7			—		—		
17	5.4			5.6		0.9		
18	9.8			7.8	Critical period (No strees)	3.9		
19	3.5			11.8		0.2		
20	3.3			10.3		—		
21	1.6			13.4		1.9		
22	8.1			19.8		2 1		
23	58.9			50.6		14.8		Critical Period
24	12.6			44.1		28.1		
25	26.0			67.1		28.1		
26	24.1			18.7		58.6		
27	71.2			52.5		7.5*		
28	36.6			53.8		32 8		
29	14.7			14.0		32.9		
30	41.6			34·4		9.1*		
31	19.5			26.4		15.9		
32	25.6			13.8		29.4		
33	33.2			36.7		0.9	Stress Period	
34	21.8			18.5		1.1		
35	18.4			6.6		—		
36	30.6			3.1		5.4		
37	0.6			7.9		1.8		
38	4.4			49.1		5.1		
39	13.0			9.2		13.3		

* Stress

mean maximum temperatures were around 30°C, whereas, during the stress periods it went as high as 35.22 and 34.02°C. The hours of sunshine too showed the same trend to a much higher extent. Nalini (1983) also observed a negative correlation between plagiotrope elongation and mean maximum temperature as well as hours of sunshine. However, the maximum temperature as well as the hours of sunshine per day during the monsoon season is greatly dependant upon the quantity and distribution of rainfall and hence the expression of these parameters can be considered only as a consequence of the rainfall pattern. However, the direct or indirect effect of these parameters. if any, is yet to be established. So also, the influence of soil moisture levels on the processes seems to be very little, if at all, as the available soil moisture was plenty althroughout the critical period. A continuously drizzling and wet atmosphere althroughout the critical period seems to be the optimum condition for maximum productivity of pepper.

Table 3 Temperature, relative humidity and hours of bright sunshine during the critical periods of flowering and fruit formation in pepper during the years 1980, 1981 and 1986

	1980		1981	1986		Mean	
Weather parameter	Stress period	Non-stress	Non-stress	Stress	Non-stress	Stress	Non-stress
1 Mean maximum Temperature (°C)	35.22	24.16	33.15	34.02	30.24	34.62	29.85
2 Mean minimum Temperature (°C)	23.87	22.80	25.24	23.21	22.52	23.54	23.52
3 Relative humidity (%)	93.98	97.40	93.56	87.40	90.97	90.54	93.97
4 Hours of sunshine per day	7.02	1.85	1.79	6.15	2.98	6.51	2.21

Table 4. Yield and spike characters of some pepper varieties during the years 1981, 1982 and 1986

	Mean number of spikes per plant					Mean yield of green pepper per plant (g)					Mean weight of a spike (g)				
Cultivar	1981	1982	1986	Mean 81+86	General Mean	1981	1982	1986	Mean 81+86	General Mean	1981	1982	1986	Mean 81+86	General Mean
Panniyur 1	91	703	385	238	393	614	6408	2180	1397	3067	6.74	9.13	5.66	6.20	7.17
Karimunda	927	1812	423	675	1054	1937	5617	1050	1493	2868	2.09	3.10	2.48	2.28	2.56
Arakkulam munda	451	1202	281	366	644.7	1527	4777	850	1188	2384	3.39	3.97	3.02	3.20	3.46
Mean	489.7	1239	363	426.3	697.2	1359.3	5600.7	1360	1359.3	2773	4.07	5.40	3.72	3.89	4.40
Percentage of reduction	60.48	—	70.70	—	—	75.73	—	75.71	—	—	24.63	—	31.11	—	—

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Studies on analysis of rainfall and its impact on Cardamom

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ABSTRACT

Drought and normal and abnormal months were calculated using frequency and probability analysis of rainfall. They accounted for 34.0, 57 7 and 8.3 per cent of the total months, respectively. The drought that prevailed during 1982-83 resulted in as high as 50 percent mortality in some of the cardamom estates. The rains received during normal and abnormal months were of high intensity and resulted in run off. Methods to reutilise the runoff water, measures to combat drought and new schemes to rejuvinate drought–hit cardamom plantations were also discussed in the pepper.

Introduction

Mercara, located at 12°25' latitude, 70°45' E longitude and an altitude of 1130 m falls in the heavy rainfall region receiving a mean annual precipitation of 3174 mm in 154 rainy days. Cardamom, the most important spice crop of the district occupies 68% and 21% of the total area of the crop (20027 ha) in Karnataka, and India (96137 ha) respectively. The national average yield of Indian cardamom is only 60 kg/ha as against 300 kg/ha in Gautemala. One of the reasons for the increased yield in Gautemala is the availability of well distributed rainfall (Mohanchandran, 1984). In India, at present 25 percent of the total area under cardamom is rainfed (Charles, 1986). The aberrant weather conditions that prevailed during the recent years coupled with poor management had resulted in low yields in India. With the denudation of forests in certain areas of western ghats, the normal congenial ecosystem for cardamom has been affected destabilising the ideal cool humid microclimate. The distribution of rainfall is the most critical factor in the region. Hence there is a need for understanding the nature of rainfall distribution by way of frequency and probability analysis and chalk out effective measures to combat drought accordingly for successful cardamom production. The present study deals with the analysis of monthly, seasonal (premonsoon) and annual rainfall.

Materials and Methods

The rainfall data recorded during the period 1981 to 1985 at Mercara (which is the taluk headquarters of Madikeri occupies 78% of cardamom are in Coorg district of Karnataka) were utilised for the study. Variability in rainfall for a given period was worked out based on C. V. (%). The criteria followed for classifying the months as drought, normal and abnormal are as follows:

Drought	:	Monthly rainfall strictly less than half the average rainfall;
Abnormal	:	Monthly rainfall strictly more than twice the average rainfall; and
Normal	:	Monthly rainfall lying between 1 to 2 times the average rainfall including the end points.

The years were classified as abnormal and drought if the annual rainfall was greater than or equal to mean annual rainfall+standard deviation, less than or equal to mean annual rainfall–standard deviation, respectively. The years falling between drought and abnormal years were classified as normal years.

Results and Discussion

The mean monthly rainfall and its coefficient of variation during the period from 1961-1985 are given in Table 1. It can be seen that the percentage contribution of rainfall to the annual during December to March was negligibly small and the coefficient of variation was also high when compared to the monsoon months.

The occurrence of monthly drought and normal and abnormal years during the study period are given in Table 2. It can be seen that January recorded the highest number of droughts (19 drought years out of 26 years) followed by February while July recorded the lowest number of droughts (1 drought year out of 25 years). December to March recorded the highest number of droughts when compared to that of the other months. Sixteen percent, forty percent and twenty four percent of total years had a drought of five months, four months and three months duration, respectively (Table 3).

The important physiological stages like panicle initiation and subsequent growth (forwarding) depend on the receipt of showers during January to May. The failure of showers during this period result in poor growth and crop yield (Ratnam and Korikanthimath, 1985). It was noticed that the meagre rainfall received during January-April in 1964, 1973, 1974, 1979 and 1983 resulted in lesser crop yields. The unprecedented drought during 1983 caused a great set back on the growth and yield of cardamom in Coorg district and the same trend prevailed in other cardamom growing tracts of India. The impact of drought on the extent of damage and loss of crop/returns in Coorg district are given in table 4 (Siddaramaiah, 1986). Prolonged drought in the first six months during 1983 when rain was most needed for cardamom plantations, brought about devastating effect leading to significant crop loss and also considerable plant loss especially in exposed areas. The entire India's production came down to the lowest level of 1600 M. T. which was even less than quantum required for domestic consumption in normal years (Anon. 1986).

Table 1. Mean monthly rainfall and its coefficient of variation at Mercara from 1961 to 1965

Month	Rainfall (mm)	% of the total rainfall	C. V. (%)
January	2.34	0.07	195.2
February	3.02	0 10	287.1
March	21.56	0.68	170.9
April	56.52	1.78	70.8
May	147.10	4.63	62.4
June	587.29	18.50	51.3
July	1025.90	32.32	42.5
August	785.67	24.75	35.5
September	263.46	8.30	39.0
October	189.13	5.96	52.0
November	78.93	2.49	107.2
December	13.22	0.42	129.1
Annual	3174.14		

Table 2. Occurrence of monthly drought, normal and abnormal spells during the period from 1961 to 1985 at Mercara.

	No. of years under		
Month	Drought	Normal	Abnormal
January	19	1	5
February	18	4	3
March	12	10	3
April	6	16	3
May	7	17	1
June	5	20	—
July	1	23	1
August	2	23	—
September	3	22	—
October	6	18	1
November	11	11	3
December	12	8	5

Most of the rainfall received during July would result in run-off leading to excessive soil erosion. It calls for proper soil and moisture conservation measures to allow maximum absorption and at the same time safe disposal of excess rain water by providing adequate drainage. The rainfall received during September-December was 544.74 mm which accounted for 17.16% of the total average rainfall. The rainfall was fairy adequate during September-November in all the years except in the month of November, 1984.

Table 3. Probability distribution of drought, normal and abnormal months in a year and percentage of total years with the given months.

No. of months in a year	Probability of the months of			No. of months in a year	Percent of total years having the same months		
	Drought	Normal	Abnormal		Drought	Normal	Abnormal
8	—	0.40	—	8	—	40.00	—
7	0.08	0.56	—	7	8.00	16.00	—
6	0.12	0.88	—	6	4.00	32.00	—
5	0.28	1.00	—	5	16.00	12.00	—
4	0.68		0.04	4	40.00		4.00
3	0.92		0.04	3	24.00		—
2	1.00		0.28	2	8.00		24.00
1	1.00		0.64	1	—		36.00

Probability worked out upto 8 months in a year. However 1969 and 1979 had 9 months as normal.

Table 4. Impact of drought on cardamom during 1982-83 in Karnataka (after Siddaramaich, 1986)

Sl No.	Name of the unit	Extent of damage in %	Loss of crop/ returns	Extent of drought affected area brought under replantation (in ha)			Special schemes implemented by Cardamom Board
				1983-84	1984-85	1985-86	
1	2	3	4	5			6
Coorg District							
1	Virajpet	50.0%	60.0%	24.60	163.77	90.55	1 Cardamom replanting scheme & Cardamom replanting loan cum subsidy scheme for drought affected areas.
2	Bhagamandala	37.5%	39.0%	94.90	194.28	78.85	
3	Mercara	50.0%	70.0%	74.88	122.77	177.88	
4	Somwarpet	70.0%	37 M. T.	26.05	51.99	63.36	2 Subsidised supply of irrigation pumpset and poly bag nurseries.
Hassan District							
5	Yeslur	38.0%	25.50 MT	73.58	95.22	170.93	3 Increased number of certified nurseries and also increased target of raising seedlings in the Boards departmental nurseries.
6	Sakleshpur	50.0%	65.00 MT	145.50	106.45	98.61	
Chickmagalur District							
7	Mudigere	40 to 50%	75%	106.07	133.20	96.67	4 Financial assistance for drought affected areas under NABARD. Refinance Scheme through Nationalised Banks.
8	Koppa	35%	50%	10.12	48.73	96.64	
9	Chickmagalur	40%	50%	0.60	24.47	41.70	
Uttar Kannada District							
10	Sirsi	40%	20 MT	3.60	7.10	29.58	
	Total			559.90	947.98	884.77	

Conservation of soil moisture during this period is most crucial by resorting to measures like planting cardamom in contours or across the slope, opening check pits, staggered trenches, weeding and adequate mulching etc. This would go a long way in retension of residual soil moisture for sustaining cardamom plants during summer wherein the premonsoon showers would be most frequent and erratic.

Mercara received the lowest rainfall of 2063.30 mm during 1965 and the highest rainfall of 5826.20 mm during 1961. Taking the average annual rainfall during all the years, it was seen that none of the years experienced the drought or the abnormal trend. Since cardamom is a rhizomatus crop, it was observed that the total rainfall did not matter much on the yield but influenced most by proper distribution. This is in agreement with the observation of Subbarao and Korikanthimath (1983) that cardamom yield was influenced more by distribution of monthly rainfall rather than the total rainfall and number of rainy days. In 42 out of 57 cases, more than 100 kg/ha was obtained when annual rainfall was less than 2000mm.

Harvesting and storing of runoff water during the rainy period in suitable structures like farm ponds, tanks and embankments and recycling it during summer as protective/life saving irrigation coinciding with critical physiological stages offer great scope for evading total failure of the crop stand and stabilising the yield of cardamom.

Acknowledgement

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Agrometeorology of coconut in Kerala

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ABSTRCT

An attempt is made in this paper to enunciate the geographical, soil and weather aspects (mainly rainfall) of Kerala and the distribution of plantation crops in different ago-climatic zones. The factors influencing the yield of coconut are also briefly discussed.

Introduction

The influence of rainfall on the distribution, growth and yield of coconut palm in Kerala is discussed in this paper.

Materials and Methods

The statistical data on crop yield and area spread on different plantation crops published by several government agencies at state and centre levels were utilised along with the available published maps of agroclimatic zones and rainfall distribution of Kerala. A detailed analysis has been made using the data.

Results and Discussion

The district-wise annual rainfall of Kerala as percentage of average for the period 1975-1984 are given in Table 1. It can be seen that there was a failure of monsoon in 1982 and it was more severe in the southern disiricts. In contrast, 1981 recorded good rainfall in most of the districts. The rainfall fell below the normal in 1976, 1979 and 1983 (southern districts) while 1975, 1977, 1980 and 1981 (most of the districts) recorded excess rainfall.

The district-wise distribution of plantation crops in percentage is given in Table 2. It can be inferred that coconut was more popular in coastal districts. Kozhikode had the maximum (14 per cent as against 49 per cent in Kerala) cultivated area under coconut. Rubber occupied the second place (17.5 per cent) followed by cashew (10.3 per cent) and pepper (7.9 per cent). And the district of Cannanore had the lion's share of area under cashewnut, arecanut and pepper. The annual yield of nuts expressed as percentage of average yield for the ten year-period for each district is given in Table 3. It can be seen that by and large, the yield was good in the beginning (1975 and 1976) and end (1984) of the ten year period. The year 1983, following the year of monsoon failure, had recorded very low yield in all the districts except Kozhikode and the state average was 82 per cent of the ten

Table 1. District-wise annual rainfall as percentage of average for the period (1975–1984)

Districts	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	10 years Average	Normal (No. of Stations)
Trivandrum	*174*	*71*	140	116	75	98	115	*41*	56	78	1325 (73)	1825 (5)
Quilon	*160*	98	138	72	95	96	95	*72*	66	107	1992 (60)	2779 (9)
Alleppey	*159*	82	138	76	58	117	129	*51*	91	98	2397 (80)	2993 (9)
Kottayam	*148*	90	134	91	58	118	118	*50*	95	108	2399 (69)	3462 (6)
Idukki	*166*	86	118	115	80	115	141	*47*	78	173	2251 (85)	2649 (5)
Ernakulam	*127*	86	115	109	70	118	106	*49*	118	93	2795 (85)	3289 (8)
Trichur	*116*	75	110	101	64	122	121	*73*	101	92	2859 (91)	3159 (6)
Palghat	*136*	72	109	56	72	131	153	*60*	107	104	2173 (91)	2398 (7)
Malappuram	*140*	80	116	108	55	114	N. R.	N. R.	N. R.	64	2597 (90)	2900 (5)
Kozhikode	*155*	86	156	86	70	86	79	*78*	115	92	2997 (82)	3636 (4)
Cannanore	*128*	79	113	110	87	100	110	*65*	103	121	3163 (90)	3526 (5)
Wynad	—	—	—	—	—	—	—	—	100	100	2394 (66)	3635 (2)
State: mms	3527	2043	3087	2323	1935	2861	3007	1455	2319	2676	2524.3	2956 (75)
%	*140*	31	122	92	77	113	119	*58*	92	106	85.4	

Source (i) Statistics for planning 1980, 1983 and 1986 issued by the Directorate of Economics and Statistics.
(ii) Monthly and annual normals of rainfall and of rainy days—1962 IMD.

Table 2 Districtwise distribution of plantation crops (per cent)—1981-82

District	Coconut	Rubber	Cashew	Pepper	Arecanut	Cardamom	Coffee	Tea	District average
Trivandrum	11.0	3.7	4.6	4.9	5.4	0.3	0.1	3.0	7.2
Quilon	12.7	16.4	6.3	9.1	7.2	0.3	0.7	4.6	10.9
Alleppey	9.3	1.8	2.7	4.4	4.6	—	0.0	—	5.7
Kottayam	7.6	26.6	1.0	11.9	4.2	0.1	1.7	6.3	9.8
Ernakulam	9.3	9.8	2.8	6.3	10.1	—	0.4	0.1	7.6
Trichur	8.6	3.9	5.2	3.8	10.8	—	0.0	1.3	6.3
Palghat	3.4	4.7	9.4	1.4	3.9	6.2	4.1	1.9	4.2
Malappuram	8.7	8.1	14.6	3.7	14.3	0.3	—	0.5	8.1
Kozhikode	14.5	2.6	3.1	12.6	8.7	0.8	—	—	9.4
Cannanore	11.6	4.8	48.6	23.9	24.5	2.3	—	—	14.6
Wynad	0.5	10.3	0.7	6.8	2.2	6.9	84.7	15.1	7.0
Idukki	2.6	7.3	0.9	11.3	3.9	82.9	8.3	67.3	9.1
Total Area (Ha)	666618 (48.9)	237769 (17.5)	139960 (10.3)	108242 (7.9)	61251 (4.5)	54516 (4.0)	57949 (4.3)	35625 (2.6)	1361930 (100)

Source: Bureau of Economics and Statistics, Trivandrum.

Table 3. Annual yield of coconut expressed as percentage of average for ten-year period

District	Annual yield as percentage										Average yield (No. of nuts)	
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984		
Trivandrum	119	104	87	104	98	99	99	78	81	130	4866	(10.5)
Quilon	123	104	101	99	98	105	105	93	74	59	4023	(8.7)
Alleppey	107	100	92	109	101	90	92	114	74	119	5170	(11.1)
Kottayam	127	103	96	90	97	94	100	114	77	102	3908	(8.4)
Ernakulam	101	90	92	103	99	103	105	101	81	125	5231	(11.3)
Trichur	97	112	103	108	100	105	106	102	90	78	6097	(13.1)
Malappuram	103	120	95	125	116	104	100	101	63	73	4258	(9.2)
Kozhikode	101	103	99	103	90	91	83	115	100	115	5324	(11.5)
Cannanore	87	100	114	105	92	109	86	95	86	125	3914	(8.4)
For the state as a whole											4279 4643.6	(9 2)

Source: Bureau of Economics and Statistics, Trivandrum.

year average. The year of drought (1982) recordad bumper yield in Alleppey, Kottayam and Kozhikode. The lowest yield (78 percent) was observed in Trivandrum. The remaining seven years commencing with 1976-77 showed a state average varying from 97 to 105 per cent of the ten year average.

The differential behaviour of yield-in districts may be attributed to the variation in weather factors and especially rainfall, temperature and humidity between the districts during certain critical phytophases of coconut palm in different soils. The study of interaction between weather, palm trees and soil depends on the availability of reliable data, village-wise or taluk-wise.

Rainfall is probably the most important weather factor influencing the yield and quality of nuts. Since the crop is produced throughout the year, ideally speaking, the palm should never undergo severe water stress. The optimum total annual well distributed rainfall lies between 1300 and 2300 mm although the tree will tolerate a far higher rainfall provided soil drainage is good. Special enviornmental conditions such as seepage of ground water through a plantation; coastal beach plantings backed by rainfed fresh water swamps and lagoons with swamp water percolating towards sea may often compensate the uneven distribution of annual rainfall. The highest yields have been found under such specialised ecological conditions with fresh water carrying traces of mineral nutrients to coconut trees growing in almost sterile sands.

The impact of drought depresses the yield of nuts harvested ten months to three years after the occurrence of drought, while that of yield of copra weight per nut shows a lag of six to eighteen months. This again will depend upon the duration and time of occurrence of drought. Patel and Anandan (1936) pointed out that severe drought at tne time of initiation of inflorescence caused the flowers to abort. In Malaya Cooke (1953) found that rainfall in the first three months, when the nuts were developing, determined the size of the crop a year later.

Many investigations have been carried out to establish the relationship between rainfall and nut yield and to forecast the yield. There is not much agreement with the results obtained and some of the important reasons are:

1 Not applying the appropriate statistical technique.
2 Too short a series of data.
3 Not taking into consideration.
   a) the soil factors nameiy soil profile, texture, water holding capacity infiltration rate, water logging and water table.
   b) agronomic practises—density of population, soil cover, loss by evapotranspiration. interline vegetation such as tapioca, pineapple and cocao and presence of weed.
   c) ground truth, mainly soil moisture profile and water balance.
   d) other weather factors mainly temperature and the diurnal range, light intensity, wind, evapotranspiration and physiological water balance.

Other weather factors affecting the coconut are temperature, wind, light ntensity and evapotranspiration.

The optimal mean temperature lies around 27°C with a diurnal range of 6°—7°C. Such conditions are usually met with in tropical sea coast where the ocean acts as a buffer against rapid changes in diurnal temperature.

The coconut grown in coastal area are exposed to strong sea wind which may uproot the tree or the crown may break off. The salt spray may get deposited on leaves leading to reduced yield.

The coconut palm, being a light loving species, does not grow well in shade or very cloudy conditions. Yield gets reduced with less than 120 hours of bright sunshine per month.

The technique for agrometeorological crop monitoring and forecasting is spelt out in FAO plant production and protection paper 17 (Frere and Popov, 1979).

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SESSION VI

Panel Discussion

Chairman : Dr. A. R. SUBRAMANIAM

Rapporteurs : Dr. (Mrs.) P. SARASWATHI
Dr. V. S. KORIKANTHIMATH

The panel discussion on agrometeorological techniques was convened by Dr. G. S. L. H. V. Prasada Rao at 3 p. m. on 13-3-87 with the following objectives:

1 To bring out a definite approach in agrometeorological research with reference to plantation crops. and

2 To provide guidelines for the young scientists who are working in the field of agrometeorology of plantation crops.

The Chairman, Dr. A. R. Subramaniam stressed the importance of this particular panel discussion which would provide a base line for strengthening research activities in the field of agrometeorology of plantation crops. He pointed out the need for using remote sensing technique in agrometeorological research. The following distinguished scientists were invited to share their in-depth knowledge.

Dr. P. S. Sreenivasan	Dr. R. C. Mandai
Dr. V. Ranganathan	Dr. V. Rajagopal
Dr. O. P. Bishnoi	Dr. Mohd. Yusuf
Dr. S. Jayaraj	Dr. G. S. Sulikeri
Dr. M. Aravindakshan	Dr. S. T. Nagaraj
Dr. A. G. G. Menon	Dr. M. M. Koshy
Dr. P. B. Pillai	Dr. K. E. George
Dr. K. V. Satheesan	Sri. R. C. Dubey

The guidelines which emerged out of the discussion are the following:

1 A multi-disciplinary approach is necessary in the formulation of agrometeorological research programmes.

2 A clear distinction should be made between tree crops and annual crops, in order to have a proper understanding of these two categories of crops while taking up agrometeorological research.

3 Intimate knowledge of a crop is necessary in order to arrive at proper interpretation of agrometeorological data.

4 Weather factors should be considered in relation to the different phases of plant growth and not with the ultimate yield factor alone.

5 The relevance of crop management in relation to crop-weather studies should be properly understood.

6 A reorientation in agrometeorological research is needed taking into consideration system approach in agriculture.

7 Establishment of agrometeorological observatories in all the crop research stations is an immediate necessity and proper data collection should be made obligatory.

8 A clear definition of the agroclimatic zone and classification of the zones on a scientific basis appear necessary.

9 Crop yield data of a plantation crop must be taken into consideration (for example, it takes about 12 to 20 years in coconut for attaining stabilised yield period and the yield declines after the palm attains 60 years) during its prime yield period. This factor must be borne in mind while taking up agrometeorological research studies in different plantation crops.

10 Lag periods must be worked out between prevalance of weather and its impact on final crop yield,

11 Though several phases are seen from germination to final crop yield, certain crop phases are critical to abnormal weather conditions which ultimately decide yield. These critical phases must be found out and prediction models worked out.

12 Appropriate statistical techniques should be applied for crop-weather relationships taking the soil factors, agronomic practices and soil moisture profile into consideration. Fisherian regression integral technique and regression function with selected periods which are critical to weather parameters may be employed for accurate yield forecasting.

13 Agroclimatic zonation of each plantation crop should be developed so that microclimatic zonation can be defined for varietal distribution.

14 Weekly crop-weather bulletins for farmers may be popularised for a better understanding of the yield variations in Farmers' fields.

15 Each research centre should maintain an agroclimatic data bank (phenological biological, pest and disease epidemics and weather parameters).

16 Weekly water balance of each plantation crop have to be studied year-wise. Surface run-off water may be used during drought periods by collecting it in ponds.

17 Pest and disease forecasting studies for each crop should be intensified.

18 Crop biophysical models of plantation crops may be developed where interactions of crop-soil-atmosphere are better defined rather than using empirical statistical models.

19 Data on agroclimatic equivalents of plantation crops need to be generated which are lacking at present.

20 Radiation environment of plantation crops should be studied in depth for improving crop productivity by exploiting thermal environments.

21 Studies on agricultural drought and methods to mitigate its adverse effects for individual crops should be taken up on priority basis as the impact of drought on plantation crops is clearly seen over a long period.

22 Studies on pest and disease surveillance, standardisation of spore trap techniques and uniform method of sampling must be taken up for developing short-term and long-term forecasting models.

23 Crop-weather models should be developed based on plant growth characters and yield.

24 Based on the vast data already available on crop yield and meteorological factors, attempt should be made to fix phytoclimatic potential for different stages of growth.

25 Education and training programmes in this particular field must be intensified at all the Agricultural universities and National Agricultural Research Institutes.

PLENARY SESSION

Chairman : Dr. R. C. MANDAL

Rapporteur : Shri. V. S. PILLAY

The plenary session was chaired by Dr· R. C. Mandal. The Chair persons of different sessions reviewed the papers presented in their respective sessions. Finally, the Chairman suggested that an inter-institutional working groups may be formed for strengthening the agrometeorological research in plantation crops on priority basis. Dr. R. R. Nair, Associate Director, Kerala Agricultural University was nominated by the house as Convener of the working group. The working group will consist of members from the following central and state research institutes.

Kerale Agricultural University
Central Plantation Crops Research Institute
UPASI Tea Research Institute
National Research Centre for Spices
National Research Centre for Cashew
Tamil Nadu Agricultural University
India Meteorological Department
Rubber Research Institute of India
Indian Cardamom Research Institute
Central Coffee Research Institute and
University of Agricultural Sciences, Bangalore and Dharwad.

The session came to a close at 6.05 p. m. after passing a unique resolution that the Indian Council of Agricultural Research and Government of India may be requested for starting an All India Co-ordinated Project on Agrometeorology of Plantation Crops.

The valedictory function took place immediately after the plenary session with the welcome address by Professor P. N. Pisharody, Associate Director.

Dr. M. Aravindakshan, Director of Research in his valedictory address pleaded for greater interaction among scientists in the various disciplines to help solve the location specific problems of crop production. The thrust areas of research identified in the seminar should receive the immediate attention of the research workers, he added.

Dr. A. G. G. Menon, presiding over the function commented the meticulous way in which the entire seminar was organised at a place where the facilities were to the bare minimum. He was happy to note that the presentations in the seminar provided a base for strengthening agrometeorological research in plantation crops at the National level. He thanked the delegates one and all who came all the way from different parts of the country and spent their valuable time during the seminar and contributed their ideas for the development of this particular branch of science.

Dr. A. R. Subramaniam and Dr. V. Ranganathan reciprocated in the same way and thanked the authorities for organising such a seminar which was the first of its kind in India.

With a vote of thanks by Dr. R. R. Nair the seminar came to a close at 6.45 p. m.

An agricultural exhibition was also organised in connection with the National Seminar. □□

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