

Value Addition to Weather Data

Advisory Service to Farmers



Edited by

V. Rajagopal
S. Naresh Kumar


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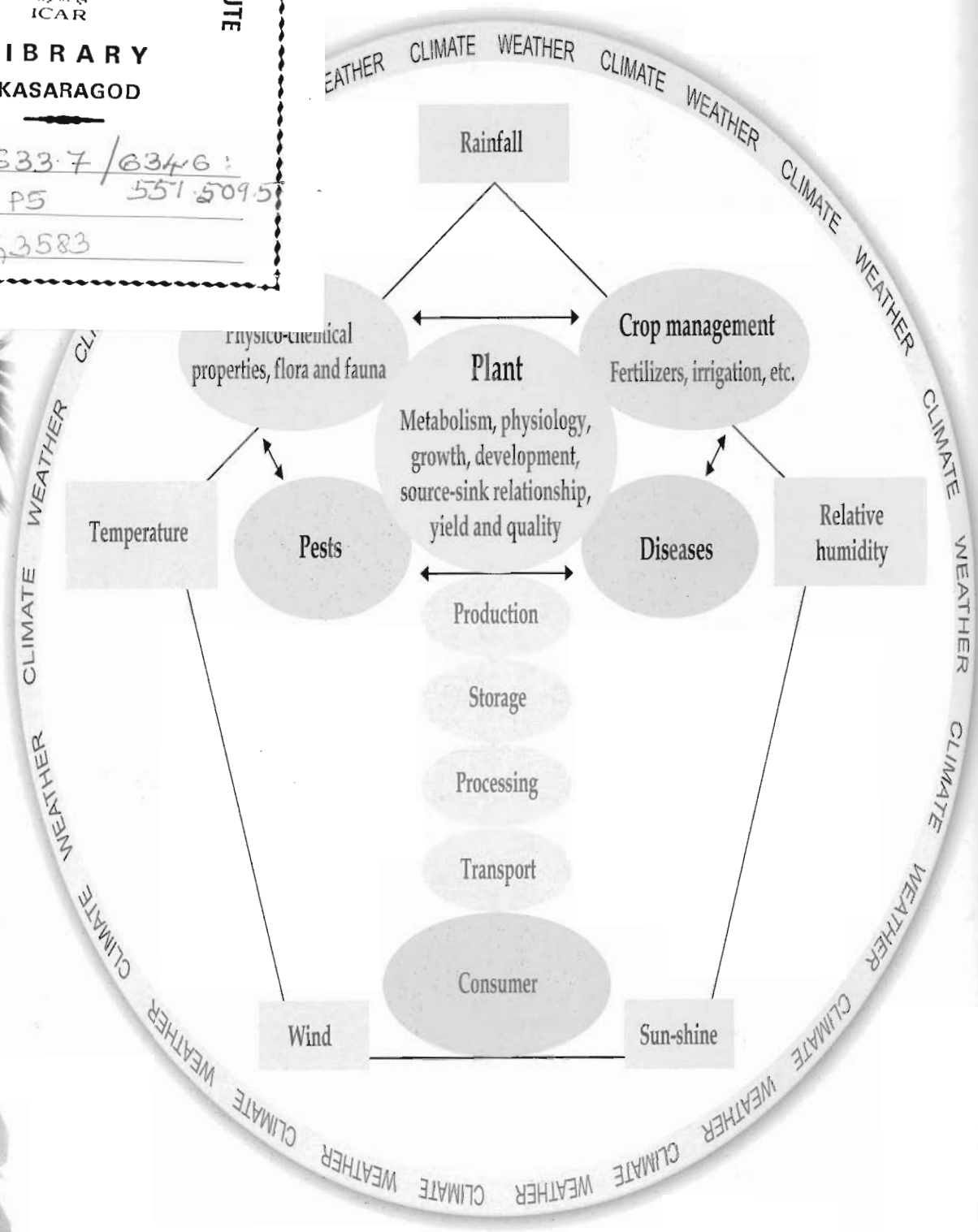
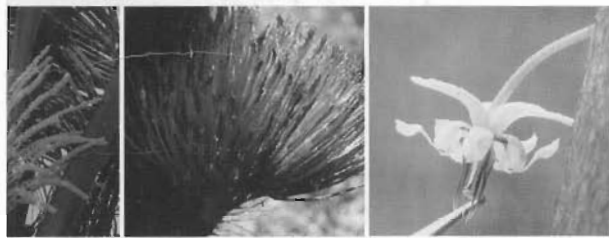
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Our ideas must be as broad as Nature if they are to interpret Nature

Sir Arthur Conan Doyle (1859-1930)
British Author of 'Sherlock Holmes'

मौसम आँकड़ों का मूल्य वर्द्धन
किसानों के लिए सलाहकार सेवा

Value Addition to Weather Data
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V. Rajagopal
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KASARAGOD - 671 124, KERALA, INDIA



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डा. मंगला राय

सचिव एवं महानिदेशक

DR. MANGALA RAI

SECRETARY & DIRECTOR-GENERAL

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Foreword

India is a country endowed with rich biodiversity and bountiful natural resources. The country has distinct agro-climatic zones with characteristic features of both soil and weather. Since agricultural performance is strongly linked to monsoon, any deviation in the rainfall pattern from the normal adversely affects the harvested yield, causing immense economic loss to the farmers. The effect of drought or floods is often compounded by the incidences of diseases and pests on various crops and animal species including fish.



Our Agricultural Research Institutes / Universities, Government Agricultural Departments and other related organizations have established weather stations at the District/Town/Village level. Enormous amount of weather data has been collected over the years throughout the country and is being utilized to compute the fluctuations in important parameters and forecast monsoon. With the advent of the powerful Information and Communication Technologies, the prediction models for drought or diseases are being attempted with reasonable degree of success.

In spite of all the advances made in Agricultural Research and voluminous weather data, the real value in terms of offering right advice at right time to the farmers is sometimes found lacking. This critical lacuna needs to be addressed immediately. In this context, it is heartening to see a publication on 'Value Addition to Weather Data: Advisory Service to Farmers' published by the CPCRI, Kasaragod. It is not only timely but most valuable for the farmers growing plantation crops like coconut. The technologies developed by the Institute like integrated disease and pest management, drought management have been projected in easy to understand language by the farmers. The salient feature is the section on advice to farmers with do's and don'ts reflect on the value added to the weather data and crop data generated by the Scientists.

I appreciate the initiative taken by the Director and efforts made by his colleagues in bringing out such a farmer friendly publication that should also be of use to extension officials, besides researchers and policy planners. I wish the Director, Scientists and Staff all the best in their endeavour to render meaningful service to the farming community.

(MANGALA RAI)

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Message

The agricultural production and the pattern of monsoon are the two inseparable entities, which determine the economic scenario in the country.

The dependence of agricultural crops on weather parameters is so complex that the country has been divided into agro-ecological zones to deal with specific crops in a given agro-climatic condition. Among the weather variables, the rainfall plays a major role as it influences both the soil and plant factors associated with the ultimate yield. The country has been experiencing either drought or floods in one or the other parts to different degrees, leading to enormous crop loss, thereby jeopardizing the livelihood of farming community. In view of the fluctuations in temperature and relative humidity, infestations by pests and diseases further aggravate the crop growth and final harvest. Thus, the farmers are at the mercy of monsoon in the country.



The researchable issues are many in the field of climate change and crop production, while the achievements so far in this important area are much less. Even the data recorded in various observatories on weather related parameters and crop growth and yield on different crops in the agricultural institutes/universities do not really come to the rescue of the farmers at times of grave situation like recurring drought or persistent pests/disease infestations. In other words, integration of weather data with crop performance to arrive at the right decision for facing the contingency situation is yet to be formulated in most of the cases. The farmer should be able to get the right advice when faced with complex problems to save his crop and thus the income. In other words, the research data collected so far should be transformed into advisory mode to bring awareness to the farmers so as to what he actually should take as precautionary / preventive measures when his crops are exposed to adverse conditions.

I am indeed happy that the CPCRI, a premier Institute of ICAR on plantation crops has made concerted efforts to add value to the weather data, linked with crop performance in the field. From this exercise a meticulous system was developed to provide the appropriate recommendation to the farmers in the area to cope up with the adverse situations to the extent possible. The successful implementation of the technologies developed by the Institute for the farmers is an indication of the acceptance and adoption of the recommendations of the Institute. The Institute has taken a right step in documenting the experiences in the publication entitled 'Value Addition to Weather Data; Advisory Service to Farmers'. I am impressed with the specific information as guidance to the farmers included in the publication. I am sure that the farmers in the area would get much needed benefit from this publication along with other pamphlets in different languages, brought out by the Institute. My compliments to the Director and his team of Scientists for keeping the needs of the farmers always in mind and disseminate the information effectively. I wish them all the best.

(G. Kalloo)

Preface



The pivotal role of weather in determining the agricultural production in the country has been well established. In fact, National economy is closely linked to farming activities, culminating in the food production and livelihood of millions of people. Several studies have unequivocally shown that the pattern of monsoon in different parts of the country has direct impact on the production potential of agricultural crops. Every farm operation depends directly or indirectly on the weather parameters like rainfall, temperature, relative humidity etc. Thus, the farmers consider the monsoon as a major factor to undertake all field related activities. So much so, either late arrival of rainfall or early cessation of monsoon, coupled with fluctuations in temperature and relative humidity reflecting on different intensities of drought result in adverse effect on yield of crops. More often than not, the country faces either drought or floods to different degrees causing miserable situations to the farmers. The occurrence of diseases and pests of complex nature on various crops accentuated by changes in relative humidity or temperature add greater dimensions to crop loss. It is in this context that the effective utilization of weather data being collected throughout the country assumes significance in providing appropriate and timely guidance to the farmers.

In recent years, it has been realized that the mere recording of data on weather parameters does not serve the purpose to the aggrieved farmers. What is more important is the value added to the data in terms of their utility to the farmers for planning farm operations. In other words, the farmers should be properly advised based on the weather data in a given location and the crops being cultivated. The scientific data generated on various cultivation practices, management of pests and diseases and weather related operations should be utilized by the farmers in an effective manner, under the guidance of scientists of ICAR Institutes / SAUs.

The CPCRI has been giving major emphasis on weather data related production and protection technologies, as also forecasting in the mandate crops. Based on the development of successful methods, tested both at the Institute farm and in farmers plots through transfer of technology, an attempt is made to document the relevance of value addition to weather data as advisory service to farmers. This compilation, comprising ten chapters, deals with weather requirements of coconut, arecanut and cocoa, weather based cultural practices, relationship between weather and incidence of pests and diseases and their management. Drought management strategies in different agro-climatic zones and forecasting of productivity and diseases based on weather data are the other two important aspects that received good coverage. Keeping in mind the needs of farmers' to face adverse situations, each chapter clearly provided advice to farmers as to what to do and what not do. Such information would serve to build up confidence in farmers to face the challenges posed by vagaries of weather. It is hoped that this publication will be useful to farmers, researchers and farm managers on the three important plantation crops. The chapters are contributed by highly experienced scientists who are specialists in respective disciplines and interacted directly with the farmers in their fields.

V. Rajagopal

(V. Rajagopal)

Director
CPCRI, Kasaragod
Date 23.7.05

Acknowledgements

Indian Agriculture has come a long way in making the Nation agriculturally self-reliant. The 'Green Revolution' led to tremendous increase in food grain production from 1960s. However, the crop productivity seemingly reached a plateau. Apart from this Indian Agriculture is mainly monsoon dependent and increased frequency of weather aberrations have telling effect upon the food grain production in the Country. Successive droughts, floods, heat and cold waves are becoming more frequent. In this connection, in depth understanding of the crop-weather relationship is indispensable to make India a sustainable agricultural platform. Information on crop-weather relationship will help in tailoring the crop management to suit the condition for sustainable production. Thus, this venture is in the direction of documenting the available knowledge on weather based management of three important plantation crops viz. coconut, arecanut and cocoa.

We are extremely grateful to Dr. Mangala Rai, Director General, ICAR and Secretary, DARE for his keen interest in the research activities of the Institute and the Foreword written for this publication. We also express our heartfelt thanks to Dr. G. Kalloo, Deputy Director General (Horticulture & Crop Science) for his constant encouragement and guidance and the Message sent for this publication.

We would like to place on record our sincere thanks to all the authors who have contributed the Chapters with their vast experience in the respective disciplines. The help rendered by Mr. M.S. Rajeev, SRF, while correcting the proof is specially acknowledged. Timely assistance provided by Mrs. C. Leela, Personal Assistant, Plant Physiology, Biochemistry and Post-Harvest Technology Division is thankfully acknowledged. We sincerely acknowledge the support and suggestions of the Institute Publication Committee, the timely help rendered by Project Monitoring and Technical Cell, Photography Unit, Krishi Vigyan Kendra, Stores section, and Administration and Accounts Divisions. Our special thanks are due to the staff of Plant Physiology, Biochemistry and Post-Harvest Technology Division.

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कृषतो नास्ति दुर्भिक्षं जपतो नास्ति पातकम् ।
मौनिनः कलहो नास्ति नास्ति जागरतो भयम् ॥

For one who cultivates the field there is
no lack of food; for one who prays there is no
fall; for one who keeps silence there is no
quarrel; for one who is (ever) alert there is no
danger.

--- Nītiśāstrā



किसलयानि कुतः कुसुमानि वा
क्व च फलानि तथा वनवीरुधानम् ।
अयमकारणकारुणिको यदा
न तरतीह पयांसि पयोधरः ॥

When (even) this selflessly sympathetic
cloud rains not, how then is it possible for the
wild plants to put forth their sprouts, blossoms
and fruits!

--- Bhōjaprabandha of Ballāla

कृषिवृष्टिसमायोगाद् दृश्यन्ते फलसिद्धयः ।
तास्तु काले प्रदृश्यन्ते नैवाकाले कथंचन ॥

Good crops are obtained by a
combination of efficient farming and good
rains; they too can be obtained only in the
proper season, and never are they seen in
unseasonable time.

--- Matsyapurānam



काले वर्षतु पर्जन्यः । पृथिवी सस्यशालिनी ।
देशोऽयं क्षोभरहितः । ब्राह्मणाः सन्तु निर्भयाः ॥

May there be timely rains
May the earth be lush green with vegetation
May this land be violence-free
May the seekers of knowledge be fearless

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Chapter 1: Introduction

V. Rajagopal, K.V. Kasturi Bai and S. Naresh Kumar

The knowledge on crop-weather relationship will be of immense use in planning strategies for improving the production and productivity of crops by better land use planning, crop zonation and situation-oriented adaptations. A thorough knowledge on crop-climate relationship will help in minimizing the crop loss due to the vagaries of nature by implementation of mitigative strategies and thereby in overcoming the extreme weather situations. Weather data are being increasingly used to develop the models to forecast the crop yields and occurrence of diseases and pests.

In India, plantation crops viz. arecanut, cashew, cocoa, coconut, coffee, oil palm, rubber, tea, etc. and spice crops like black pepper, cardamom, clove, etc. are grown in large areas of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, West Bengal and Assam. Among these, coconut, arecanut and cocoa plantations provide sustenance to the millions of the farmers across these states. The area, production, productivity and export earnings of these three crops are given below.

Table 1.1: Statistics on coconut, arecanut and cocoa in India.

Crop	Area (million ha)	Production	Productivity	Export earnings (million rupees)
Coconut ¹	1.913	12,141.2 million nuts	6345 nuts/ha/year	2507
Arecanut ²	0.313	3.79 lakh tonnes	1210 kg/ha	45
Cocoa ³	0.0178	10,200 tonnes	5.6q/ha	11.42

Source: Directorate of Economics & Statistics, Ministry of Agriculture, Government of India; Directorate of Cashewnut and Cocoa Development

¹2002-03; ²2001-02; ³2002-03.

Plantation crops are perennial in nature and are exposed to variable weather conditions during their life cycle. Thus, weather plays an important role in

productivity of these crops. Among the different weather parameters rainfall, humidity and temperature play a major role in deciding the crop productivity. As regards rainfall, the quantity and distribution are important. The yields of plantation crops are affected if there is a wide deviation in weather from the normal requirement. The weather not only affects the productivity directly but also indirectly by influencing the incidences of pests and diseases.

It is well known that Indian agriculture is mainly dependent on South-West monsoon, thus making the food grain production directly dependent on monsoon. Several climate models are in operation for forecasting the onset of monsoon. However, the degree of accuracy in forecasting is still to be improved. India is divided into six major zones based on the moisture regimes. Further, it is classified into eight zones based on soil type and climate. Later, it is classified into 15 agro-climatic zones by the Union Ministry of Agriculture. Indian Council of Agricultural Research classified India into 129 zones. On the basis of quantity of rainfall received, India is classified into five divisions. Average annual rainfall of India is 850 mm which has been recorded from 306 Stations. Per cent variability of annual rainfall is 22 to 30 while monthly variability for rainfall is 50 to 80 per cent. In most parts of India annual rainfall is less than 750 mm. Recurrence period for high deficit rain is 3 to 7 years.

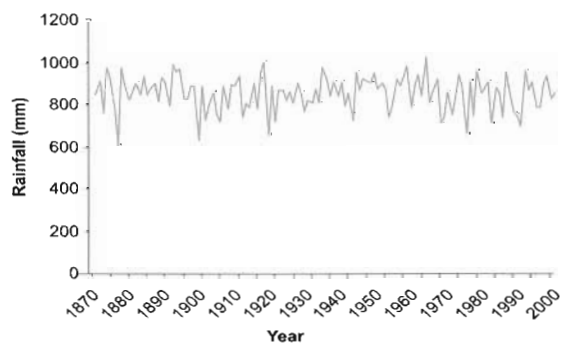


Fig. 1.1: Rainfall in India from 1870 to 2000 (Source: Parthasarathy, 1998 and IMD, Pune).

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The South-West (SW) monsoon, North-East (NE) monsoon and summer showers (March & April) are major rain fall source of the country. The time of early on set of South-West monsoon is last week of May to first week of June and North-East monsoon sets in the middle of October. The SW monsoon progresses gradually to North-East and North-West by the second fortnight of July. By this time in normal years, it covers almost the entire country. However, aberrations in monsoon like delayed onset, poor progress or early withdrawal of monsoon result in less rainfall situation leading to droughts in most parts of the country. Drought year is defined as the year in which rainfall is less than 80% of the normal. Based on the extent of deficit in rainfall, the drought situation is broadly classified into 'moderate' and 'severe'. In a vast country like India with large spacio-temporal variations in annual precipitation, it is difficult to categorize the areas affected by drought. Nevertheless, there are valuable data to indicate the drought years in the country as a whole, where both moderate and severe droughts occurred simultaneously but at different locations. There are classic examples of both being severe in 1899 with 68.4% of total area in the country being affected. Of this, 44.1% area was moderately affected while 24.3% area was severely affected. It was also reported that in years like 1918 (70% of total area), 1932 (40.4%), 1987 (23.7%), etc. droughts caused havoc by severely affecting the food grain production in the country. In some years like 1951, 1966, 1979, the country experienced moderate drought. However, in all these years economy is affected due to adverse impact on agriculture.

In India the normal rainfall varies from less than 500

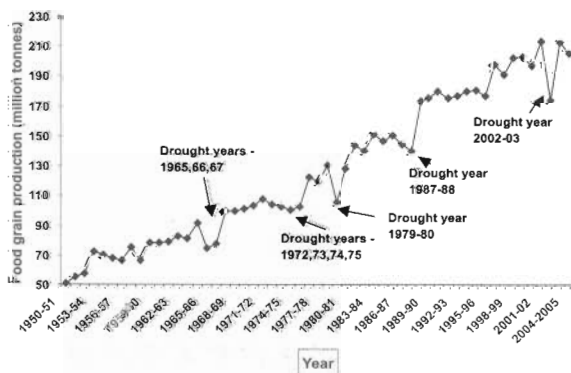


Fig. 1.2: Food grain production in India after independence.

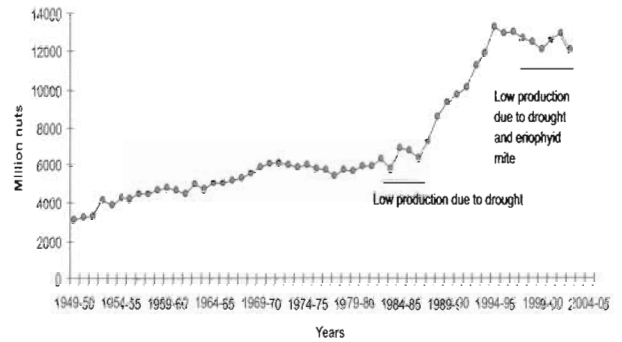


Fig. 1.3: Coconut production in India after independence.

mm in parts of Rajasthan to 3,600 mm in Kerala. Apart from this, distribution of rainfall is crucial for agriculture. Deficit in annual rainfall or deviation from normal is not only limited to low or medium rainfall zones, but even in high rainfall areas in Kerala, such variations do occur. As per classification, Kerala comes under heavy rainfall zone. Northern Kerala receives maximum rainfall during SW monsoon which is around 84 per cent. Only 7.4 per cent rainfall is received during NE monsoon and the rest received during off season. On the other hand, Southern Kerala receives

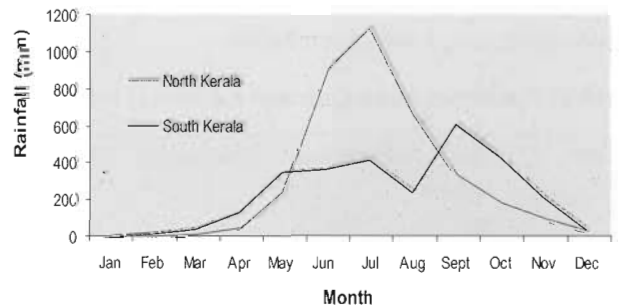


Fig. 1.4: Spatio-temporal variations in rainfall pattern in Kerala.

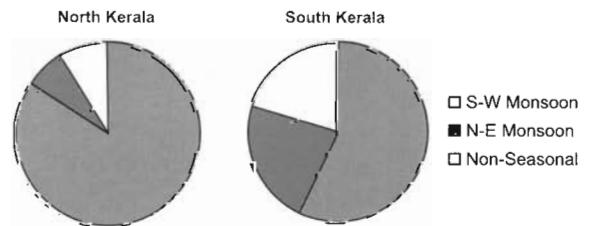


Fig. 1.5: Distribution of South-West and North-East monsoon and summer rainfall in North and South Kerala.

maximum rainfall during SW monsoon which is around 57 per cent and 22.5 per cent of total rainfall received during NE monsoon while the rest 20.5 per cent is received as off season rainfall. Due to this well distributed rainfall, the plantation crops experience less moisture stress in South Kerala. Whereas, in North Kerala summer dry spells cause moisture stress periods. Thus, even in a high rainfall zone, wide variations occur reflecting on yield differences of sensitive crops. All the above indicate wide variations in quantity and distribution in rainfall across the country.

The extreme weather conditions affect not just the physiology of crop plants but their associated pests and diseases, because temperature, light and water are the major factors for their growth and development. Thus, it is important to understand the complex nature of the relationship between climate and pests or diseases. Insect pests and disease organisms are strongly dependent on micro-climate and respond to all the weather events such as heavy rains, floods, droughts, wind and temperature with varied rates of development and infestations. The impact of weather aberrations on plantation crops are visible not only in the same year, but adverse effect is carried out to subsequent years as well. Further, the affected crop takes two to three years to recover, causing severe economic loss to the farmer. Since the commitment of the land to crop is perennial and the lag period from planting to yield is more (two to seven years), it is very important to safeguard the plantations from weather vagaries. Timely mitigative measures will save the plantations and ensure sustainable productions. Attempts are already underway to develop weather-based pest forecast models for diseases and insects of many crop plants. This can help farmers to get the information about the outbreak of specific pests to take timely eco-friendly measures to save our precious crop species and environment.

The main objective of this publication is to provide the information on weather related crop management in general. Farmers need to be educated on the right cultural practices to be taken up at the right time with an understanding of impact of normal or adverse weather. It is the later which needs mitigative strategies with available technologies. Keeping these as background, the following chapters are designed to create an awareness on both basic information and to provide applied value to the

weather-driven cultural practices. The crops dealt in this publication are three important plantation crops viz. coconut, arecanut and cocoa, but the fact remains that the approach made in meticulously documenting all the available knowledge and linking it as an advisory service to farmers is relevant and applicable to many crops.

This compilation pertains to value addition to weather parameters, in which efforts are made to give crop weather requirements, weather related cultural practices, weather in relation to pest and disease incidence and management, weather related post harvest processing and value additions and finally the forecasting models for yield and disease. In each component, advice to farmers is provided in simple terms, which will be useful as a ready reckoner to the farming community. It is hoped that this compilation will be highly useful to not only farmers but also to the researchers, managers and policy makers.



Chapter 2: Climatic Requirement of Coconut, Arecanut and Cocoa

S. Naresh Kumar and Ravi Bhat

Like all other crops, coconut, arecanut and cocoa also require specific climatic conditions for high productivity. Since these perennial crops experience all seasons of a year and for several years during their life cycle, it is important to understand the climatic requirements of these crops.

COCONUT (*Cocos nucifera* L.)

The coconut palm is highly adaptable to a variety of environments. But, for healthy growth and satisfactory production, soil and climate parameters have to be given due consideration, particularly when establishing plantations in new regions where it was not grown before. The coconut palm derives its characteristics from the fact that it is essentially a tropical plant. In this connection factors such as latitude, altitude, rainfall, temperature, humidity, sunshine etc. require detailed consideration.

Coconut, a perennial tree, produces inflorescence



Plate 2.1: Coconut palm

almost every month of the year. Coconut inflorescence ontogeny indicates that from the initiation of inflorescence primordium to nut development it takes 44 months, of which the last 12 months represent the period taken from the fertilization to maturity of nut. Effects of weather are evident at all stages of development but the degree of influence depends on the stage of development. When other external factors such as fertility, management, pest and diseases are non-limiting, the yield variation can be explained mainly based on influence of weather parameters such as rainfall, evapotranspiration, temperature, solar radiation, sunshine hours, relative humidity and wind velocity, which are the major climatic variables that influence the coconut yield.

Geographical position and coconut

Latitude

The coconut palm occurs widespread in the coastal area of the tropics, 90% of the world's total acreage and production of the crop lie in between 20° N and 20° S latitude (mostly in Philippines, India, Indonesia, Sri Lanka, South Pacific Islands and Malaysia). The palm is grown even beyond this region, as far as 27° N and 27° S, but not on an extensive or commercial scale. In extreme latitudes the palm is reported to put on good vegetative growth but not to bear fruits satisfactorily. In India the palm is found to be grown at different altitudes within 26° N latitude. At different latitudes, it is the temperature that determines the limit to altitude up to which the palm can be grown successfully. Moving further from the equator the temperature tends to drop and becomes less favorable and, consequently the cultivation is to be confined to low lands.

Altitude

In areas farther from equator, the palm is confined to low lands. In India, Sri Lanka, Philippines and Malaysia, the major parts of coconut areas extend to

an altitude of up to 600 m. It may be possible to grow the palm at elevations up to 900 m in areas near the equator, where temperature is favorable for its growth. At higher elevations the palm has poor and stunted growth, takes considerably longer period to bear, and yields only a few nuts of small size. Critical studies of the performance of palms in different countries are inclined to conclude that 800 to 900 m is possibly the upper limit for economic production.

Weather variables and coconut

Temperature

Temperature is the one weather factor that seems to decide the territorial boundaries of the coconut area in latitude and altitude. A mean annual temperature of 27 °C with diurnal variation not exceeding 7 °C is considered optimum for the coconut palms. A temporary steep fall or rise in temperature, which probably happens occasionally in all places does no harm, provided that such extremes do not last for long periods at a stretch. However, places where the climate is characterized by long spells of hot day weather during summer and severe cold associated with cold wave and frost during winter; cyclone prone areas; and also places at high altitude lying farther from the equator where temperature would act as a limiting factor are not suitable for coconut cultivation. High temperature might cause the young developing inflorescences to dry up, and limit production to those months in the year when the temperature remains at favourable level. Higher temperature than the optimum are tolerated and are only harmful when they coincide with low humidity, possibly aggravated by hot dry winds. Occasional short spells of low temperature, provided they do not reach freezing point, may do no considerable damage, but may check development. Frequent, even short periods of temperature below 15 °C result in abnormalities of fruit such as bicarpelate nuts.

Rainfall

Rainfall is one of the important factors that affect successful growth of coconut palm under natural conditions. The coconut palm can grow and bear fruits with a well-distributed rainfall of 100 cm, but for the profitable cultivation, 100 to 225 cm per annum, evenly distributed throughout the year appear necessary. It can withstand even much higher precipitations, if the soil is well drained. As the tree

stores little moisture and has no tap roots, it is not suited for regions with long and pronounced dry spells during which the water table goes down considerably, is harmful to growth and production. In shallow and well-drained soils the adverse effects will be more pronounced. Under such conditions and also where annual rainfall is less than 100 cm, economic production is possible only under irrigation. In parts of Gujarat state in India, receiving only 25 cm to 50 cm of rainfall per annum, good coconut gardens have been raised with abundant irrigation water. On the other hand palms do not tolerate high water table and stagnant water over long periods.

Spikelets on the inflorescence are formed about 15 months before the opening of the spathe, and the pistillate flowers before 12 months. Even after the spathe is opened, female flowers remain for about 11 to 12 months to develop into full mature nuts. Therefore, severe drought during early formative period of the inflorescence may kill the growing points due to desiccation resulting in the abortion of spadix. However, rainfall is not a limiting factor under certain favorable conditions if irrigation facilities are provided. The distribution of rainfall is more important than the total quantity. On the West coast of India where in lies the major coconut belt with high rainfall but its distribution becomes less and less favourable from the south to north. This difference in the distribution is reflected in the general productivity of rainfed crop.

The gross effect of severe drought is very pronounced in coconut plantations of the dry zones. Unless ground water conditions are favorable, a period of three months with less than 50 mm precipitations per month will be deleterious

Relative humidity

The coconut palm, in general, likes a climate characterized by warm and humid conditions. The highest relative humidity is generally recorded on the West coast of India; the average monthly forenoon humidity rarely falls below 70%. Persistence of highly humid condition right through is not considered good for the palm from two aspects. One is that it reduces transpiration and thereby reduces the uptake of nutrients. Relative humidity plays very important role in pollination and fertilization thus directly influencing the yield.

Further, it provides congenial conditions for the rapid spread of fatal disease of the palm, viz. bud rot, leaf rot, etc.

Sunshine

The coconut palm requires plenty of sunlight and does not grow well under shade or too cloudy regions. For optimal growth, Sun shine (250 to 350 Wm²) of 2000 hrs./year with at least 120 hrs. per month is required. It becomes stunted under heavy shade, and cannot survive competitions from other trees. Young palms may be grown for a time under the shade of old palms, as during replanting, but the competition for root zone and light by the under plants makes it desirable to remove the old plants by the time seedlings attain eight years age. Accelerated development of spadix primordia was related to length of day. The copra out-turn and the potash-copra out-turn response were correlated with sunshine in later months of ripening of the nut.

Wind

Dry and windy atmosphere is conducive to the best growth of the palm provided soil moisture conditions remain at optimum level, but where the soil is dry, only gentle wind is desirable. Regions prone to frequent violent winds are not suitable for the palm. They not only twist the crown or break the leaves but also uproot or break the trees and destroy a considerable part of the crop. The cyclones have destroyed so many plantations in Andhra Pradesh and Orissa. Recently occurred Tsunami also damaged several coconut seedlings and palms situated near by the coast of Kerala, Tamil Nadu, Andhra Pradesh and Anadamans and Nicobar Islands. In Sri Lanka in October 1967, it was estimated that of a total of 6.5 million palms in Chilaw district, about 400,000 (6%) had fallen, about 300,000 were slanting perilously and a further 350,000 had crown damage or other injuries, a total of over 10 per cent. In addition there was a high proportion of remaining palms liable to rhinoceros beetle and red palm weevil attack. The remote possibility of a cyclone occurring, however, is no reason why coconut cultivation should not be undertaken if the area is otherwise congenial for the crop. In near-coast sandy soils, *Casurina* crop can be raised to serve as a wind break to protect the coconut plantations.

ARECANUT (*Areca catechu* L.)

The yield potential of areca palm mainly depends on climate. Generally more than 50% of variation in yield is due to climatic differences. Though, arecanut is grown under different agro-climatic conditions, it is very sensitive to extreme climatic conditions. The most important climatic factors that influence the growth and development are altitude, relative humidity and rainfall. Temperature also influences the crop growth and yield to some extent. Regression



Plate 2.2: Arecanut palm.

analysis of weather variables of 12 years indicated that arecanut yield is influenced by relative humidity, evaporation and rainfall.

Geographical position of arecanut

Latitude and altitude

The cultivation of arecanut is mostly confined to 28° North and South of the equator. In general, arecanut is mainly grown in low altitudes. This to some extent depends on the latitude. In North-East region of India (Assam and West Bengal) major areca growing area is in plains, since at higher elevations the winter temperature would be too extreme for the crop. Although areca palms grow at altitude up to 1000 m above MSL, at higher altitudes the quality of the fruits will not be good. In the high altitude areas like

Wynad (Kerala) and Coorg (Karnataka) the endosperm of the fruit does not develop sufficient hardness. It is also reported that high altitudes affect the germination of seeds and quality of 'Chali' (dry kernel). The percentage of germination of nut and the proportion of dry weight of kernel to whole fruits are less at altitudes above 850 m than in the lower altitudes.

Weather variables and arecanut

Temperature

Areca palms grow well within the temperature range of 14 °C-36 °C. However, the crop is being grown in temperatures ranging from 5 °C (as in places like Mohitnagar, West Bengal) and at 40 °C (Vittal in Karnataka and Kannara in Kerala). But extreme temperatures and wide diurnal variations are not conducive for the healthy growth of the palms. Heavy damage to foliage and death of palms in Florida was reported during December 1957 when the minimum temperature was below -2.8 °C. Even temperature around 5 °C with low humidity causes severe foliage damage, which was observed in Dakshina Kannada district of Karnataka during early seventies.

Rainfall

Arecanut flourishes well in tracts of heavy rainfall. However it is grown in areas with wide variations in rainfall such as Malnad of Karnataka where the annual rainfall may go up to or even more than 4500 mm as well as in low rainfall areas like Maidan parts of Karnataka and parts of Coimbatore district in Tamil Nadu, where the annual rainfall is about 750 mm. In areas of prolonged dry spell the palms are irrigated.

Relative humidity

Very high or low relative humidity is not conducive for growth and development of arecanut. Relative humidity directly influences the water relations of palm and indirectly affects leaf growth, photosynthesis, pollen dispersal, occurrence of diseases and finally economic yield. High humid conditions provide congenial conditions for the rapid spread of diseases like fruit rot, bud rot, etc. Relative humidity has considerable influence on evapotranspiration hence on the water requirement of arecanut.

COCOA (*Theobroma cacao* L.)

Though cocoa is grown under wide climatic conditions, its yield potential is higher in humid tropics where the climate shows relatively less variation throughout the year, especially in terms of temperature, solar radiation and day length. The climatic conditions suited for cocoa cultivation were found to be under coconut and arecanut palms in Southern India. However, the climatic conditions are different in these regions, with well-distributed rainfall in Southern Kerala compared with long dry



Plate 2.3: Cocoa tree.

spells during summer months in Northern Kerala and coastal Karnataka. The drought intensity is more pronounced in northern regions of Kerala and coastal Karnataka extending up to five to six months subjecting plants to severe stress especially when they are grown as intercrop in rainfed coconut gardens. However, the situation is slightly better when it is intercropped in arecanut gardens, which are irrigated. But non-availability of water towards the end of summer exposes the plants to stress. Two dissimilar crop patterns are observed under rainfed and irrigated conditions.

In India, cocoa yield is significantly correlated with the number of rainy days in the previous year, sunshine hours and maximum and minimum temperatures of the current year. Relative humidity,

minimum temperature, rainfall and rainy days during the flowering period have significant negative correlation with yield while sunshine hours and maximum temperature have positive correlation with yield. Thus, it can be concluded that weather at flowering stage is an important factor influencing the yield of cocoa. The number of rainy days, evening temperature and wind speed occurring six months earlier contributed 69.65% of the variation in the number of pods, and these three indices, occurring seven months earlier, contributed 66.92% of the variation in bean fresh weight.

Geographical position of cocoa

Latitude and altitude

Most of the cocoa growing areas lie below 300 m. However, cocoa can be grown successfully up to a height of 1100-1200m provided the temperature is congenial during flower production. Cocoa can be grown within 20° North and South of the equator. However, over 75% of the world's cocoa lies within 8° North and South of the equator.

Weather variables and cocoa

Temperature

The temperature in most of the cocoa growing areas lies between a maximum of 30-32 °C and a minimum of 18-21 °C. The mean daily minimum in the coldest month should not be less than 15 °C with an absolute minimum of 10 °C. Cooler temperatures during flowering period will result in lack of good harvest after seven months. Low temperatures have an inhibiting effect on cambium growth, which is linked to flowering, and results in low yields seven months later. Mean minimum temperature when dropped from 13-14 °C to 10 °C for several consecutive days the yield was reduced by about 50%. Cocoa can tolerate a mean monthly maximum temperature up to 33 °C and the optimum range is 30-32 °C.

Rainfall

Rainfall and its distribution is one of the most important climatic factors deciding the cocoa cropped area. Annual rainfall in most of the cocoa growing areas lies between 1,250 and 3,000 mm. If rainfall is less than 1,250 mm the crop needs irrigation during rainless period. Annual rainfall in excess of 2,500 mm may lead to problems such as black pod

disease due to more humid conditions. The distribution of rainfall is more important than the total rainfall. Usually dry spells longer than four months are detrimental to the crop under rainfed conditions.

Relative humidity

Cocoa needs uniformly high humidity, often 100 per cent during night, falling to 70-80 per cent by day. This may go still lower during dry seasons. Plants grown under less relative humidity conditions produce small leaves and tend to be curled and withered at the tip.

Wind

Heavy persistent wind damages the cocoa plants. Young cocoa leaves get damaged by persistent movement caused by steady wind. This finally leads to defoliation. The effect of wind damage will be severe when cocoa is grown without shade. If proper protection from wind is provided the cocoa can be grown without shade like in valleys.

Table 2.1 : Summary table on weather requirement for optimal growth of coconut, arecanut and cocoa.

Parameters	Coconut	Arecanut	Cocoa
Latitude	20° N and 20° S,	28° N - 28° S	20° N - 20° S
Altitude	600	1000	300
Rainfall (mm)	1000-2500	1500 - 2500	1250-3000
Temperature (°C)	27 ± 5	14 - 36	30-32
Relative humidity (%) > 60		>60	> 60
Solar radiation	250 to 350 Wm ² of 2000 hrs./year with at least 120 hrs./month	120	120



Weather Requirement and Natural Calamities

- Drought, flood, cyclone and wind damage to plantations

S. Naresh Kumar

The coconut plantations require a well-distributed rainfall (130 to 230 cm/year), mean temperature (27 °C with diurnal variation of 7 °C) and sun shine (250 to 350 Wm²) of 2000 hrs./year with at least 120 hrs/month. The major areas of production lie between latitudes 20° N and 20° S, and below the 300 m contour. The cyclones that struck the southern districts of Madras (India) in 1952 and 1955; Andhra Pradesh, Gujarat and Orissa states (India) in 1996 and 1998 have destroyed so many palms that it took four years before the level of production can be brought back that of the pre-cyclone period.

Coconut palm growth and production gets hampered when exposed to irradiation above 265 Wm², temperature above 33 °C and vapour pressure deficit of 26 m bar, aggravated by soil water deficit during the period. The impact of drought on coconut yield will be seen till four years due its long lag period from inflorescence primordial initiation to nut maturation. An aridity index of 100% for a prolonged period of 5 to 10 weeks drastically affects productivity of coconut palm. Duration of dry spell during initiation of inflorescence primordium, ovary development and button size nut stages, in that order have greater influence on nut yield than other stages. Continuous drought years in parts of Tamil Nadu and Karnataka have caused severe loss to the farmers as lakhs of palms are died or severely affected. The palms, which could survive drought years with barely one or two leaves, are reviving now due to irrigation through drip and will take another two years to yield.

Arecanut plantations also are affected by drought stress, which caused a loss ranging from 10-50%. The loss due to drought was more severe in non-traditional areas than in traditional areca growing



Drought affected coconut garden in Tamil Nadu.



Drought affected arecanut garden in Karnataka.

areas. Once affected, palms need 2-3 years to come to normal condition. Even death of palms was reported in some areas where scarcity of water was severe.

East coast of India is prone to cyclones and floods. The coconut plantations were badly affected by the recent cyclones that occurred in 1996 and 1998 in Andhra Pradesh and Orissa states. Many places palms were uprooted or lost the crown leaving stems on the ground. In places, where the impact was less, palms were seen either tilted or with partial damage to the crown. These occurred due to high wind speed. Palms take 2 to 3 years to recover and come to

yielding again. The damage was severe where surface planting was practiced and also where exposed roots were cut. In surface planting condition, one can see the exposed roots on the base of stem. Cutting of these roots is a general practice in certain pockets of Andhra Pradesh. During high wind speeds and

cyclone rains, pollination also is hampered leading to low fruit set. Apart from this falling of button size, fist size, immature nuts is common due to mechanical force.

To withstand the impact of cyclone or high wind speed damage, it is advised to plant seedlings as per recommended practice of placing in 1 m³ planting pit with planting the seedling 50 cm below the ground level and filling the pit to surface level in subsequent years. By doing so, exposure of roots at the base of stem can be avoided. In old plantings where roots are exposed, practice of cutting of roots should be discontinued. Planting of *Casurina*, etc. can serve as wind shield in coastal areas in long run. Cyclone affected coconut palms can be revived fast by proper management. Application of FYM or burial of farm waste in the basin, application of recommended dose of fertilizers, providing irrigation (with sea water, where ever it is available) can rescue and revive palms much faster. In coasts Andhra Pradesh, the cyclone hit gardens revived faster in cases where proper management is done.



Cyclone up rooted thousands of coconut palms in Orissa.

Flooding for shorter duration will not cause much damage to the palm. But if water stagnation prolongs palms suffer from physiological drought, where palms will not be able to uptake water or nutrients due to hampered root function because of lack of O₂ for respiration. Apart from this, flooding coupled with leaf eating caterpillar damages the entire photosynthetic area of coconut by scrapping chlorophyll. This causes sever loss in terms of nut yield. Coconut palm do not perform well in soils with poor drainage. In such soils occurrence of *Ganoderma* stem bleeding disease is very common. Hence it is suggested to make good drainage provision in coconut gardens. Tsunami, that struck the Eastern coastal areas on December 26th, 2004 affected many coconut gardens as well.

Advice to farmers

What to do

- Plant seedlings in 1 m³ pit at 50 cm below the ground level and filling the pit to surface level in subsequent years.
- Plant *Casurina*, etc. to serve as wind shield in coastal areas
- Revive affected palms by proper management. Apply FYM or burial of farm waste in the basin, apply recommended dose of fertilizers, provide irrigation.
- Earthen up in basin and cover the exposed roots due to flood.
- Ensure proper drainage.

What not to do

- Avoid shallow planting.
- Do not cut the exposed roots.

Abiotic stress – what makes it so complex?

In nature, abiotic stresses vary to a great extent in their intensities. Occurrence of drought also coincides generally with high light intensities and high temperature regimes. Further, length and severity of these stresses vary with place to place and time to time in a place. This special and temporal variations make the issue more complex. More over the response of a plant to abiotic stress is a multidimensional one with responses starting at cellular, inter-cellular level to organ and phenological stage level varying with space and time.



Tsunami affected coconut garden.

Chapter 3: Weather with Respect to Cultivation Practices in Coconut, Arecanut and Cocoa Gardens

R. Dhanapal, Ravi Bhat and S. Naresh Kumar

Weather is one of the major factors influencing crop husbandry. Management of perennial plantations such as coconut, arecanut and cocoa, which even though not much influenced by one or two days of weather aberrations, is important for providing the conditions for better growth and yield.

COCONUT

Maintaining proper growing conditions is essential for getting better yield from any crop and coconut is no exception. Growth conditions have to be congenial for coconut right from germination to seedling growth in nursery; and then after for establishment of field planted seedling; through to juvenile phase to yielding and yield establishment phase. Thus weather during entire growth and development of coconut, till economic yield phase for 60 years, determines the productivity of the palm.

Nursery stage

Field nursery

Selected mature nuts are sown in nursery during May to October, coinciding with the onset of monsoon in coconut growing areas. For better and



Plate 3.1: Mulching nursery bed with coconut leaves.

early germination, quality seed nuts, adequate soil moisture and optimum temperature are essential. Hence, mulching the seed beds with coconut leaves, etc. and watering once in two to four days, depending on the soil type, is essential. Partial shade



Plate 3.2: Coconut nursery.

is provided to these nursery beds either by providing temporary/ permanent sheds or by raising nursery beds in the inter spaces of adult coconut palms.

Polybag nursery

For raising the polybag nursery, germinated nuts (three months after sowing in field nursery) are lifted and transferred to polybags containing potting



Plate 3.3: Polybag nursery.

mixture. For polybag nursery also, shade and frequent irrigation are essential for maintaining required humidity, temperature and light levels.

Advice to farmers

What to do

- Use raised beds for nursery.
- Provide shade to the nursery bed.
- Choose the nursery site near water source.
- Mulch with coconut leaves or any other organic material.
- Water once in two to four days in summer.
- In heavy soils, mix sand while preparing nursery bed.

What not to do

- Do not expose the seedlings to high sunlight.
- Avoid moisture stress to the nursery.

Garden maintenance with respect to climatic variations

Site selection and layout

Coconut can grow in diverse environments. However, for high production of nuts, it requires specific climatic conditions. Even though a high or low temperatures for one or two days; water stress for 10 days; or short periods of water stagnation do not affect the palm much but prolonged dryspells, successive droughts will not only harm the palm but also kill it. Thus the site selected should have sufficient irrigation facility and drainage to drain away excess water especially in heavy rainfall and low lying areas. Even though coconut is grown mainly as a rainfed plantation in Kerala and parts of Tamil Nadu, its growth and productivity are good only under assured irrigated conditions. In South Kerala, where rainfall is well distributed almost throughout the year the palms can be grown as rainfed with occasional irrigation during summer. But in areas with long dry spells or in areas of less rainfall, irrigation during dry weather becomes essential. Providing irrigation through drip is proved to be beneficial in coconut gardens. This ensures high water use efficiency and low labour requirement. Soil moisture conservation by mulching will help to retain the soil moisture for prolonged periods and reduce the frequency of irrigation. In windy areas such as Orissa, raising of *Casurina* along the border

will serve as a wind break. This will help in reduction of evapotranspiration losses.

Advice to farmers

What to do

- Site should have provision for at least life saving irrigation.
- Provide drip irrigation.

What not to do

- Do not plant in areas where very high or very low temperatures prevail.
- Avoid low lying/water logging areas.
- Avoid planting in sites with soil depth less than 1.5 m.

Spacing and depth of planting

The recommended spacing is 7.5 m x 7.5 m for ensuring proper interception of light. These interspaces can be used for growing the intercrops in early stages (upto 8-10 years after planting) and inter/mixed crops in later stages (20-22 years onwards). Closer planting will cause mutual shade, leading to delayed flowering resulting in reduced yields. The recommended practice is planting in a pit of 1 x 1 x 1 m dimensions. In hard laterite tracts, planting in bigger pit is suggested. Deeper planting is always preferred as it provides firm anchorage to the roots and provides large volume of space for spread of roots. When deeper planting is not practiced, the roots get exposed and the palm needs earthing up. Heavy winds and cyclones cause tilting or uprooting of shallow planted palms.



Plate 3.4: Seedling planting in 1 m³ pits.

Advice to farmers

What to do

- Adopt recommended spacing.
- Plant in pits of recommended dimension (1 x 1 x 1 m).
- Plant on mounds in low lying / temporary water logging areas.
- Provide mulch.

What not to do

- Avoid shallow planting.
- Avoid closer planting.
- Do not plant in prolong water logged areas.
- Avoid spillage of soil on the growing point of seedling.

Season of planting

Planting in the main field can be taken up either in the month of May-June or September-October. In areas of heavy rainfall due to South-West monsoon, on river banks where there is likely danger of inundation, and in areas with North-East Monsoon planting can be done in September-October. If planting is done during summer periods, frequent irrigation must be provided for better establishment of seedlings.

Advice to farmers

What to do

- Plant in the right season, preferably in monsoon.

What not to do

- Avoid planting during heavy rainfall period.

Shading during seedling establishment

For better growth and establishment seedlings



Plate 3.5: Wrapping of seedlings with dry coconut leaves to protect from sunlight and animals.

should be given protection against the direct exposure to sun during summer, for at least one year of planting. This may be done by covering the plants with dry coconut leaves. Frequent irrigation is a must for good establishment and early growth of field planted seedling. To avoid sun scorching and for better establishment, place dry coconut leaves in South-West direction to provide shade to seedlings during afternoons.

Advice to farmers

What to do

- Provide shade during summer.
- Plant shade trees in the border on Southern and Western sides of the garden.
- Provide frequent irrigation to seedlings.
- Provide drains to avoid water logging.

What not to do

- Do not plant in areas where sufficient shade cannot be provided.
- Do not leave the seedlings unirrigated for more than one week.
- Do not provide shade during monsoon.

Cultural operations

The cultural operations vary from area to area depending upon the climatic and soil variations. The main components of cultivation include fertilizer application (organic and inorganic), water management, weed control and crown cleaning. Details about soil moisture conservation are given in subsequent chapters. Generally, crown cleaning and weed control are done as and when required. During early monsoon period or after monsoon, crown cleaning is done once a year at any harvest time. Two ploughings/ tillages, one after pre-monsoon showers and second at the end of the monsoon are recommended, which also control weeds.



Plate 3.6: Timely cultural operations.

Advice to farmers

What to do

- Follow regular crown cleaning procedure
- Plough the soil twice, one immediately after summer showers and one at the end of the monsoon.
- Add green manure @ 30kg/palm/year during September/October.

What not to do

- Do not disturb the basins while ploughing/ tilling the soil.

Harvest

Tendernut

Generally, tendernut demand is more during summer. Hence, in a coconut garden tendernut harvest can be done by different combinations, for example tender nuts can be harvested from one half of the palms and remaining can be left for mature nut harvests. Alternatively, tender nut harvests can be made during summer and during remaining period of the year, the nuts can be harvested at full maturity. In another approach, tendernut harvests can be made in alternate years also. It should be noted that the palms from which tendernut harvests are made throughout the year must be well managed by providing adequate fertilizers and irrigation to sustain the yields. Depending on the season, the length of the nut maturity varies. In hot areas nut matures earlier than in cooler areas; so also nut maturity will be earlier in summer months than in cooler months.

Mature nut

Generally, nuts are mature by 11 to 13 months after fertilization. Nuts are harvested either at monthly interval or at 45 days interval. In areas like West Bengal and North-East States, where low temperatures prevail during winter, six to eight harvests are done.

ARECANUT

Maintaining proper growing conditions is essential for getting better yield from arecanut. Congenial growing conditions have to be provided at different growth stages of arecanut.

Nursery stage

Primary nursery

The seednuts are sown in nursery immediately after harvest. The seednuts need high humidity and optimum temperature for better and early germination. So mulching the seed beds and watering daily is essential. They also need shade. The



Plate 3.7: Polybag nursery of areca.

shade may be provided by making temporary/permanent pandal. Cooler temperature prevailing at higher altitudes lead to delay in germination.

Secondary nursery

The sprouts are prone to sun scorching when directly exposed to Sun-light. Also they are prone to water logging during rainy season. So providing shade and proper drainage facility is essential. Mulching and watering daily during summer is essential to maintain high humidity and optimum temperature.

Advice to farmers

What to do

- Provide shade to the nursery bed.
- Mulch with paddy straw or areca leaf.
- Water daily during summer.
- Ensure proper drainage during rainy season.

What not to do

- Avoid sowing during cooler periods in areas where temperature falls below 15 °C.

Garden maintenance with respect to climatic variations

Site selection and layout

Arecanut thrives well in humid areas when protected against hot Sun and heavy wind. It cannot withstand

both drought and water stagnation. Thus the site selected should have sufficient drainage to drain away excess water in heavy rainfall areas and irrigation facility for irrigation during dry weather. The palms also cannot withstand high temperature and exposure to direct Sun. Exposure to direct Sun causes scorching on stems and the palms become weak and breakable to heavy winds. So the site selected should have protection from hot Sun on Southern and Western side either by hillock or by tall growing trees.

Aligning the rows in North-South direction and planting in quincunx system with angling 35° (for Karnataka) towards west lowers the incidence of Sun-scorching.

Advice to farmers

What to do

- Select site with sufficient water source and drainage facility.
- Plant in North-South direction with angling 35° towards west.

What not to do

- Avoid planting in areas where paddy was cultivated for many years under puddled condition.

Spacing and depth of planting

The recommended spacing is 2.7 x 2.7 m. Depth of planting is mainly decided by the soil type and the height of water table. In laterite soil with good drainage, seedlings planted at 90 cm depth were more vigorous, flowered early and gave increased yield than those planted at 30 cm or 60 cm depth. But in heavier soils and soils with higher water table, deeper planting beyond 60 cm did not give added advantage. Deeper planting is always preferred as it provides firm anchorage to the roots and provides large volume of space for spread of roots. When deeper planting is not practiced, the roots get exposed and the palm needs earthing up. Thus in soils where natural drainage can be provided, particularly during the heavy rainfall period, deeper planting of seedlings up to 90 cm depth is preferred. The pit is to be mulched with green leaves.



Plate 3.8: Planting of Areca seedling.

Advice to farmers

What to do

- In places with heavy rain fall and heavy soils, planting depth can be at 60 cm.
- In places with heavy rain fall and light soils, planting depth can be at 90 cm.
- In places with low rain fall and heavy soils, planting depth can be at 60 cm.
- In places with low rain fall and light soils, planting depth can be at 90 cm.

What not to do

- Avoid shallow planting.

Season of planting

Planting in the main field can be taken up either in the month of May-June or September-October. In areas of heavy rainfall due to SW monsoon and in river banks where there is likely danger of inundation, planting can be done in September-October. In other areas planting can be done in May-June.

Advice to farmers

What to do

- Plant in the right season.

What not to do

- Avoid planting in the winter when temperature falls below 15 °C.

Drainage

For better growth and development of the plants proper drainage is essential since arecanut cannot

withstand water stagnation especially in heavy rainfall areas. The number of drainage channel depends upon the soil type and slope of area. In light soils the number of channels may be less; and in heavy soils the channels should be dug in each row for proper draining of the excess water. The channels should be at least 15 – 30 cm deeper than the depth at which the seedlings are planted. The channels have to be cleaned every year for easy flow of water. The planted pits also should be provided with outlets to drain away the water.

Advice to farmers

What to do

- Provide channels 15-30 cm deeper than the depth of planting.
- Clean channels every year before monsoon.

What not to do

- Avoid planting without proper drainage facility.

Shading

The palms are highly susceptible to Sun-scorching. Seedlings should be given protection against the



Plate 3.9: Shading of seedling by wrapping with areca leaves and basin mulching with arecanut husk.

direct exposure to Sun. This may be done either by covering the plants with areca or coconut leaves or by raising crops like banana in between two rows of arecanut. Sun scorching is mostly seen during October – January period. During this period even the stems of young palms have to be protected since the part once lost or got damaged cannot recover.



Plate 3.10: Shading of stems of areca palms with dry leaves; note the Sun-scorching in unprotected stem.

Dry leaves of arecanut can be used to cover the stems. This can also be achieved by planting quick growing shade trees on southern and western sides of the garden. The palms have to be irrigated to reduce the effect of scorching. Drip irrigation was found to reduce the Sun-scorching effect.

Advice to farmers

What to do

- Provide shade during October to January.
- Plant shade trees in the border on Southern and Western sides of the garden.

What not to do

- Do not plant in areas where sufficient shade cannot be provided.

Cultural operations

The cultural operations vary from area to area depending upon the climatic and soil variations. In *Malanad* tracts of Kerala the main purpose of cultivation is to loosen the soil and to rebuild the soil fertility after the heavy rains during monsoon. Where as, in *Maidan* tracts of Karnataka, the purpose of cultivation is to conserve the soil moisture and prevent the hardening of the soil, as the soils are heavy in these areas. In general, cultivation was found to increase the yield by 10-20 per cent.

In *Maidan* tract, digging the garden twice a year (June and December) had given higher yield. When planting is done on slopes, contour planting and



Plate 3.11: Mulching of areca basins with arecanut husk.

clean cultivation gave highest yields. Mulching is another operation being followed in the arecanut gardens of *Malnad* and sub-mountane region of Karnataka to conserve moisture and to avoid soil erosion. They mulch the garden by spreading leaves and twigs. This checks evaporation during summer,



Plate 3.12: Mulching of areca basins with dry leaves.

erosion during rainy season and keeps the weeds under check; and also forms humus, which acts as organic manure. In some parts viz., Dakshina Kannada district of Karnataka and Cannanore district of Kerala, green leaves are applied only in the basin of the palms. In some areas, dry leaves are spread in the interspaces during summer. Chopped areca leaves, grass, arecanut husk and dry leaves collected from the forests can be used as mulch in areca gardens. The loss of moisture from the mulched plot was considerably lower than plots without mulch.

Advice to farmers

What to do

- Intercultivate the soil by digging wherever the soil hardens after monsoon.
- Mulch the garden with dry leaves or fallen areca leaves.

What not to do

- Do not allow soil erosion.

Water management

This depends upon different agroclimates. When the rainfall is distributed throughout the year like in parts of Southern Kerala irrigation is not required. In areas where rainfall is heavy and soils are light in texture, during summer the gardens have to be irrigated at higher frequency of once in three to five days as the water holding capacity of these soils is low. In low rainfall areas with heavy soils, the irrigation interval can be increased up to seven days as these soils hold moisture for longer time. When drip irrigation is followed, the number of drippers per palm should be more (three to four) in light soils and less (two) in heavy soils.

Advice to farmers

What to do

- Follow drip irrigation.
- Maintain 3 to 4 drippers per palm in light soils and 2 drippers per palm in heavy soils.

What not to do

- Avoid flood irrigation.

COCOA

The practices being followed for cocoa cultivation should aim at meeting the needs of plant for optimum weather conditions for better productivity through more flower production, fruit set, fruit development and low disease incidences. By adjusting the time of operations the productivity can be increased.

Nursery stage

Propagation

Cocoa can be propagated through seeds and clones. The seeds can be sown in polybags filled with potting mixture of topsoil, sand and FYM (2:1:1) which can hold more moisture. Bags have to be kept under shade to avoid sunscorching and evaporation losses.

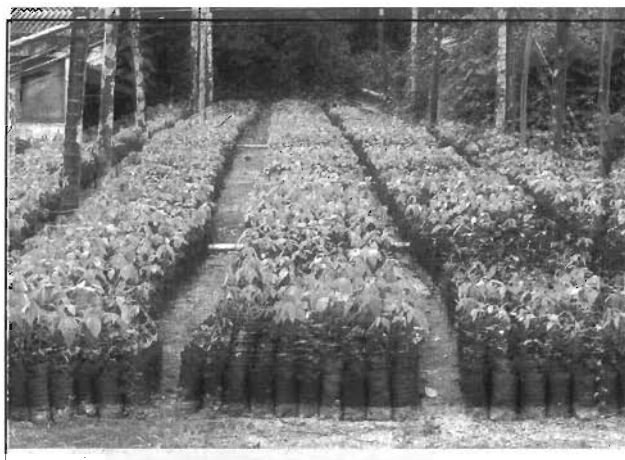


Plate 3.13: Cocoa nursery.

Sowing of seeds during the period of cooler temperature should be avoided as this will give poor germination. Grafting is another popular method of propagation. Once the grafting is done the scion portion should be covered with polythene strips to maintain higher humidity around the graft union. This will give better success rate of grafting. Grafts also should be kept under shade and watered daily during dry periods.

Advice to farmers

What to do

- Keep the bags under shade after sowing.
- After grafting, cover the scion portion with polythene strips.
- Water daily.

What not to do

- Avoid sowing during cooler months.

Garden maintenance with respect to climatic variations

Time of planting

This depends on the climatic condition of the place. The young seedlings need moisture for better establishment. The seedlings cannot withstand excess water also. So in areas where rainfall intensity and amount is less planting can be done on the onset of monsoon. Where as, in areas of heavy rainfall the planting can be done at the end of the monsoon. If the moisture can be maintained by irrigation, planting can be done at any time of the year. Planting in cooler periods of the year can be avoided.

Advice to farmers

What to do

- Plant after monsoon in heavy rainfall areas.
- Plant after pre-monsoon showers in low rainfall areas.

What not to do

- Avoid planting in cooler period.

Shade

Cocoa grows under shade. If grown under open condition the life of cocoa will be reduced. Cocoa, when grown under shade will get a condition of high humidity which is a better growing condition for it.



Plate 3.14: Cocoa grown under areca shade.

In India it can be grown successfully under arecanut and coconut. Shade acts as a buffer against changes in the environment.

Advice to farmers

What to do

- Provide proper shade if not grown as mixed crop.

What not to do

- Avoid growing sole crop of cocoa.

Time of application of nutrients

The time of application of nutrients is decided by the moisture availability in the field and stage of the crop. In unirrigated crop fertilizers can be applied just before monsoon coinciding the months of May-June and after monsoon (September-October). When the crop is irrigated the pre-monsoon application can be advanced to February-March. As far as possible the fertilizers should be applied before main flush



period, before flowering and two months before the peak of the main harvest.

Advice to farmers

What to do

- Apply fertilizers just before monsoon for unirrigated crop.

What not to do

- Avoid application of fertilizers during dry season.

Irrigation

Cocoa is generally a rainfed crop in the traditional cocoa growing countries where the rainfall is distributed throughout the year. In India, it is grown under coconut and arecanut as an irrigated crop. Under these conditions since the rainfall occurs only from June to October, the remaining period remains dry. The crop has to be irrigated during this period. Cocoa when grown under arecanut has to be irrigated with 20 liters of water per day per tree through drip irrigation for achieving maximum yield.

Advice to farmers

What to do

- Follow drip irrigation.

What not to do

- Do not over irrigate.

Pruning

Pruning is one of the important operations in cocoa cultivation. This is more important when grown as mixed crop under arecanut and coconut. By making adjustments in time of pruning many of the problems related to climate can be solved. Pruning is done periodically to allow Sun-light and air to penetrate the crown as a preventive measure against disease.

Time of pruning has an important role to play in controlling flowering, fruiting season and disease avoidance. In areas where the problem of pod rot is severe due to heavy monsoon from June-September, by advancing the pruning time to July end and August beginning, the flowering can be advanced. This helps in completing the main harvest before the onset of monsoon and thereby the incidence of pod rot can be avoided. This practice can also be followed



Plate 3.15: Canopy pruning for better light penetration

in areas where cooler temperature prevail during winter season. Early pruning leads to early flowering and the low temperatures will not have any adverse effect on the flowering.

Advice to farmers

What to do

- Compulsorily pruning operation has to be done.
- Take up pruning at the end of July or first week of August.
- Remove choupans regularly.
- Maintain one storey under arecanut.
- Paste Bordeaux mixture at cut ends after pruning.

What not to do

- Do not delay the pruning operation.
- Avoid severe pruning.

Alternate Strategies to Manage Contingent Situations in Plantation Crops

The rainfed plantations face water scarce conditions during summer. The situation will be further worsened due to the delayed onset of monsoon, early withdrawal of monsoon or due to long dry spells during monsoon. In such unforeseen situations effective contingent plan is a must to avoid or reduce the adverse impact on plantations.



COCONUT

Normal monsoon and timely on-set

Cultural practices

Next to manuring and irrigation, intercultivation is the most important operation. Intercultural operations increase the yield not only through weed control per se, but also by providing a soil rhizosphere environment favourable for mineralisation and soil moisture conservation. Cultivation alone, twice a year, one at pre-monsoon and another at the post-monsoon in the coconut gardens was found to increase the yield by 30 to 35 nuts/palm/year, compared to the neglected plots. The response of West Coast Tall palms to management practices viz. cultivation + organic + inorganic manuring, has shown an increase in yield by four folds compared to the neglected palms under rainfed conditions.

Moisture conservation

Coconut is mainly grown under rainfed conditions in most coconut growing regions of Kerala and Tamil Nadu. For reducing surface evaporation, improving the water retention under rainfed conditions and to reduce the erosion hazard the following conservation methods are suggested.

- i) Mulching with coconut husk, coir dust, green leaves, dried coconut leaves, etc.
- ii) Addition of 30 to 50 kg organic manures or green manure
- iii) Husk burial- effect lasts for seven years
- iv) Bunding, terracing, etc.

Apart from these intercultivation may be followed.

Green manuring and cover cropping

The nitrogen fixing potential of legumes - Rhizobium symbiosis can be exploited in the interspaces of coconut through intercropping of green manures, cover crop legumes and forage legumes. *Purureraria phaseoloides*, *Calapogonium muconoides* and *Mimosa invisa* can be grown as green manure crops in coconut basin as well as in the interspaces. Cover cropping helps to prevent soil erosion, weed growth, add a large quantity of organic matter and form a thick mulch that improves soil fertility and water holding capacity. Legume cover crops also fix atmospheric



Plate 3.16: Cover crop in coconut basin.

nitrogen. When these legumes are grown in coconut basin (1.8 m radius), they contribute 15-30 kg of green matter which adds 150-200 g of nitrogen per basin, when incorporated at four months of growth. Green manuring results in enhanced microbial activity and fertility of coconut soils. From the interspaces of one hectare of coconut garden, about three to four tonnes of green matter can be obtained, which will supply nutrients, equivalent to 20 to 111 kg N, 4 to 21 kg P_2O_5 and 15 to 67 kg K_2O per hectare.

Delayed on-set of monsoon

Since coconut is a perennial crop, delay in monsoon by two to three weeks would not adversely affect the yield and so no special cultural practice is followed. If the previous year monsoon is normal there will be sufficient water for irrigation. If there is shortage of water micro-irrigation can be followed where only 66% of open pan evaporation (E_o) is

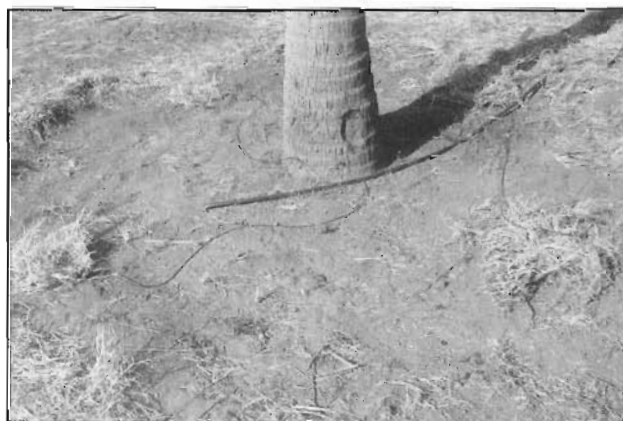


Plate 3.17: Drip irrigation at 66% E_o -most suitable for coconut.

provided in the basin area wetting only 15 to 20% of the active root zone. Along with drip irrigation mulching the coconut basin (1.8 m radius) with 15

to 20 dried coconut leaves is advised. Coconut husk can also be used as mulching material. If coir factory is in the vicinity coir pith can also be used as mulching material. To use the available water through drip irrigation effectively, the water given through drip should be allowed to drip at 30 cm depth by making four pits at equidistance of one meter away from the bole of the tree. The pits should be covered with mulch to avoid evaporation from the pit opening.

Dry spell in the midst of monsoon

For perennial crop like coconut the dry spell of 10 to 15 days in the midst of monsoon season does not affect the growth and yield as there will be sufficient moisture in the soil to meet the water requirement.

Early withdrawal of monsoon

In the event of early withdrawal of monsoon, for *in situ* water conservation in the coconut basin leaf or husk mulching may be followed. Open a trench (4 x 1 x 0.5 m) in the inter space of coconut palms and fill with the coconut husk for water conservation. Create half moon bunds in the down slope two meters away from the trunk. These may be followed in monocrop and mixed crop situations, respectively.

Further, *in situ* water conservation by creating a slope along the coconut rows on both sides of the palms is recommended for mono crop of coconut.

ARECANUT

It is a perennial crop which needs irrigation during summer for the growth and yield. This crop also suffers from water stress during summer and from water logging during rainy season. Hence, all the arecanut gardens in the heavy rainfall area are provided with artificial drains.

Normal monsoon and timely on-set

Cultural practices

As indicated earlier the cultural operations vary from area to area.

Organic matter recycling

On an average, annually five to six tonnes of biomass is available from one hectare of areca garden. This can be effectively used as organic source of nutrients for areca plants. But direct application of these wastes in the garden will take long time for

decomposition and will not meet the nutrient demand of the crop immediately. Hence, these materials can be effectively composted by earthworms and used as organic manure in areca gardens. To prepare vermicompost, areca wastes are chopped into small pieces of 10 cm and heaped. The heap is mixed with cow dung slurry at the rate of 10 kg / 100 kg of biomass. Water is sprinkled daily and kept for two weeks. Then the chopped material is arranged in beds of one-meter width and convenient length. Cement tanks or trenches can be used for this purpose. A layer of 10-15 cm waste material is alternated with two centi meter layer of cow dung over which earthworms are released at the rate of 1000 numbers per square meter. The wastes are converted into fine granular, odourless vermicompost within 60 days. About 8 kg / palm / year of vermicompost meets the crop nutrient demand. The two species of earthworms viz. *Eudrilus eugeniae* and *Eisenia foetida*, can be used.

Irrigation

Arecanut cannot withstand drought for a long time. Being a perennial crop, once affected by water stress, it may require two-three years to regain the normal



Plate 3.18: Areca vermicompost.

vigour and yield. The death of palms due to moisture stress is also not uncommon.

In West Coast of India, where more than 50 per cent of total arecanut area lies in the country, rainfall is mostly confined to June-November months. Monsoon is followed by a prolonged dry spell normally extending from November to May. Excess evaporation, high wind speed, greater vapour pressure gradient in the above ground atmosphere and rise in temperature are the regular features of summer in these regions and as a result, the crop is

invariably subjected to drought conditions. If the monsoon is delayed, the drought situation further aggravates. Therefore optimizing the irrigation requirements and also economizing the irrigation water assumes major importance in arecanut cultivation. At Vittal (South Kanara, Karnataka) conditions, irrigation intervals of 5 and 10 days were found superior throughout the season. When irrigation treatments were based on IW/CPE ratio, the results showed that irrigation of 30 mm of water is optimum when the CPE is 30 mm (i.e. IW/CPE = 1). This works out to an irrigation frequency of once in seven to eight days from November to December, once in six days during January-February and once in four to five days during March-May period. Accordingly, for Vittal condition, the quantity of water to be applied is about 200 litres per palm per irrigation.

During summer, majority of the farmers face scarcity of water and it will be difficult to supply the required water to the palms. To overcome this problem, new irrigation methods were tried which can save water without affecting the yield of arecanut. They are sprinklers and drip irrigation methods. Sprinkler and drip irrigations can save 20 and 44 per cent of water under Vittal conditions for an Eo of 66%, respectively compared to conventional method of irrigation (flooding, basin and hose irrigation). About 20 litres of water per day per palm is to be given through drip irrigation. Two to three drippers or micro tubes should be placed in the basin at 50 - 60 cm away from the trunk.

Delayed on-set of monsoon

Mulch the palms with arecanut husk and practice micro-irrigation. Twenty litres of water per day per palm is to be given through drip irrigation. Two to three drippers or micro tubes should be placed in the basin at 50 - 60 cm away from the trunk at a depth of 15 cm to avoid evaporation. If there is a shortage of water, irrigation at the rate of 20 litres per palm can be given on alternate days.

Dry spell in the midst of monsoon

For perennial crop like arecanut the dry spell of 10 to 15 days in the midst of monsoon season does not affect the growth and yield as sufficient moisture will be available in the soil to meet the water requirement during the dry spell.

Early withdrawal of monsoon

In the event of early withdrawal of monsoon, mulch the basin with dry arecanut leaves or husk. Also open the trenches (2 x 0.75 x 0.5 m) in the inter space of arecanut and fill with coconut husk for water conservation. These are recommended for arecanut monocrop and arecanut based mixed cropping systems, respectively.

In situ water conservation by creating a slope along the arecanut rows on both sides of the palms is recommended for mono crop of arecanut.

COCOA

Cocoa is a perennial crop invariably grown under irrigation. This crop generally is grown as an inter crop in coconut and arecanut gardens. So no special inter cultural operation are taken up. A lot of leaf fall occurs in the cocoa garden which act as mulch. Pruning is the main operation that is done for cocoa for obtaining better yields and to facilitate easy movement in the field for various operations like fertilizer application and harvesting. Since it is mainly grown as mixed crop all that is applicable for coconut and arecanut is applicable for cocoa also.



Coconut/Arecanut Based High Density Multi-Species Cropping System

R. Dhanapal

Inter/mixed cropping is practiced

1. To avoid total failure in case of any adverse situations,
2. To increase the income from a unit area,
3. For better utilization of the added inputs like water and fertilizer as the roots of different crops mines the nutrients from different depths, and
4. To increase the employment generation.



Coconut based high density multi-species cropping system.



Arecanut based high density multi-species cropping system.

All these objectives are directly or indirectly met through the coconut based HDMSC. Where Coconut based HDMSC with component crops at several layers for example, clove, banana, nutmeg, pineapple, etc., is having conducive micro-climate for better growth of component crops and coconut. In this system the recyclable biomass provides nutrients there by scaling down the additional inputs of fertilizers. The system will help the farmers to sustain the income in adverse climatic conditions and acts as insurance cover under vagaries of nature.



Vegetables can be successfully grown in the inter spaces of coconut and arecanut palms.

Soil and Water Conservation in Sloppy Areas

R. Dhanapal

Conserving natural resources like water and soil is essential for sustaining the crop production in both high- and low-rainfall areas, particularly in sloppy areas, which are prone to soil erosion.

The role played by the bio-engineering and agronomic measures in reducing the soil and nutrient loss and in conserving the run-off water is immense. Various conservation measures for sloppy areas were tried at CPCRI which include half-moon bund with planting pineapple on the bund, staggered catch-pit with planting pineapple on the bund, long trenches filled with coconut husk and planting pineapple on the bund and growing fodder grass across the slope for dual purpose (fodder production as well as soil and water conservation).



Bio-engineering for soil and moisture conservation.



Water harvesting pond.

Due to the adoption of these conservation measures, the coconut yield has increased by 200 to 300 per cent in various treatments compared to the pre-treatment yield. Further, coconut based cropping system was made possible in the rain fed situation. The soil loss in the plots where no conservation measure followed was 10.53 t/ha, whereas in plots with conservation measures it was less than 1 t/ha. Out of various methods, the minimum loss of soil nutrients (N, P and K) was observed in the plots where trenches were

filled with coconut husk with planting pineapple on the bund (1.28, 0.2 and 1.15 kg N, P and K/ha). The maximum nutrient loss was observed in un conserved plots and it was approximately 100-times more for N and P and 15-times more for K as compared to that in conserved plots. Water harvesting structure with micro-conservation area of three hectares could store approximately eight million litres



Channels across the slope.



Soil and water conservation using coconut husks.

of water which can be recycled through micro-irrigation covering 1.5 ha of coconut based cropping system (eg. coconut, banana, pineapple and pepper) for a period of 5 months during summer.

Chapter 4: Drought Management in Coconut Gardens

S. Naresh Kumar and V. Rajagopal

Coconut palms, as rainfed crop, are exposed to annual summer dry spells as well as frequent drought years of different intensities and durations in various parts of the country. The impact of drought on coconut persists for two to three years in view of the indeterminate flowering habit and perennial nature of the crop. As coconut yields are closely linked to favorable weather conditions, occurrence of drought leads to significant reduction in yields thereby resulting in considerable economic loss to the growers. Impact of drought stress and response of palms to tolerate drought was studied in India and abroad. Investigations based on physiological, anatomical and biochemical characters resulted in identification of some of the genotypes capable of withstanding drought conditions. A sound knowledge on the character of drought, available local natural resources, etc. is an essential pre-requisite to initiate any action on drought management. Investigations were carried out to characterize the nature of drought in different agro-climatic zones and to evolve soil moisture conservation practices suitable for specific locations. Apart from this, *in situ* drought tolerant palms were identified in farmers' fields under different agro-climatic zones.

IMPACT OF DROUGHT ON COCONUT

Drought stress affects coconut seedlings

Seedlings need to be protected from high Sun-light



Plate 4.1: Water-stress affected coconut seedlings.

intensities by providing shade. A dry spell of 15 to 20 days makes seedlings to experience water stress resulting in leaf wilting and scorching and ultimately leading to seedling death.

Frequent drought stress affects the adult palms

Drought affects coconut palms and the impact can be seen from the year of drought till four years. Since the inflorescence primordial initiation to nut maturity takes 44 months, any coincidence of drought or dry spell with critical sensitive stages viz. inflorescence primordial initiation, ovary development, button size nut stage, adversely affects the nut yields. For the recovery also coconut takes at least three to four years. The coconut palm experiences moisture stress when exposed to solar radiation above 265 Wm^{-2} , temperature of 33°C and vapour pressure deficit of 26 m bar, aggravated by soil water deficit during the period.

The rainfed coconut gardens also face summer dry



Plate 4.2: Breaking of coconut frond due to drought.

spells causing drooping of leaves due to low leaf water potentials, shedding of buttons and immature nut fall. In severe stress conditions bending and breaking of leaves occur. Drought occurrence



Plate 4.3: Drought affected coconut palm.

aggravates the situation causing these symptoms early and in severe cases crown gets damaged leading to detopping and death of palms leaving only dead stems in the field. Most of the palms will be without any bearing inflorescence or inflorescences with barren nuts thus affecting the productivity and income to the farmer. Such gardens take three to four years to revive once soil moisture



Plate 4.4: One of the drought affected coconut gardens in Pollachi (Coimbatore, Tamil Nadu) area.

conservation practices are adopted. For example, in areas like Pollachi in Tamil Nadu and Northern Districts of Karnataka, the coconut plantations faced successive drought years leading to defoliation and death of the plant. In Pollachi Taluk alone lakhs of palms were dead across thousands of hectares and many more were severely affected. The severely affected palms had two to six leaves left intact during

severe drought years. These palms, upon drip irrigation, are now reviving. However, these palms will take at least another two years to bear the nuts. Thus, farmers lost the income for almost five to six years. Providing flood irrigation during water abundant times and leaving them starved during water scarce periods lead to severe stress on palms. As flood irrigation promotes root growth only to the top layers, in water scarce period palms will not be able to uptake water from deeper zones because of the lack or less of active root system. Hence, it is recommended to follow the drought management practices to mitigate dry spell effects, apart from discontinuation of the flood irrigation practice. Soil moisture conservation practices should be followed based on the availability of material. Available scarce water resources can be used for providing summer irrigation to all palms in the field even at deficit levels. Old leaves can be cut to reduce the transpirational water loss. Drip irrigation can increase the water use efficiency at field and plant level. At larger scale, *in situ* water harvesting is one of the important methods to increase the soil water table.

DROUGHT MANAGEMENT STRATEGIES

Drought management involves soil moisture conservation, water and plant management. It is recommended that for effective drought management in coconut gardens, any treatment of the following, alone or in combination depending on the suitability and availability of material, may be followed.

Drought tolerant cultivars/hybrids

Plant drought tolerant cultivars like WCT, LCT, etc. Among the hybrids WCT x COD, LCT x GBGD, LCT x COD are relatively drought tolerant.

Drought management

Nursery and seedlings

As mentioned in chapter 3 at nursery and seedling stage coconut needs to be well irrigated. Seedlings are very sensitive to moisture stress and high light intensities. Thus at nursery level and till two years after field planting seedlings need to be provided the irrigation (at least once in a week) and partial shade. Expose of seedlings to water stress coupled with high Sun-light intensities will lead to the leaf



Plate 4.5: Coconut nursery raised under the shade of adult palms.

scorching and in severe cases to seedling death. Shade is generally provided during summer by covering with dried coconut leaves either by wrapping the entire seedling or by erecting the dry leaf screen on the South-Western side of the seedling so that the after noon Sun-rays can be checked from falling on the seedling.

Advice to farmers

What to do

- Irrigate seedlings once in 4 days during summer.
- Provide shade.

What not to do

- Do not expose seedlings to water stress.

Juvenile and adult palms

Ideally coconut palms should receive water every week for good yields. The frequency and amount of irrigation influences the growth and yield of coconut palm. Soil moisture conservation practices and irrigation management to mitigate drought and summer dry spells help to maintain or increase nut yield in coconut. Potassium nutrition also plays important role in drought tolerance in coconut. Apart from these, the crop management should also be followed. In the subsequent sections all these are explained.

Soil moisture conservation in coconut basins

Conserving soil moisture is one of the effective ways

of drought management. Soil moisture conservation practices should be imposed just after first spell of monsoon showers in the areas where the gap between rainy spells is long. In areas with high rain fall, it is recommended that the soil moisture conservation treatments may be imposed at the end of the rainy season. Depending on the availability of material, suitable practice can be adopted as recommended. It is also advisable to conserve the summer rainfall water as well. By practicing soil moisture conservation methods one can reduce number of summer irrigations. Different soil moisture conservation practices were evaluated for their effectiveness in various agro-climatic zones. Efficiency of soil moisture conservation practices depends on soil type also.

Details of *in situ* soil moisture conservation in basins

Basin opening

Conservation of soil moisture in root zone is very important for ensuring the moisture availability for



Plate 4.6: Opened coconut basin.

prolonged periods. For imposing soil moisture conservation practices in root zone, coconut basin (1.8 m radius from bole) can be opened to a depth of around 20 to 30 cm. Basin opening can be done from base of trunk if planting is done in pits of 1 x 1 x 1 m and no roots are visible near base; or 30 cm away from the trunk if roots are exposed near base of palm. In opened basins, materials like coconut husk, farm waste, green manure, composted coir pith, etc. can be placed and covered with soil.

Advice to farmers

What to do

- Impose soil moisture conservation treatment immediately after cessation of rains.
- If long gap between rainy periods is a common phenomenon, impose the treatments at the end of first rainy spell.

What not to do

- Do not damage the roots while opening the basins.
- Do not damage the roots exposed at the base of the shallow planted palms.

Husk burial

The coconut husks (half pieces) can be buried in opened basin. Half splits of dry coconut husk should be placed in this trench with convex side facing up. Husks should be placed closely so as to cover the entire area as a mulch. This can be done in one or



Plate 4.7: Placing of husks in opened basin.



Plate 4.8: Husks should be fully packed in opened basin.



Plate 4.9: Leaving space from bole in plantations where roots are seen while opening the basin and placing the husks.

two layers. Husk layers should be covered with soil. This will help to retain the husks in trench for longer time and also to absorb the air moisture or rain-water in side. About 1000 husk pieces per palm are required for this treatment. This method of conservation is very effective and buried husks can remain intact for two to four years depending on soil type. It was observed that in light soils this remains for longer period.

Advice to farmers

What to do

- Place the husks close to each other in circular fashion.
- Place at least 2 layers in such a way that all the gaps are fully covered.
- Cover the layers with soil.

What not to do

- Do not leave the husks uncovered.
- Do not place husks loosely leaving gaps.

Composted coir pith

Coir pith is easily available in areas where coir industries are located. This material is largely unused and wasted. Composted coir pith (around 50 kg/palm) can be buried in the entire area of opened basin and covered with soil. Care must be taken to apply only thoroughly composted coir pith. Do not use fresh coir pith as it is rich in ployphenols, which affect the palm growth.



Plate 4.10: Coir pith burial in coconut basin.

Advice to farmers

What to do

- Use only composted or highly decomposed/leached out coir pith.

What not to do

- Do not use fresh coir pith.
- Do not waste coir pith

Potassium application

Potassium can be applied at increased dosage than recommended dose as per regular fertilizer application schedule. After application of fertilizers in opened basin, it should be covered with soil. Application of 500 g NaCl (common salt) around the palm basin will also be beneficial.

Advice to farmers

What to do

- Apply in equal split dose once during June (onset of monsoon) and once during October (end of monsoon).

What not to do

- Do not leave the fertilizer uncovered with soil.

Burial of farm waste

Farm waste (fresh and dry material) can be put in opened basin and covered with soil. Materials such as leaves and small twigs of *Casurina*, *Glyricidia*, coconut bunch waste, and other farm waste can be used for burial. Addition of green manures and organic manures (FYM @ 50 to 60 kg/palm) and / or tank silt at 100 to 200 kg/palm/year also can be taken up. Do not leave the organic material

uncovered with soil as it may act as the breeding material for pests.

Advice to farmers

What to do

- Chop the farm waste material before placing in the basin.

What not to do

- Do not leave the material uncovered with soil.
- Do not waste farm waste.

Surface mulching

Mulching can be done by either placing dried coconut leaves, composted coir dust or any other leaf material in the entire basin area in three to four layers. Coconut leaves can be cut in to two to three pieces before putting for mulching. This treatment is very effective if it is maintained continuously since strong winds disturb the mulched leaves leaving the surface exposed for drying.



Plate 4.11: Mulching coconut basin with leaves.



Plate 4.12: Mulching coconut basin with leaves in one of the coconut gardens in drought affected areas.

Advice to farmers*What to do*

- Mulch with leaves at least in three layers.
- Replace the disturbed mulch material.

What not to do

- Do not allow establishment of ant colonies in mulched leaves.

Heaping of weeds

In some locations this method is practiced. Weeds in the farm can be collected or rooted out and placed in the entire basin around trunk of the palm in a heap. Height of heap can vary from one to four feet depending on the availability of material.

Advice to farmers*What to do*

- Place only dried weeds in the basin.

What not to do

- Do not allow heaped weeds to establish in basin.

Fertilizer application method

It is recommended that the soil moisture treatments may be imposed at the end of rainy season, fertilizers can be applied before imposition of treatments. In case, burial of husk or farm waste is practiced, in the first year, the treatments may be imposed after the application of fertilizers or organic manures. In subsequent two years, the fertilizers and organic manures can be applied over the decomposing husk or farm waste material and may be covered with soil. In areas where the gap between rainy spells is too long, it is recommended that the soil moisture conservation treatments may be imposed at the end of first spell of rain. In such situation, for application of fertilizers and manures, a slight circular gap (without husks) may be provided at about one meter radius to facilitate fertilizer application. Organic manure may be applied in entire basin area.

Advice to farmers*What to do*

- Replace the mulch material after fertilizer application wherever necessary.

What not to do

- Do not apply fertilizer above undecomposed surface mulch.

Soil water conservation in coconut gardens

This includes the practices like burial of husk or coir pith, etc. in trenches in between palms, or between palm rows, etc. This way, every year, trenches are taken in different directions to fill with husk, coir pith, etc. thus covering most of the areas with in a few years. This helps in overall improvement of soil moisture retention capacity.

Advice to farmers*What to do*

- Do not damage the coconut root system.

What not to do

- Do not bury undecomposed coir pith.

Water management in coconut gardens

- Adopt drip irrigation at 66% Eo: Three or four drippers may be placed per palm. Drip irrigation is shown to increase not only field water use efficiency (WUE) but also the physiological WUE of plant.



Plate 4.13: Drip irrigated coconut gardens saved from adverse impact of drought. Note the drought affected garden on the right side.

- If adequate water is available, irrigate with 200 L water/palm once in four days and mulch with dry leaves.
- Bury two or three earthen pots or hollow bamboos in the basin area and fill with water.
- Ensure life saving irrigation at least once in 15 days during dry/summer water scarce periods.
- Ensure all palms are irrigated in the garden even at deficit irrigation, this will protect all

the palms from being affected by dry spell and droughts.

- Apart from this, supply of available water to all palms in the garden helps in protecting them from moisture stress and maintaining yield per palm even during drought years.

Advice to farmers

What to do

- Ensure recommended irrigation levels.
- Ensure life saving irrigation.
- Recycle the waste water from backyards for irrigation.
- Ensure all palms are irrigated in the garden even at deficit irrigation.
- Provide mulching all the time to reduce evaporation losses.

What not to do

- Avoid flood irrigation.
- Do not waste available water.

Water management at farm/local level

The following soil and water conservation methods can be adopted at a larger level.

- In sloppy lands, terrace the palm basins for interception and percolation of run off water to enhance soil moisture.
- Prepare bunds dividing the field into plots to prevent run off of water.
- Construct water harvesting tanks/ponds/furrows in mildly sloped area.

Advice to farmers

What to do

- Make collective/community effort for water harvesting and water sharing.
- Store water for irrigation during summer/dry period.

What not to do

- Do not allow run-off of surface soil and water.
- Do not waste water when available.

Crop management

Crop management also offers scope to reduce the impact of drought on crop mainly by the removal of senescent (drying) leaves to reduce transpiration loss. If late rains occur, pulses or fodder crops can be sown in between coconut rows. After harvest, the plant residues can be used as mulches. Simultaneously, green manure crops can be raised in the coconut garden. Ploughing back tender *Glyricidia* has given encouraging results in alleviating the impact of water stress on production, by increasing the soil water holding capacity.

Advice to farmers

What to do

- Cut the dried/ senescent lower leaves.

What not to do

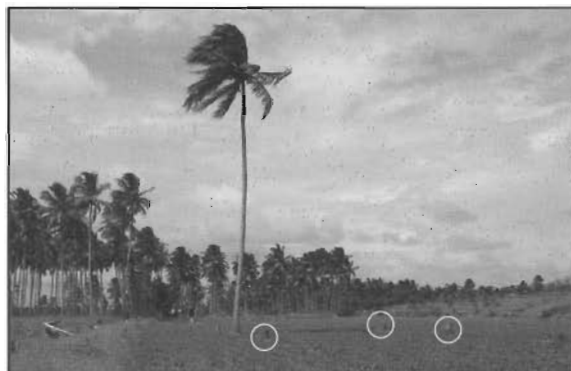
- Do not leave the senescent and old leaves intact to the palm.



In situ Drought Tolerant Palms

S. Naresh Kumar

It is important to identify the palms, which survive and yield heavily in drought prone locations. These palms have desirable traits for drought tolerance, thus are able to withstand drought and yield high. Identification of such palms will help in increasing the genetic variability for the crop, which can be used for crop improvement programme. Such field tolerant palms were identified *in situ* during surveys conducted in farmers' plots under rainfed condition at Arsikere, Ambajipeta and Ratnagiri. These field drought tolerant



In situ drought tolerant palm. Note palms in vicinity are dead due to drought and are cut.



In situ drought tolerant palms have high WUE and yield.

palms had more number of leaves, bunches and mature nuts/ bunch compared to the other palms in the vicinity. These palms also exhibited good water use efficiency. The superiority of these palms in the photosynthetic parameters showed their capacity for drought tolerance and high yield (~ nuts/palm/year). They can be used as mother palms in breeding programme for drought tolerance. Conservation and characterization of desirable gene pools present in such palms should be a priority. For marking a palm as field drought tolerant, it is absolutely necessary

that the physiological, morphological and yield superiority of those palms should be monitored for at least three years.

Button Shedding in Coconut

K.V. Kasturi Bai

The coconut palm produces one mature bunch more or less regularly every month. In general, the summer yields are high and post monsoon yield are low in Kerala. The fluctuation between seasons is mainly due to the impact of climate on button nut shedding. Shedding of button nuts occurred not only when there was a moisture deficit but also during the wettest times of the year. Button shedding was high during the south-west monsoon from June to September and low during the cold weather period from December to February in the North Kerala. The percentage of button shedding varies greatly with the cultivar, season apart from being influenced by management levels. Seasonal variations indicated that 83% of nuts from inflorescences those opened during the South-West monsoon (June – September) were shed but only 39% were shed from those opened during the winter (December –February). The percentage of button nuts shed was significantly correlated with total rainfall and minimum air temperature.

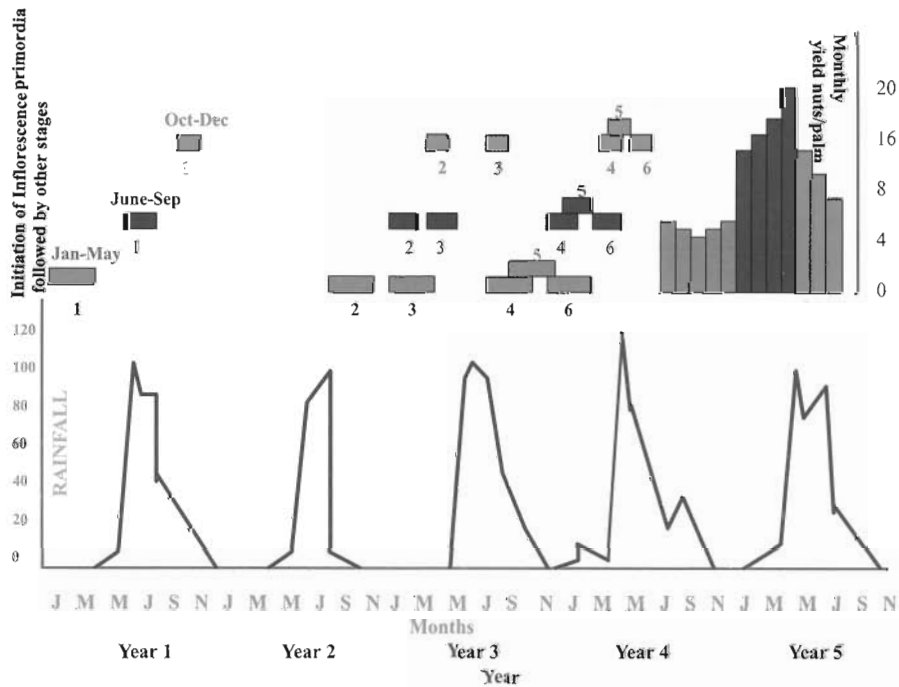
Coconut Inflorescence Ontogeny in Relation to Rainfall, Dry-spells and Yield

V. Rajagopal and S. Naresh Kumar

The tall coconut palm with its indeterminate flowering habit, comes to flowering by the seventh year after planting. The first inflorescence emerges from the 45th leaf axil and thereafter one inflorescence arises every month from the subsequent leaf axils. The period reckoned from the initiation of the inflorescence primordium (IP) to full maturity of the nut (MN) lasts about 44 months, out of which the pre-fertilization phase accounts for 32 months (i.e. 73% of the total reproductive phase), as compared to only 12 months for the fertilization and post-fertilization phases.

In the West Coast Tall variety, the formation of female and male flowers takes place 20 and 21 months respectively, after initiation of the primordium. The spathe opens at the 32nd month, fertilization takes place during the 33rd month and the nut development proceeds through the formation of button size, fist size and immature nut stages before the nut maturation at the 45th month. Generally, the nuts are harvested 11 to 12 months after fertilization.

The inflorescence primordium which was initiated in the month of January of year I attains maturity by September after three years. The monthly harvest data of rainfed palms (histograms on the right scale) between the 45th and 56th months clearly show that the low nut yields during September to December (45th to 48th months) of each year could be traced back to the initiation of the respective primordium during dry months three years earlier. On the other hand, high nut yields obtained during December to May (48th to 53rd months) could be attributed to the primordial initiation coinciding with wet months between June and October three years



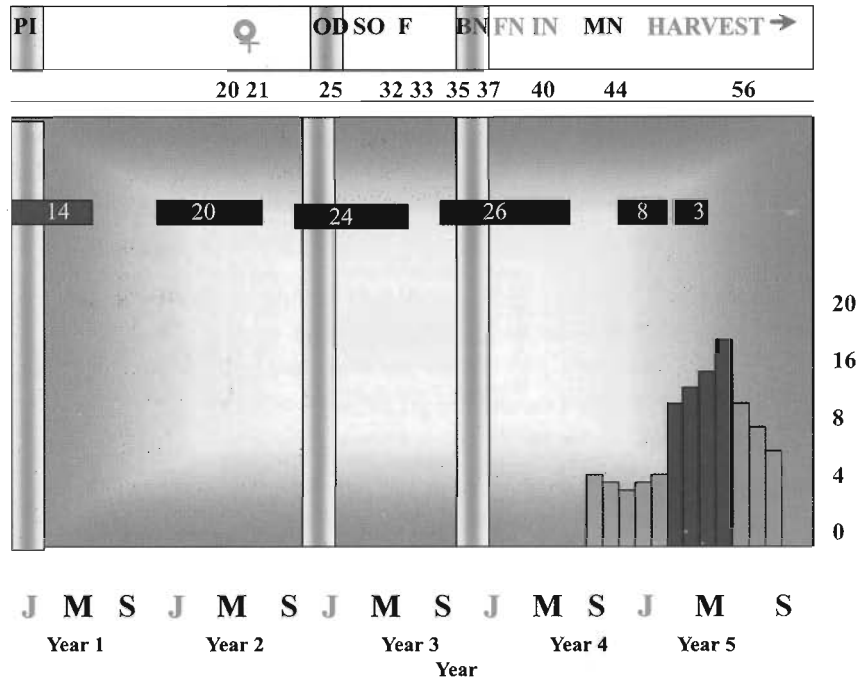
Schematic diagram depicting the monthly rainfall (peaks) or dry spell (drought) superimposed on growth stages divided into three groups based on initiation of the inflorescence

to the primordial initiation coinciding with wet months between June and October three years

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earlier. Thus, there is an indication that adequate soil moisture availability during the initiation of the inflorescence primordium is favourable for high nut production. The length of dry spells during the summer of the previous three years and not the dry period during the year of harvest influences nut yield.

The figure indicates the data for rainfall or a dry spell at each stage under each group, making it thus clear whether a particular stage is coinciding with peaks of rainfall (for instance, stage 1 of group 2) or falling in the trough i.e. dry spell (stage 1 of group 3). The figure also precisely reveals distances or overlaps between the stages among the three groups. It may be noted that the length of the dry spell at each stage was the highest in group 1, followed by group 2 and group 3.



Schematic diagram depicting the coincidence of dry spells with sensitive stages of inflorescence ontogeny and resultant nut yield in corresponding harvest periods.

From the foregoing, it is also apparent that the total rainfall, number of rainy days and the total dry spell are not as crucial as the length of dry spell at the critical stages such as, primordium initiation, ovary development and button size nuts which ultimately determine the yield potential of rainfed palms. It was found that out of an average of 18 months of dry period, PI, OD and BN experienced dry spells of 4.2 months, 4 months and 3.2 months respectively which worked out at 23.4%, 22.2% and 18% of the total. This clearly indicated that the PI stage was the most sensitive to moisture stress, followed by the ovary development stage. These three stages together accounted for 63.6% of the total dry spell, while other stages shared the remaining 34.4%.

It can be concluded that i) coconut production under rainfed conditions is influenced significantly by the length of dry spells at critical stages, ii) the availability of adequate moisture in the field on primordial initiation, ovary development and button size nut in that order, are most crucial for the production of nuts and iii) nut production can be sustained at relatively high levels by giving life saving irrigation during summer months by reducing the ill-effects of dry spells, especially on the development of the inflorescence primordium. The study highlights the possibility of developing a computer model for prediction of coconut yield based on the rainfall and dry spell pattern during the three critical stages prior to harvest.

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Chapter 5: Weather in Different Agro-climatic Zones, Dry-spells, Drought and Coconut Yield

S. Naresh Kumar

It is well known that nature of drought varies from place to place. Hence, it is essential to know about the nature, intensity and length of drought as well as available natural resources for efficient management of drought situation. The characterization of drought and evaluation of soil moisture conservation strategies in different agro-climatic zones viz. Western ghats -high rainfall zone (Kidu-Karnataka), Western coastal area – hot sub-humid-per-humid (Kasaragod – Kerala; Ratnagiri – Maharashtra), hot semi arid (Arisikere – Karnataka) and Eastern coastal plains- hot sub-humid (Veppankulum- Tamil Nadu; Ambajipeta- Andhra Pradesh), provided valuable information for drought management. These zones represent the major coconut growing areas in India.



Plate 5.1: Coconut growing areas in India.

Weather data based characterization of drought and its intensity indicated variations in length and number of dry spells in each zone. Apart from this they also differed for rainfall, temperature regimes and light intensities, thus bringing about the different intensities of drought. Soil characters were also taken into consideration as the soil types vary from zone

to zone. When expressed as number of days, dry spell in a year was longer in Ratnagiri (216 days) and Arsikere (202 days) and shorter at Kidu (146 days). Impact of such variations in dry spell on nut yield was discernible and the nut yield exhibited large

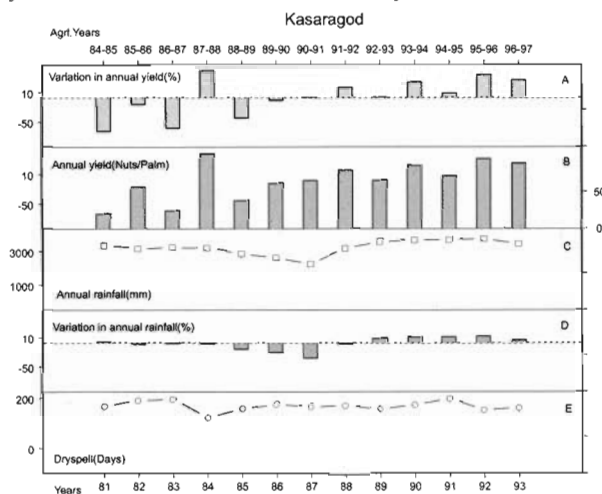


Fig. 5.1: Annual nut yield and variation in annual yield as influenced by rainfall and dry spell over a period of time at Kasaragod. X1 axis for A and B; X2 axis for C, D and E graphs. Note that the X1 (agricultural years) axis is having 4 years gap at a corresponding point of X2.

variations over the years in all the centres. In view of long duration of 44 months between the initiation of inflorescence primordium and ultimate nut yield, with about 70% period of pre-fertilization and only 30% represented by fertilization / post-fertilization phases, any fluctuations in dry spell coinciding with sensitive stages of floral / fruit development would reflect on nut yield. The study revealed that the coincidence of dry spell during these stages ultimately determine the nut production. The coconut production varied in different centres. Longer dry spell was found to affect nut yield in the fourth year. Annual rainfall and its distribution has greater influence on the nut production in coconut. The length of dry spells in relation to coconut yield indicated definite inverse trends. Further, it should be noted that successive drought years spell doom for coconut growth and yield as explained in Chapter 4.

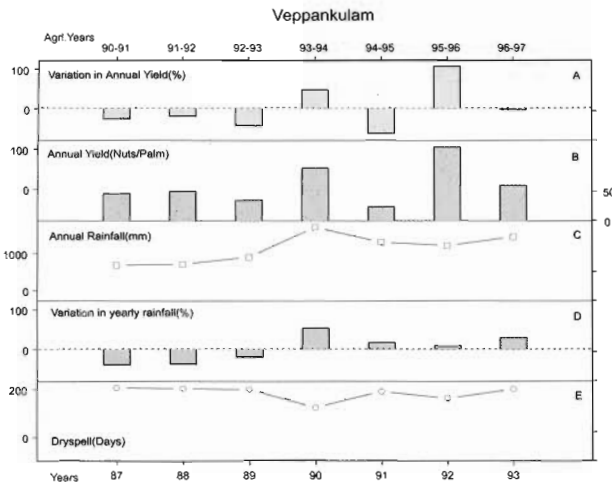


Fig. 5.2: Annual nut yield and variation in annual yield as influenced by rainfall and dry spell over a period of time at Veppankulam. X1 axis for A and B; X2 axis for C, D and E graphs. Note that the X1 (Agricultural years) axis is having 4 years gap at a corresponding point of X2.

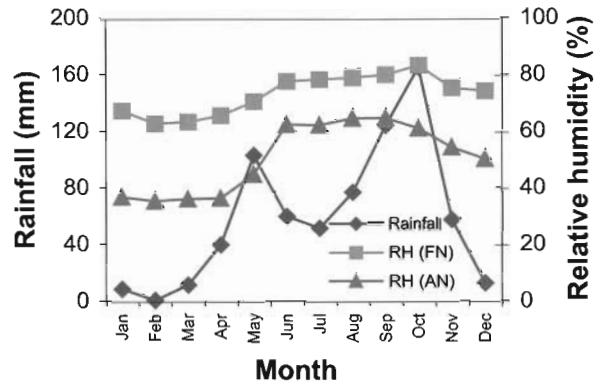


Fig. 5.4: Monthly patterns of rainfall and relative humidity in Arsikere area (mean of 15 years data).

In the following the climatic conditions of each agro-climatic zone and possible soil moisture conservation measures are given. For details on methods for imposition of treatments, please refer to Chapter 4.

Hot semi-arid (represented by Arsikere, Karnataka)

Arsikere receives an annual rainfall of 718 mm with rainy days spread over all 12 months of the year. The rainfall is maximum during October (166 mm). Summer showers also occur with relatively higher rainfall during May (104 mm). In this area, apart from adoption of soil moisture conservation measures, removal of old leaves will help to reduce transpiration losses. Further, adaptation of drip irrigation with mulching will help in increasing water use efficiency.

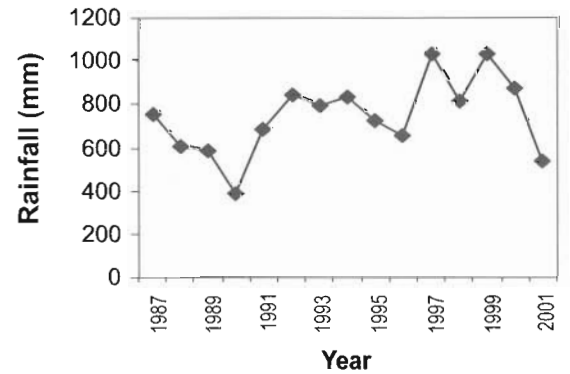


Fig. 5.5: Annual rainfall pattern over 15 years period in Arsikere area.

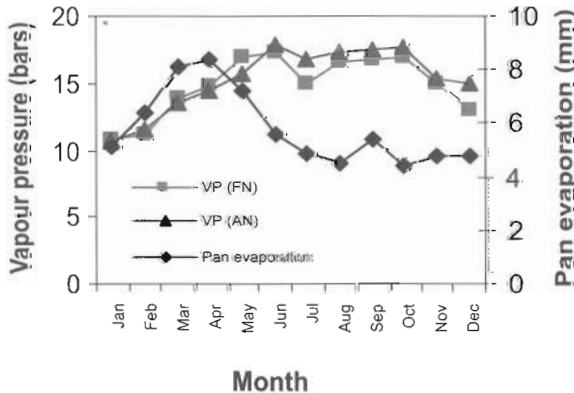


Fig. 5.3: Monthly patterns of vapour pressure and pan evaporation in Arsikere area (mean of 15 years data).

Drought Management

Table 5.1: Soil moisture conservation practices suitable for Arsikere area and their scope for adaption.

Best suitable soil moisture conservation practice	Locally available material	Scope for promotion
FYM+ Glyricedia > composted coir pith > double the dose of recommended K ₂ O application > husk burial > mulching with leaf.	Coir dust, husk, leaf, FYM and green manure.	Since a lot of coir pith is locally available, use of composted coir pith may be promoted extensively to conserve the soil moisture in this drought prone area. This will also create a demand situation for coir pith, which other wise is dumped on the roadsides. Apart from this, burial of green waste also can be recommended.

Chapter 5
Climatic conditions & Agricultural climatic zones



Advice to farmers

What to do

- Impose, the soil moisture conservation practices during late October or early November.
- Apply either FYM, *Glyricedia*, composted coir pith or bury husks in basin.
- Remove old senescent leaves.
- Adopt drip irrigation with mulching.

What not to do

- Avoid basin irrigation with out mulching.

Eastern coastal plains- hot sub-humid (represented by Veppankulam, Tamil Nadu)

Veppankulam receives an annual rainfall of 1117 mm with maximum during November. North -East monsoon is prominent in this area and summer showers also occur with relatively higher rainfall during May. Flood irrigation is a common practice in this area. This practice may be discontinued in this region and in most parts of Tamil Nadu as it makes the palms more prone to drought affects by promoting root growth only in top layers of soil. If drought year occurs these palms will not be able to withstand water scarcity due to the non-availability of enough functional root system in the deeper layers of soil.

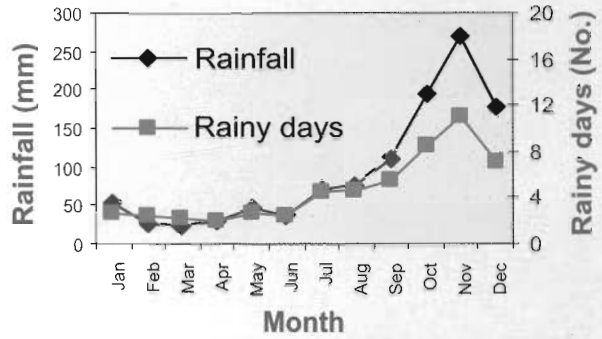


Fig. 5.7: Monthly patterns of rainfall and number of rainy days in Veppankulam area (mean of 19 years data).

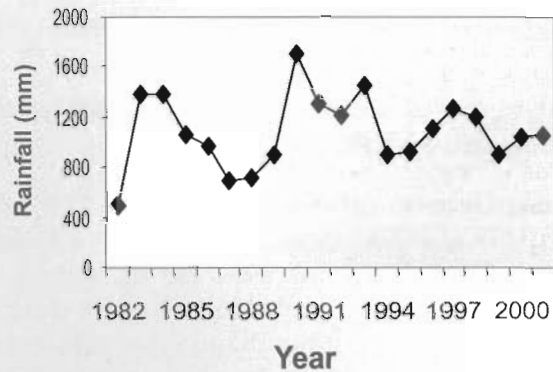


Fig. 5.8: Annual rainfall pattern over 19 years in Veppankulam area.

Drought Management

Table 5.2: Soil moisture conservation practices suitable for Veppankulam area and their scope for adaption.

Best suitable soil moisture conservation practice	Locally available material	Scope for promotion
Double the dose of recommended K_2O application > husk burial > mulching with leaf > composted coir pith > mulching with coir dust.	Coir dust, husk and leaf.	In this area also coir pith is locally available. Use of composted coir pith may be promoted extensively to conserve the soil moisture in this dry area. This will also create a demand situation for coir pith. Apart from this burial of farm waste and husk also can be recommended.

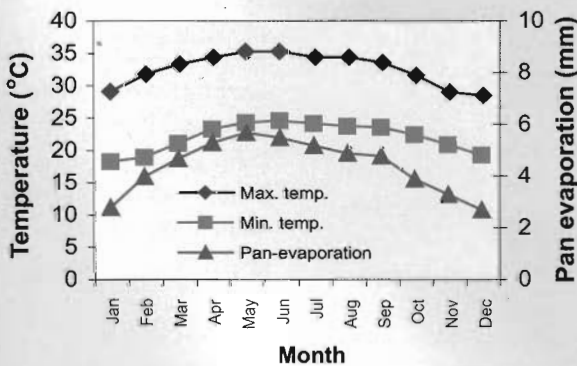


Fig. 5.6: Monthly patterns of temperature and pan-evaporation in Veppankulam area (mean of 19 years data).

Advice to farmers

What to do

- Impose soil moisture conservation practices during December month.
- Bury husks in palm basin, apply composted coir pith, mulch basin with dry coconut leaves.
- Remove old and senescent leaves.
- Adopt drip irrigation with mulching.

What not to do

- Avoid flood irrigation.

Western coastal area – hot sub-humid-per-humid (represented by Ratnagiri, Maharashtra)

Ratnagiri receives an average annual rainfall of 2803 mm. Rainfall is maximum during July (946.7 mm). The maximum temperature lies during May while the minimum day temperature occurs during August. On the other hand the minimum temperature is low during January while it is high during May. The relative humidity is low during the first and last two months of the year and it is high in July (89.7%). In this zone the South-West monsoon is the only source of rainfall. Since rains do not occur from November to April, conservation of soil moisture is at most important to help retain the moisture for longer period.

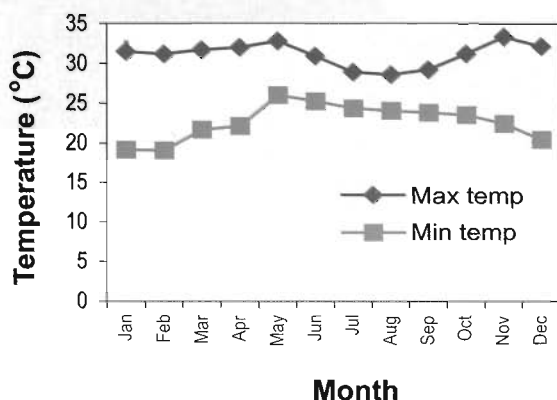


Fig. 5.9: Monthly pattern of temperature in Ratnagiri area (mean of 21 years data).

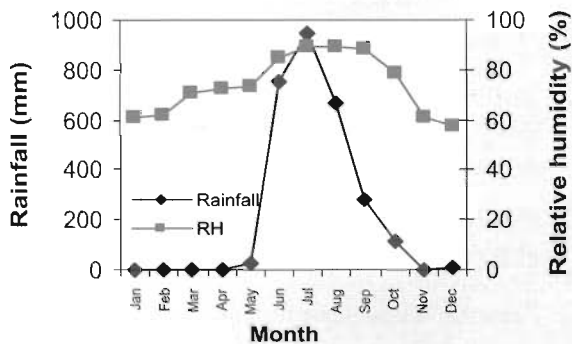


Fig. 5.10: Monthly patterns of rainfall and relative humidity in Ratnagiri area (mean of 21 years data).

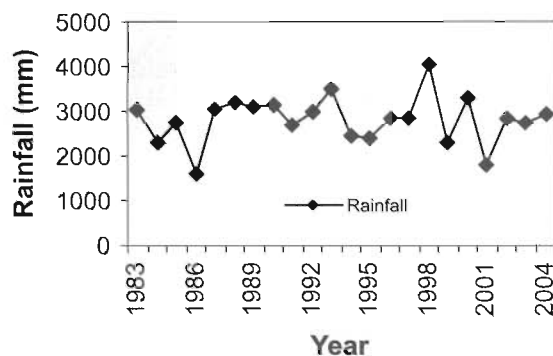


Fig. 5.11: Annual rainfall pattern over 21 years in Ratnagiri area.

Drought Management

Table 5.3: Soil moisture conservation practices suitable for Ratnagiri area and their scope for adaption.

Best suitable soil moisture conservation practice	Locally available material	Scope for promotion
Mulching with farm green waste/ weed heaping> Agrisorb > double the dose of recommended K ₂ O application> mulching with leaf> husk burial.	Husk, leaf and green manure.	Leaf mulching, burial of coconut husk or farm waste in palm basins can be followed. Mulching with farm green waste/ weed heaping, a local practice also have given better results.

Advice to farmers

What to do

- Soil moisture conservation practices may be imposed during September-October months.
- Mulch palm basin with coconut leaves or bury husks in palm basin.
- Remove old senescent leaves.
- Adopt drip irrigation with mulching.
- In sloppy areas, follow *in situ* water harvesting methods by collecting the run-off water in trenches.

What not to do

- Do not overspend the available water.
- Avoid flood irrigation.

Eastern coastal plains- hot sub-humid (represented by Ambajipeta, Andhra Pradesh)

Ambajipeta receives an annual rainfall of 1140.7mm and highest rainfall is obtained during July and October (211.8 and 221.9 respectively). In this zone also the South-West monsoon is the main source of rainfall. Since the rains do not occur from December to April, conservation of soil moisture is at most important to help retain the moisture for longer period in this area as well. Also, *in situ* water harvesting needs to be followed. In areas near to the coast or to the back waters, providing summer irrigation may not be a problem if seepage pits are taken in place between palms to get the water source in the field it self. From this irrigation may be provided after diluting with fresh water. Further, in areas located far from the water source, drip irrigation may be adopted. In either case adoption of soil moisture conservation practice is essential.

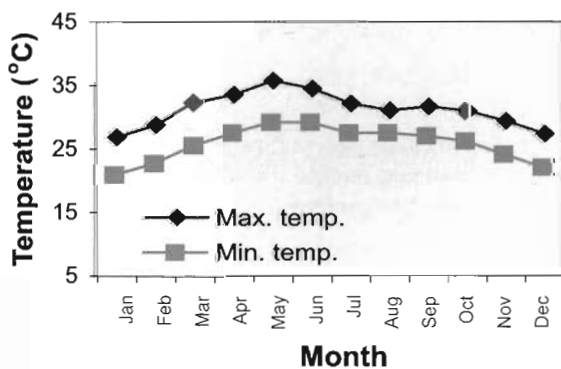


Fig. 5.12: Monthly pattern of temperature in Ambajipeta area (mean of 23 years data).

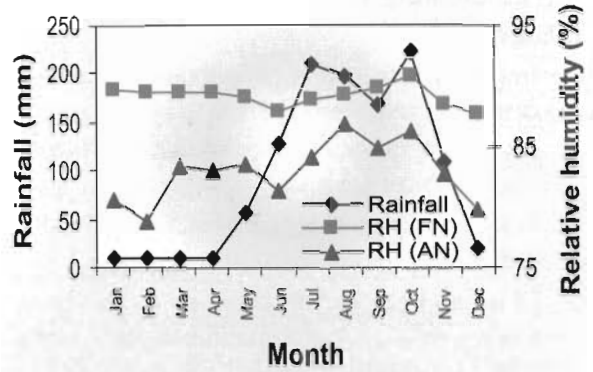


Fig. 5.13: Monthly patterns of rainfall and relative humidity in Ambajipeta area (mean of 23 years data).

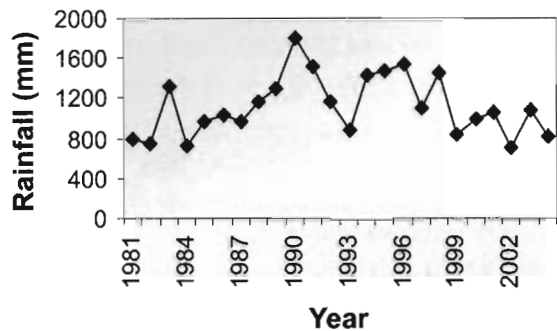


Fig. 5.14: Annual rainfall pattern over 23 years in Ambajipeta area.

Drought Management

Table 5.4: Soil moisture conservation practices suitable for Ambajipeta area and their scope for adoption.

Best suitable soil moisture conservation practice	Locally available material	Scope for promotion
Husk burial > mulching with leaf > burial of farm waste in palm basin > double the dose of recommended K ₂ O application.	Husk, leaf and green manure.	Here burial of husk or farm waste in palm basin may be recommended.



Advice to farmers

What to do

- Impose soil moisture conservation practices during November.
- Bury husks in palm basin, mulch palm basin with coconut leaves.
- Remove old senescent leaves.
- Adopt drip irrigation with mulching.
- In areas near to the coast or to the back waters, take seepage pits in between palms to get irrigation water.

What not to do

- Do not overspend the available water.
- Avoid flood irrigation.

Western coastal and ghats high-rainfall zone

Western ghats (represented by Kidu, Karnataka)

This centre receives an average annual rainfall of 2788 mm with maximum rainfall in July (791.3 mm). Temperatures are maximum during April (37.9 °C) and minimum during January (12.4 °C). In this zone also the South-West monsoon is the main source of rainfall along with occasional summer showers. Conservation of soil moisture helps to retain the moisture for longer period in this area. Removal of old leaves and adaptation of drip irrigation with mulching will help in improving water use efficiency. Also *in situ* water harvesting needs to be followed. In either case, adoption of soil moisture conservation practice is essential. In undulated terrains, contours may be made to reduce the soil and water loss. Seepage pits and water harvesting structures at farm level will help in harvesting the run-off water, which can be used for summer irrigation.

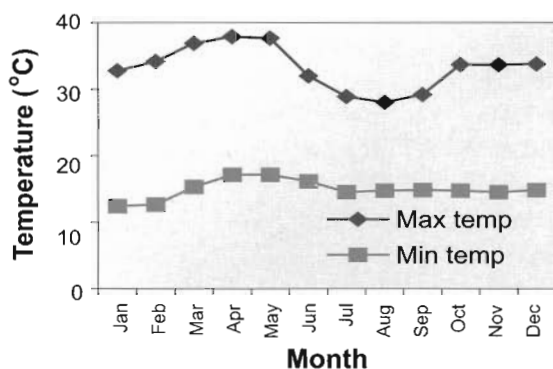


Fig. 5.15: Monthly pattern of temperature in Kidu area (mean of 13 years data).

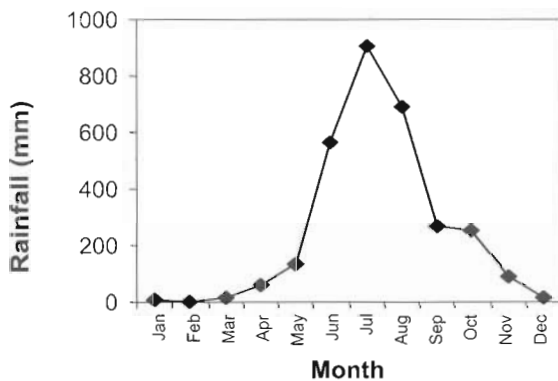


Fig. 5.16: Monthly rainfall pattern in Kidu area (mean of 13 years data).

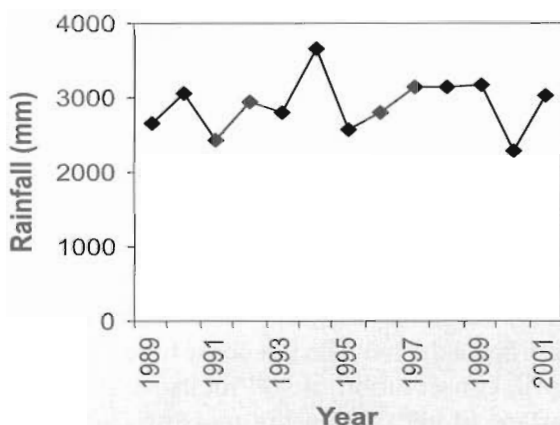


Fig. 5.17: Annual rainfall pattern over 13 years in Kidu area.

Western coastal plains (represented by Kasaragod, Kerala)

This centre receives an average annual rainfall of 3600 mm with maximum rainfall in June and July (around 950 mm in each month). Temperatures are maximum during May and minimum during July.

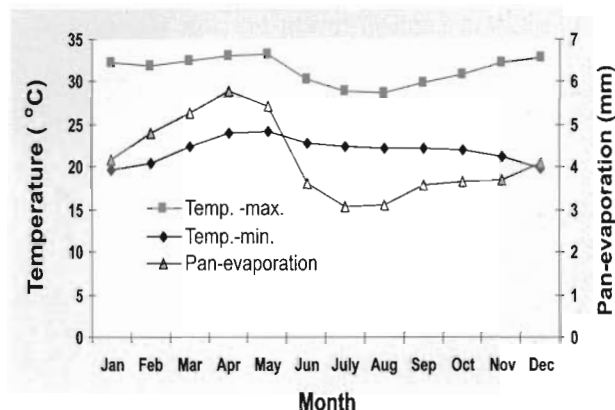


Fig. 5.18: Monthly patterns of temperature and pan evaporation in Kasargod area (average of 25 years).



In this zone also the South-West monsoon is the main source of rainfall along with occasional summer showers. The soil moisture conservation measures are same for this area as well.

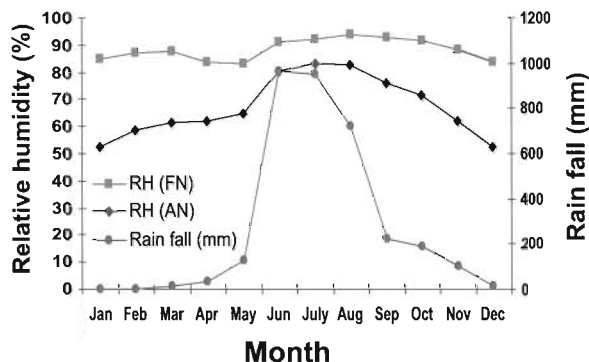


Fig. 5.19: Monthly pattern of rainfall and relative humidity in Kasargod area (average of 25 years).

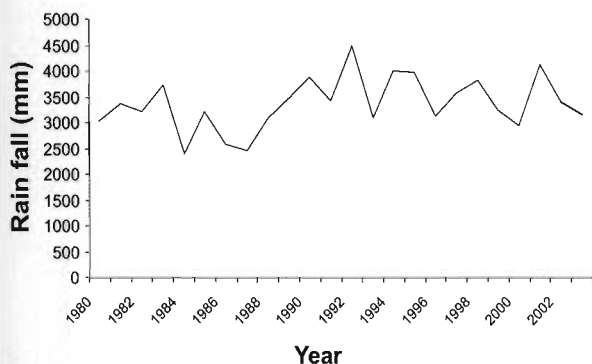


Fig. 5.20: Rainfall pattern in Kasargod area over 25 years.

Drought Management

Table 5.5: Soil moisture conservation practices suitable for Kidu area and their scope for adaption.

Best suitable soil moisture conservation practice	Locally available material	Scope for promotion
Husk burial> composted coir pith> double the dose of recommended K ₂ O application> mulching with farm green waste/ weed heaping> mulching with leaf.	Husk, leaf and green manure.	Here burial of husk in palm basin may be recommended. Apart from this heaping of farm waste also is useful.

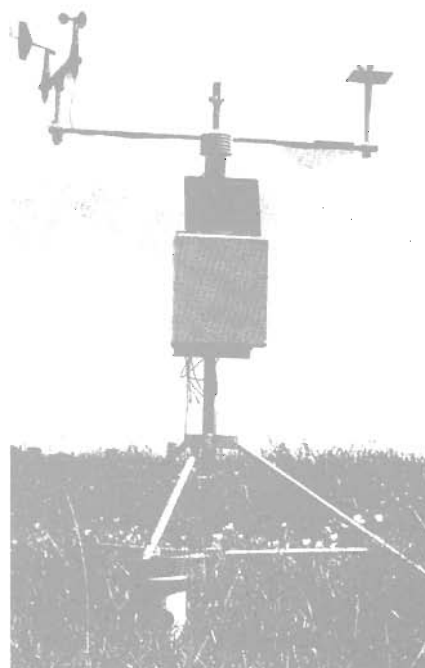
Advice to farmers

What to do

- Impose soil moisture conservation practices during October-November months.
- Bury husks in palm basin and /or mulch palm basin with coconut leaves.
- Remove old senescent leaves.
- Adopt drip irrigation with mulch.
- Follow *in situ* water harvesting. Construct water harvesting structures or dig seepage pits for summer irrigation.
- In undulated terrains, make contours across the slope.

What not to do

- Do not overspend the available water.
- Avoid flood irrigation.



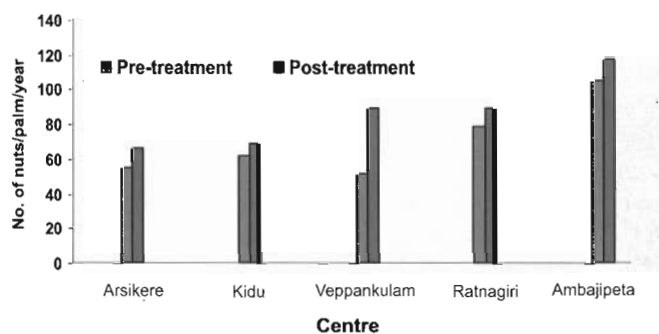
Soil Moisture Conservation Improved Coconut Yields

V. Rajagopal and S. Naresh Kumar

Soil moisture conservation practices led to relative moisture retention up to ~60% at Veppankulam (Sandy loam soil) followed by Kidu (~35%; red laterite soil), Ratnagiri (30%; sandy loam soil), Arsikere (20%; black loam soil) and Ambajipeta (~20%; coastal sandy soil). In general, local practice of soil moisture conservation also gave promising results at all the centres. Soil type played a crucial role in determining the efficiency of treatment. In soils with good water holding capacity, soil moisture conservation practices lead to retention of moisture for longer duration during dry period, on the other hand in soils with low water holding capacity, the moisture retention will be high for short duration only.

In general, palms under soil moisture conservation treatments and irrigated palms had higher rate of leaf production, number of leaves on crown, annual bunch production, number of pistillate flowers, particularly during dry periods at all the centers. Nut retention was also higher in these palms, particularly during summer months. Pistillate flower production in rainfed palms was low especially during summer. Peak production of pistillate flowers also varied with agro-climatic zone.

Soil moisture conservation practices significantly increased nut yields which was the highest at Veppankulam with ~55% increase over rainfed palm yield. At Arsikere, Kidu and Ratnagiri the increase was up to the tune of ~40%, 20% and 20%, respectively over rainfed yields at respective places.



Soil moisture conservation improved coconut yields in different agro-climatic locations.



Coir Pith Dumpings in Coconut Areas

S. Naresh Kumar

Coir pith is a by-product of coir industry but is wasted by dumping on road-sides. The dumpings are either burnt or left as such forming huge heaps on which grass is grown. This wasted product can be made to a potential commercial value product by vermicomposting or by using *Pleurotus sajorcaju*. Composted coir pith not only can be used for soil moisture conservation but also can be used in potting mixture for raising nursery of garden plants. By converting the coir pith to several end products, the coir industry can not only add additional income to its economy but also contribute to the cleaner environment.



Coir pith dumpings in areas near Veppankulam (TN).



Coir pith dumpings in areas near Arsikere (Karnataka).



Coir pith dumpings in areas near Pollachi (TN).



Chapter 6: Influence of Weather on Vermicompost Production from Coconut Leaves

Murali Gopal, Alka Gupta and George V. Thomas

Earthworms are one of the most important members of the soil fauna. They are involved in the regulation of decomposition and nutrient cycling process in the soil. Through their activities they not only improve the soil aeration and drainage but also plant and microbial productivities. The earthworms are broadly classified under three ecological categories viz. 'epigeics', or litter-dwelling species (e.g. *Perionyx excavatus*, *Eisenia foetida*, *Lumbricus festivus*, *Eudrilus eugineae* etc.) are important in litter comminution; 'endogeics' (e.g. *Aporrectodea caliginosa*, *A. rosea*, *Octochaetona serrata*, *Pheretima posthuma*, *Pontoscolex* sp., etc.) are typically soil inhabitants that ingest large quantities of soil and are responsible for changes in soil physical structure; and 'anecics' (e.g. *Lumbricus terrestris*, *L. polyphenus*, *Aporrectodea longa*, etc.), which bury surface litter and form vertical burrows important in soil gaseous and water regimes.

In recent years, the 'epigeic' worms have been exploited to produce vermicompost from agricultural and industrial wastes. Vermicomposting is the process in which digestion of organic materials by earthworms produce excreta known as 'vermicasts' or 'vermicompost'. Adding earthworm casts to soil has been observed to improve the crop production capacity of the soil in sustainable manner. This has been particularly recorded with many horticultural and agronomic crops.

At Central Plantation Crops Research Institute, *Eudrilus* species, a local strain of earthworm, was screened which is capable of converting recalcitrant and lignin rich coconut leaf waste to good quality vermicompost in 3 months period. The *Eudrilus* species is darkly pigmented and vigorous and the cocoon case is thick.

The composting process can be done in open field, pits dug in ground and in cement tanks through out the year. The average nutrient composition of coconut leaf vermicompost is N (1.8%), P (0.216%),

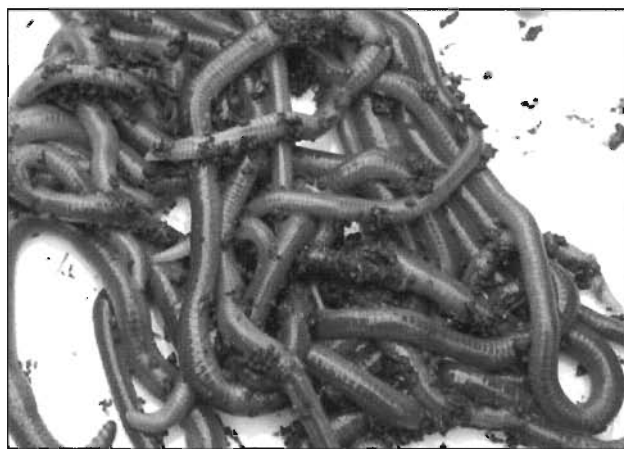


Plate 6.1: *Eudrilus* sp. earthworms.

K (0.16%), organic carbon (17.84%) with a C/N ratio of 9.95. It also contains high population of agriculturally important microbes like the nitrogen-fixers, phosphate solubilizers, cellulose degraders and fluorescent pseudomonads. This technology has become very popular among coconut farmers and has been adopted by many of them in Kerala, Tamil Nadu, Andhra Pradesh and Karnataka.

The procedure for coconut leaf vermicompost production

Around six to eight tonnes of leaves are shed from one hectare area of coconut garden having 175- 180 palms. Vermicomposting of these leaves can be done in cement tanks, open pits in ground or by stacking the leaves on the ground. Cement tanks of 7.5 x 2.5 x 1.0 m dimensions (length x width x depth) have been observed to produce the best results.

Shed coconut leaves (weighing 2.5 to 3 kg each) are collected from the coconut gardens, cut into half and are placed with lower side facing up inside the tank to about 1 foot height. A layer of fresh cow-dung slurry is spread uniformly over the stacked coconut leaves. Three such layers (coconut leaves + cow dung slurry) are accommodated in a tank. This way approximately 1000 kg of coconut leaves are heaped

inside the tank and 100 kg of fresh cow dung slurry is spread (25-30 kg at each 1 foot layer of coconut leaves). Water is sprinkled regularly to keep the substrate at 50-60% moisture. The surface is mulched with grass or coconut leaves to prevent moisture loss.

The whole material is allowed to undergo preliminary microbial decomposition for 15-20 days, after which, 1000 *Eudrilus* worms are introduced into the substrate for vermicomposting. Further, adequate moisture (40-50%) is maintained by sprinkling water.

After 60-75 days of vermicomposting, watering is stopped so that the earthworms move to deeper wet layers. Fifteen days after watering is stopped and the ready vermicompost is separated from the undecomposed and undigested debris and then earthworms are sorted out for further use.



Plate 6.2: Heap of coconut leaves.



Plate 6.3: Tanks filled with coconut leaves and cowdung slurry, and mulched on top.



Plate 6.4: Coconut leaf vermicompost.



Plate 6.5: Packed coconut leaf vermicompost.

Effect of weather on vermicomposting process

Earthworms, like all life forms, require particular environmental parameters within which they flourish and do efficient conversion of substrates to vermicompost. Studies were undertaken to record the influence of prevailing weather conditions on the efficiency of coconut leaf vermicomposting in the coastal tract of Kerala.

The optimum weather conditions for efficient vermicomposting of coconut leaves was observed to be 28 – 32 °C temperature (max.) and relative humidity (forenoon) of 90 – 95 %. Increase in temperature above 32 °C combined with fall in relative humidity below 90% reduced the efficiency of the process. Favourable weather conditions for effective vermicomposting coincided with the monsoon and post-monsoon periods (June to November). Whereas, climatic conditions during December to May were found to be unfavourable.

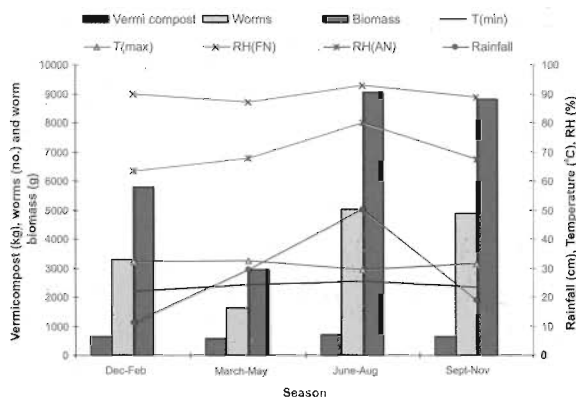


Fig 6.1: Influence of temperature and relative humidity during different periods of a year on number and biomass of *Eudrilus* and vermicompost production.

Economics

Through simple calculations (Table 6.1), it can be observed that a farmer can earn approximately Rs. 6573/ tank of 7.5 x 2.5 x 1 m dimensions, through the sales of compost and worms during the favourable climatic periods as compared to Rs. 3685/- during unfavourable periods. Weather, therefore, influences the economic returns to the practicing farmers also.

Table 6.1 : Estimate of income from a unit area (cement tank of 7.5 x 2.5 x 1 m dimensions) of coconut leaf vermicomposting during favourable and unfavourable weather periods ^{1,2}

Period	Outputs from the process	Selling price at CPCRI in 2004 (Rs.)	Income from sale (Rs.)	Total income (Rs.)
Favourable weather conditions (30-32 °C temp. and 80-90% RH)	685 kg compost ³ 5100 worms ³	5.50/ kg compost 0.55/ worm	3767 2805	6572
Unfavourable weather conditions (32-34 °C temp. and below 80 % RH)	580 kg compost ⁴ 900 worms ⁴	5.50/ kg compost 0.55/ worm	3190 495	3685

¹ It is assumed that coconut leaves and cow dung are available with the farmer, free of cost, and family labour is utilized for vermifarming.

² One time expenditure on construction of tank and procurement of earthworms is not taken into consideration.

³ Average values obtained during the period June to August and September to November in the years 2002 and 2003.

⁴ Average values obtained during the period Dec. to Feb and March to May in the years 2002, 2003 and 2004.

Advice to farmers

What to do

- Stack the coconut leaves with their lower side facing up; this will help in saving moisture in the folds of the leaves and improve the composting.
- Mulch the top with dry grasses or coconut leaves to improve moisture retention.
- Cover the tank with wire mesh to prevent the entry of rhinoceros beetle or rodents. Rhinoceros beetle can be managed by addition of fungus *Metarhizium anisopliae* (1.5 litres of coconut water-cultured spores mixed with 30 kg of vermicompost and spread along with cow dung slurry).
- Make a water channel around the tank to prevent entry of ants.
- Erect a slanting shade over the tank by thatching coconut leaves to prevent direct fall of sun shine and rain.

What not to do

- The depth of the cement tank should not exceed 1 m.
- Do not add too much water to the substrate as this may suffocate the earthworms active in the bottom portion of the tank.

Chapter 7: Influence of Weather on Major Pests of Coconut, Arecanut and Cocoa

K. Subaharan, K.N. Ponnamma, Mariamma Daniel and Gulsar Banu

Coconut, arecanut and cocoa being perennial crops attract pest attacks round the year. All parts of the coconut, arecanut and cocoa *viz.* leaves, stem, root, inflorescence and the nuts/ pods are subjected to attack by pest. Damage caused to the leaves leads to reduction in photosynthetic efficiency, and damage to inflorescence and nuts / pods leads to direct economic loss. The fluctuations in temperature and failure of monsoons have caused the pest incidence to be erratic. The study on the population dynamics of the pest in relation to weather helps to forecast the pest incidence in advance. This would help the farmer to decide on the management measures to be under taken.

PESTS OF COCONUT

Nearly 1000 species of insect pests have been reported to be associated with coconut, but only a small fraction of this is of economic importance. In recent times, explosive multiplication was observed in pests that were once considered to be occasional in nature. Among the major pests of coconut, rhinoceros beetle (*Oryctes rhinoceros*), red palm weevil (*Rhynchophorus ferrugineus*), leaf eating caterpillar (*Opisina arenosella* Walker), eriophyid mite (*Aceria guerreronis* Keifer), root grub (*Leucopholis coneophora* Burm.) were reported to be influenced by weather factors.

Rhinoceros beetle, *Oryctes rhinoceros* Linn. (Scarabaeidae: Coleoptera)

Rhinoceros beetle is a major pest of coconut palm.



Plate 7.1: Adults of rhinoceros beetle.

Adult is a stout built black beetle with an upturned horn which is very prominent in the case of males.

Symptoms and nature of damage

Adult beetle bores through the unopened fronds and spathes. The fronds in which the beetle has bored when opened show characteristic geometric cuts. Infestation on spathes results in the drying of the inflorescence. Pests such as red palm weevil may lay eggs in the injured portions. The injuries also pave way for fungal infection leading to bud rot. Repeated attacks to the growing points may eventually lead to the death of the young palms.



Plate 7.2: Rhinoceros beetle infested palm. Note the 45° cut in the infested leaves.



Plate 7.3: Spathe damaged by rhinoceros beetle.

Life cycle

The adult beetle breeds on decaying organic debris such as farmyard manure, compost, dead coconut stumps and logs. There are three larval instars and the fully-grown grub is ash grey and 'C' shaped with brownish hairs on the body. Pupation takes place in cocoon. Life cycle is completed in six to seven months.

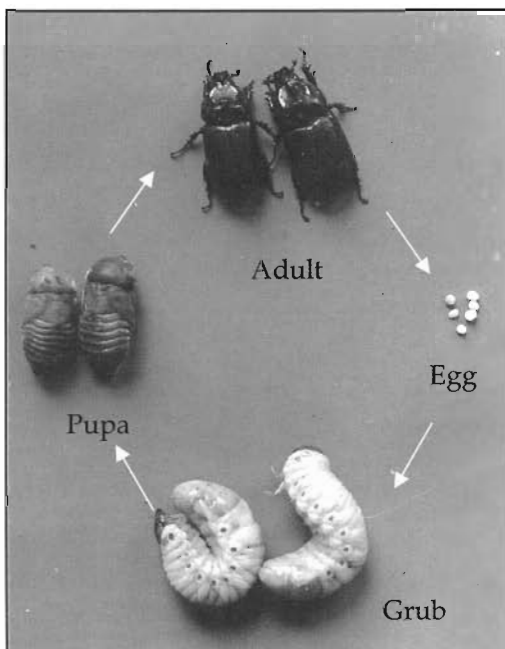


Plate 7.4: Life cycle of rhinoceros beetle.

Population dynamics

In Kerala, the pest is found throughout the season; however, its population is high during June to September

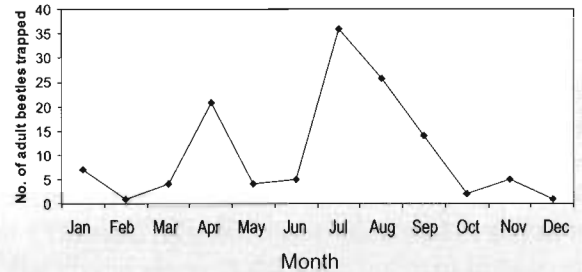


Fig. 7.1: Population dynamics of *O. rhinoceros* in Kerala.

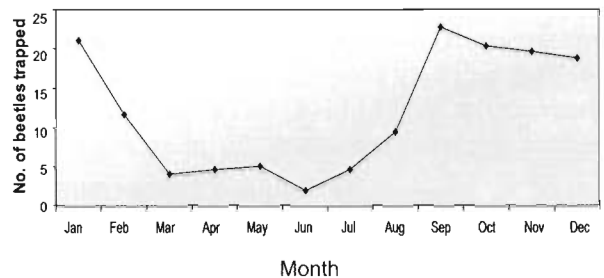


Fig. 7.2: Population dynamics of *O. rhinoceros* in Andhra Pradesh.

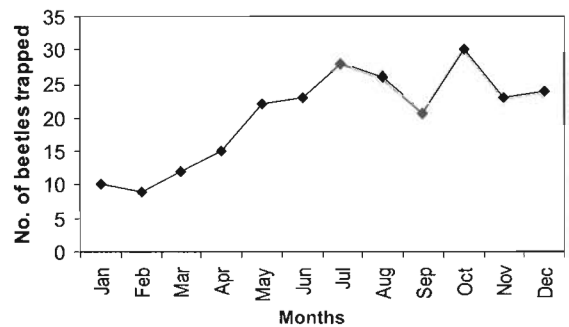


Fig. 7.3: Population dynamics of *O. rhinoceros* in Andaman Islands.

In Andhra Pradesh, the beetle population was high when the maximum temperature was less than 35 °C and the relative humidity was more than 75% i.e. during September and October, coinciding with the North East monsoon. In Andaman and Nicobar islands, two peaks of pest population were observed during July and October.

Bio-control measures

Bio-control measures include release of beetles inoculated with *Oryctes baculovirus* @10 to 15 beetles / ha in the dusk. The beetles should be placed on top of a stone or hard surface for effective take off.

Apart from this, application of *Metarhizium anisopliae* during monsoon period to the pest breeding sites like cow dung pits, farmyard manure heaps and other breeding sites is important for effective control of rhinoceros beetle.

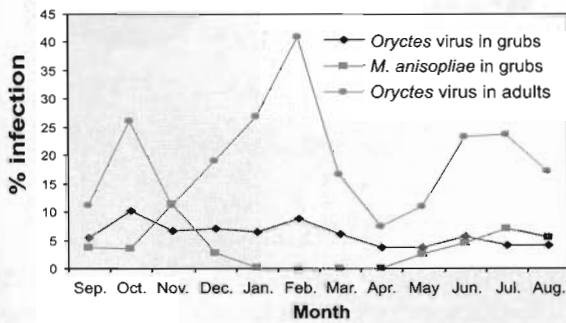


Fig. 7.4: Trends in occurrence of *Oryctes* virus and *M. anisopliae* infection.

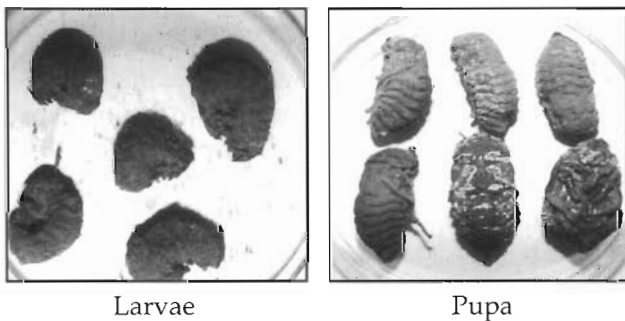


Plate 7. 5: *Metarhizium* infection of *Oryctes* larvae and pupa.

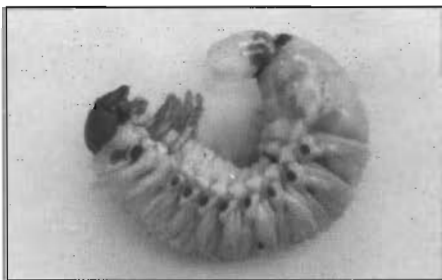


Plate 7. 6: Baculovirus infection of *Oryctes* larva.

Advice to farmers

What to do

- ❑ Field sanitation – remove decaying logs and pest-breeding materials.
- ❑ Hook beetles out from the crown periodically.
- ❑ The adult beetle emergence coincides with the onset of monsoon. Adopt prophylactic method of leaf axil filling with 10 g Naphthalene balls (four numbers) + sand or neem cake / marroti cake (*Hydnocarpus* sp.) 250 g + fine sand (250 g) before monsoon to prevent the beetle from damaging the spindle leaves.
- ❑ Spray carbaryl 50 % WP 0.01% (200 mg/ lit. of water) on breeding sites.
- ❑ Release beetles inoculated with *Oryctes baculovirus* @10–15 beetles / ha in the dusk, and place the beetles on top of a stone for effective take off.
- ❑ Apply *Metarhizium anisopliae* during monsoon period in cow dung pits, farmyard manure heaps and other breeding sites for effective control of rhinoceros beetle.

What not to do

- ❑ Do not leave dead stumps or logs in the garden.
- ❑ Avoid simultaneous application of *M. anisopliae* as well as release of virus-inoculated beetles, as fungus suppresses the virus spread, particularly during monsoon.

Coconut black headed caterpillar, *Opisina arenosella* Walker (Oecophoridae:Lepidoptera)

The coconut black headed caterpillar, *Opisina arenosella* is a serious pest of coconut especially in the coastal and backwater areas. The caterpillars cause more than 70 % leaf damage. The pest is abundant in all the coconut growing tracts in India.

Symptoms and nature of damage

Appearance of green and dried up patches interspersed on the upper epidermis of leaves and



presence of larval galleries and pupal cases on the under surface of leaves are the symptoms of infestation. In cases of severe infestation, the whole plantation presents a scorched appearance. The caterpillar lives on the lower surface of leaflets in galleries made of excreta and silken web and feed on the chlorophyll containing parenchymatous tissues resulting in considerable reduction in the photosynthetic area.



Plate 7.7: *Opisina* infested garden.

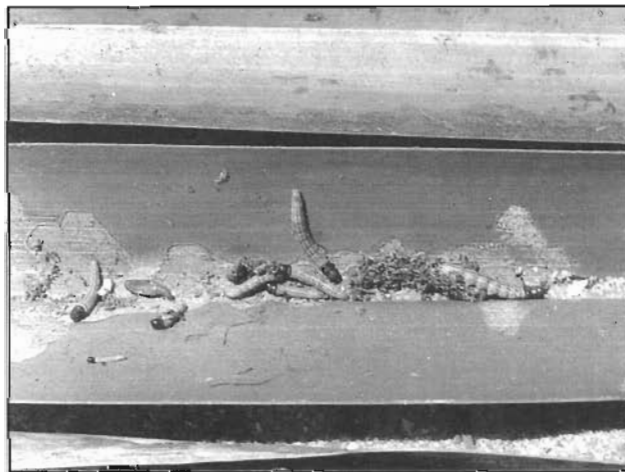


Plate 7.8: *Opisina* infested leaflets.

Life cycle

The adult is a grayish moth. The fully grown larva is about 15 mm long, light green with reddish brown stripes and with a black head. It pupates in a silken cocoon in the larval gallery. The total duration of the pests from egg to adult stage is completed in about two months.

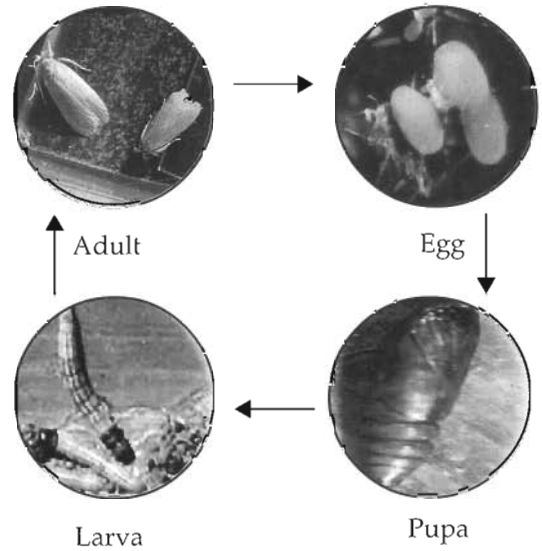


Plate 7.9: Life cycle of *O. arenosella*.

Population dynamics

The population of *O. arenosella* is governed by both biotic and abiotic factors. In Kerala, the peak period of larval population is during April, June and August when relative humidity is high with moderate temperature and lower sunshine hours. Relative humidity is directly correlated with the abundance of caterpillars and sunshine was inversely proportional to the population. High humidity favoured the rise in population to the highest level during June. The peak population during April synchronizes with medium relative humidity and a fall in temperature and sunshine hours. Low level of population is noticed during November, December and January when temperature and sunshine are high and relative humidity is very low.

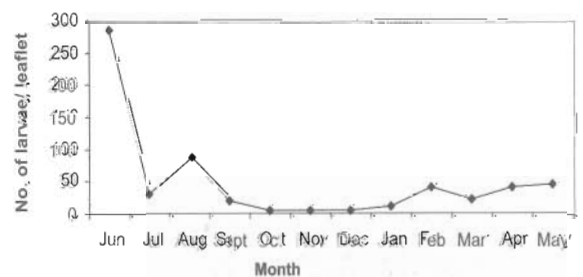


Fig. 7.5: Population dynamics of *O. arenosella* in Kerala.

In Bangalore (Karnataka), where the variation in temperature and humidity was narrow, the egg

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laying activity was more from November to March and there was a steep increase in the early larval instars during the cooler months (November and December). As against this, the extreme high temperature during summer in Mangalore (Karnataka) favoured the pest to multiply faster reaching the peak during May.

In Andhra Pradesh, the pest population was maximum during June when the climate was warm and humid. The pest population increased with an increase in maximum temperature and relative humidity as in the case of Kerala.

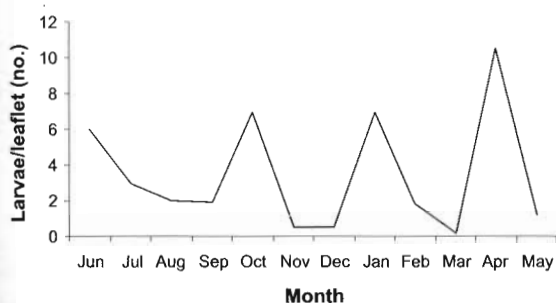


Fig. 7.6: Population dynamics of *O. arenosella* in Karnataka.

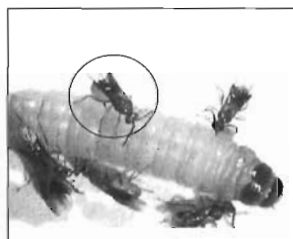
Warm humid climate is congenial for pest build-up. When there is high humidity prevailing during summer, pest-prone areas are to be monitored regularly and if initial pest incidence is noticed, stage-specific parasitoids are to be released to prevent an outbreak. Integrated management strategy is to be adopted to manage *O. arenosella*.

Biocontrol

Release *Goniozus nephantidis* for 3rd instar larval stages (@20%), *Elasmus nephantidis* (@50%) for pre-pupal stage and *Xanthopimpla punctata* (@30%) for pupal stage.



Goniozus nephantidis



Bracon brevicornis

Plate 7.10: Adults of *G. nephantidis* and *B. brevicornis*



Plate 7.11: Release of parasitoids for black headed caterpillar.

Advice to farmers

What to do

- Mechanical control: Cut heavily infested outermost two to three leaves and burn.
- Adopt bio-control measures.
- During severe outbreaks, cut and burn severely infested two to three outer leaves and spray dichlorvos @ 0.02 % or malathion @ 0.05 % to bring down the pest population.

What not to do

- Do not harvest coconuts immediately after spraying or root feeding with insecticides mentioned above. Follow a safe waiting period of 45 days before harvesting the nuts from treated palms.

Red palm weevil -*Rhynchophorus ferrugineus* (Curculionidae : coleoptera)

This is one of the major pests of coconut, which proliferates on dead plant material and spreads.

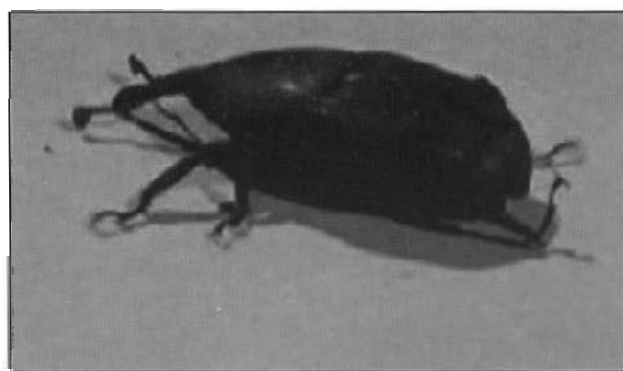


Plate 7.12: Adult weevil.

Symptoms and nature of damage

This pest causes damage to the crown and stem close to the crown. Feeding on the growing point by the grubs results in death of the palm. Other symptoms include wilting of leaves in the inner and middle whorls, presence of holes in the stem and petioles showing viscous brown ooze, extrusion of chewed up fibers through the holes and withering of central spindle and toppling of the crown.



Plate 7.13: Damage due to red palm weevil.



Plate 7.14: Red palm weevil infested trunk.

Life cycle

The female weevil scoops out small holes in soft tissues and lays the eggs. Incubation period is two to three days. Soft white legless grubs bore into the interior of palms feeding on the soft tissues. The grubs pupate in cylindrical cocoons made out of

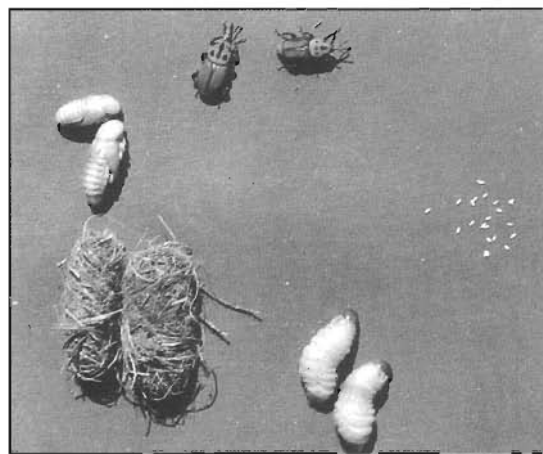


Plate 7.15: Life cycle stages of red palm weevil.

fibrous strands. The whole life cycle from egg to adult takes about four months. This pest is found round the year.

Population dynamics

R. ferrugineus can breed in a wide range of climates, and this is largely because the larvae feed protected within their host palms. The weevil is able to complete several generations in a year and in some host itself before the tree collapses. Occurrence is more severe after the monsoon.

Control measures

For controlling red palm weevil an integrated pest control measure needs to be taken.



Plate 7.16: Trunk application of pesticide.

Advice to farmers

What to do

- ❑ Field sanitation and control of rhinoceros beetle.
- ❑ Fill the leaf axil with 10 g Naphthalene balls (four numbers) + sand or neem cake / marroti cake (*Hydnocarpus* sp.) 250 g + fine sand (250 g) during May, September and December.
- ❑ Cut and burn dead palms harboring the pest.
- ❑ Stem inject 1% Carbaryl 50 % WP @ 1 litre per palm.
- ❑ Place pheromone traps @ 1 per ha.
- ❑ Trap and kill adult weevils using attractants such as fresh toddy fermented with yeast/ acetic acid or fermented mixture of crushed sugarcane+ jaggery + banana.

What not to do

- ❑ Do not tie pheromone traps to young palms. They should be hung in a separate pole.
- ❑ Never make cuts / injuries to the palms as this would serve as a site for oviposition by the weevil.

Eriophyid mite, *Aceria guerreronis* Keifer

The first report of this pest in India is from a village in Ernakulum District of Kerala in 1998. Subsequently it spread to the adjoining states of Tamil Nadu and Karnataka. From the year 2000 onwards, the pest further spread to other coconut growing areas in the country.



Plate 7.17: Adults of *A. guerreronis*.

Symptoms and nature of damage

Eriophyid mite infests the upper portion of the developing nut under the perianth and sucks the sap. Elongated white lines appear below the perianth which later develop into triangular yellow patches. As the nuts mature, these patches turn brown and form longitudinal fissures and finally appear as warts on nut surface.



Plate 7.18: Triangular yellow patches on coconuts due to mite infestation.



Plate 7.19: Variations in severity of mite infestation. Note warts on the nut surface due to mite damage.

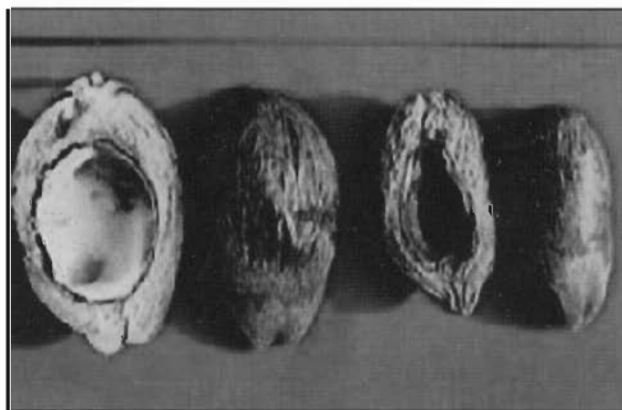


Plate 7.20: Reduced copra out-turn in severely infested nuts.

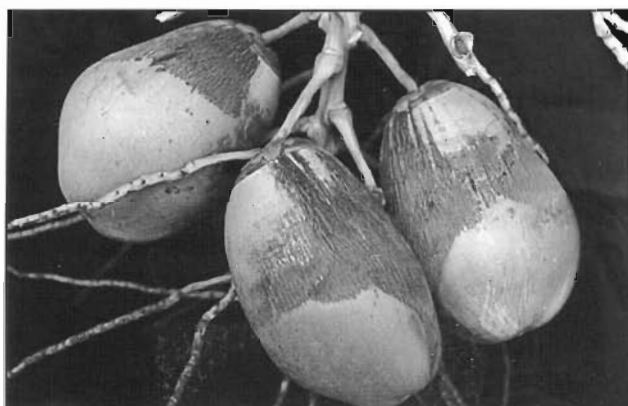


Plate 7.21: Mite infested coconut bunch.

Life cycle

Life cycle of the mite is completed in 7-10 days. Under favourable conditions, these mites multiply enormously. Mite is a microscopic creamy white slender organism, elongated and cylindrical. Adult female mite is 200-250 micron long and 36-52 micron wide. It has an anterior cephalothorax and an annulated tapering abdomen with two pairs of legs and needle like mouthparts, which are anteriorly placed. Finely ringed body is beset with bristles arranged in rows. Dispersal is mainly through wind. Hence they can spread very fast.

Population dynamics

Incidence is noticed throughout the year with a peak during April-May (summer months) in Kerala when the temperature and humidity are very high. In Tamil Nadu, population was high during March - May and October - December.

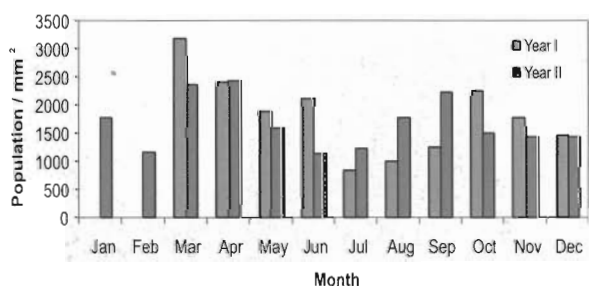


Fig. 7.7: Population dynamics of coconut eriophyid mite.

Incidence of eriophyid mite is very high when the climate becomes hot and humid. Hence, it is better to give prophylactic spraying to the 3rd and 4th bunch

before the onset of hot and humid climate during summer to avoid heavy incidence. Predatory mite *Bdella* sp. and *Amblyseius* is effective against mites.

Advice to farmers

What to do

- Do prophylactic spraying to the 3rd and 4th bunch before the onset of hot and humid climate during summer.
- Apply organic manure @ 50 kg/ palm.
- Apply neem cake @ 5 kg/ palm.
- Apply the recommended dose of fertilizers in two splits.
- Root feed Neemazal 5% @ 7.5ml+ 7.5 ml water in sandy and sandy loam soils.
- Spray neem oil-garlic-soap mixture at 2% concentration.
- Spray neem formulations containing 0.1 % Azadirachtin / Neemazal @ 4 ml/ lit. of water during April-May and in August - September.
- The spray droplets are to be directed towards second - fifth month bunch.

What not to do

- Avoid spraying in unpollinated inflorescence.
- Avoid using wettable sulfur as it brings down the myco-acarides population.

White grub, *Leucopholis coneophora* Burm. (Melolonthinae: Coleoptera)

The white grubs are one of the major pests of coconut palm found mostly in sandy loam tracts of Kerala and Karnataka. The adult beetles are very sensitive to light traps.

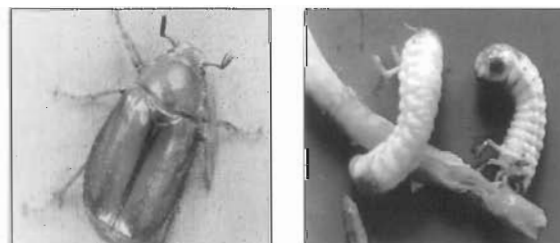


Plate 7.22: Adults and larvae of white grub.

Symptoms and nature of damage

The pest damages mainly roots of palms and the grubs tunnel into the bole and collar region of seedlings. Palms show yellowing of leaves, premature nut fall, and reduction in yield. In seedlings, drying up of spindle leaves is followed by gradual death.

Life cycle

Adult beetles are of chestnut brown colour. Eggs are laid in soil where the pest undergoes different stages. It has an annual life cycle with grub period of eight months. The grubs are creamy white in colour with a brown head.

Population dynamics

There is preponderance of 1st and 2nd instar grubs from June to September. The third instar grubs emerge from August onwards in small numbers and their presence continues up to April. Overlapping with other instars, reaches a peak in the month of September.

Adult emergence of *L. coneophora* starts in the last week of May. A combination of three to five rainy days and fall in soil temperature triggers the adult emergence. Saturation of atmospheric humidity seems to have more influence on adult emergence than the moisture content of soil.

Advice to farmers

What to do

- Deep plough during pre- and post-monsoon periods to expose the grubs to birds and other predators.
- Collect adult beetles during peak period of emergence (May-June).
- Set light traps in early May since peak period of adult emergence is during May-June
- Apply Phorate 10 G @100 g/palm in the basin during pre- and post-monsoon periods.

What not to do

- Do not harvest coconuts immediately after application of insecticides.

Coreid bug -*Paradasynus rostratus* Dist. (Coreidae: Hemiptera)

This pest causes economic loss as it damages the nuts.

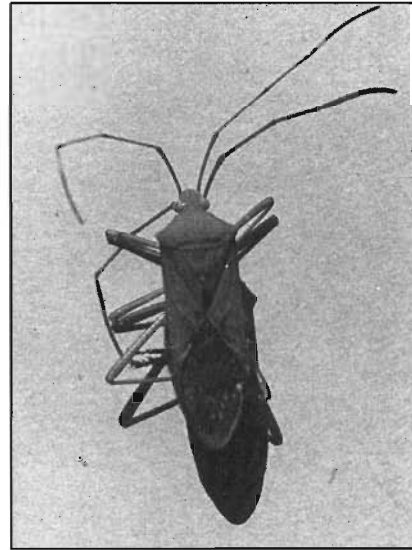


Plate 7.23: Adult coreid bug.

Symptoms and nature of damage

Adults and nymphs suck sap by piercing the stylet into the tissues just below the perianth from the buttons and developing nuts. The feeding marks later develop into brown lesions with gummosis. Infestation results in immature nut fall and also production of malformed nuts with cracks and crinkles on the surface. Most of the nuts become barren.

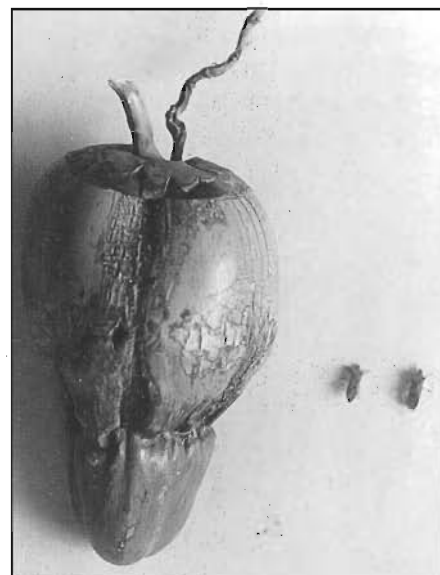


Plate 7.24: Coreid bug infested nut.

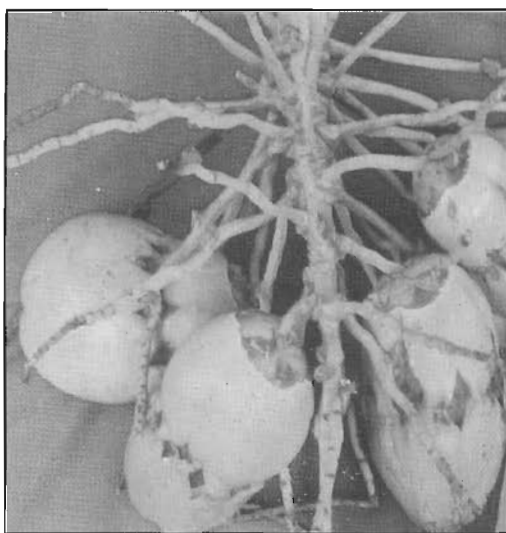


Plate 7.25: Coreid bug infested coconut bunch.

Life cycle

The adult is a brown coloured large bug measuring about 2 cm in size. Nymphs are ant-like and reddish brown in colour. The eggs are laid in clusters of 3-4 rows. The average number of eggs laid on coconut is 54. Incubation period is 8-10 days. There are five nymphal instars and total nymphal period is 25-34 days (average 29.5 days). Adult longevity varied from 48-52 days.

Population dynamics

Build up of population starts by June and maximum incidence is noticed during October–November. Farmers are to be aware that the incidence initiates when the temperature is very high before the onset of monsoon. Hence, prophylactic spraying is to be given to young unfertilized nuts during the pre-monsoon period to avoid heavy incidence.

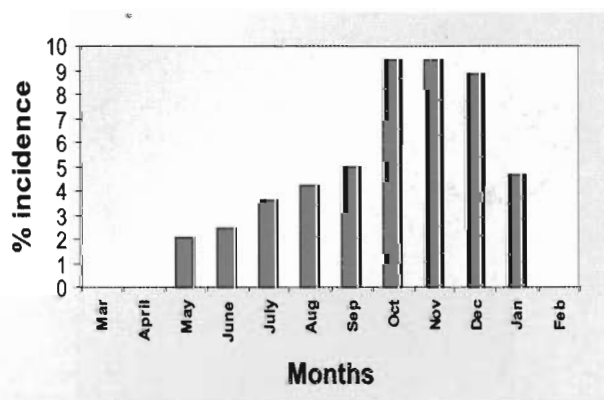


Fig 7.8: Population dynamics of coreid bug.

Farmers are to be aware that the incidence is initiated when the temperature is very high before the onset of monsoon. Hence, prophylactic spraying is to be given to young unfertilized nuts during the pre-monsoon period to prevent heavy incidence.

Advice to farmers

What to do

- ❑ Undertake prophylactic spraying on young unfertilized nuts during the pre-monsoon period to prevent heavy incidence.
- ❑ Spray with 0.1 % carbaryl on the crown, avoiding young unfertilized pistillate flowers.
- ❑ Spray during the afternoon without affecting the pollinators.

What not to do

- ❑ Avoid spraying on pistillate (female) flowers.

Nematode Pests of Coconut

As many as 165 species of nematodes belonging to 77 genera were reported from the rhizosphere of coconut. Red- ring nematode, *Rhadinaphelenchus cocophilus* and the burrowing nematode, *Radopholus similis* are the two major nematode pests of coconut which cause considerable damage to the crop. Red-ring nematode has not yet been reported from India.

Burrowing nematode, *Radopholus similis*

The most important nematode pest of coconut in India is the burrowing nematode, *Radopholus similis*. Large number of crops like arecanut, banana, black pepper, ginger, turmeric, sweet potato, groundnut, sugarcane, betel vine and avocado are the known hosts of this nematode. *R. similis* is widely distributed in most tropical and sub-tropical areas of the world.

Symptoms and nature of damage

Burrowing nematode-infested coconut palms exhibit general decline symptoms like stunting, yellowing, reduction in the number and size of leaves and leaflets, delay in flowering, button shedding and reduced yield. As the above ground symptoms are non-specific, the definite method to identify the existence of the nematode is to look for the characteristic lesions on the young creamy white

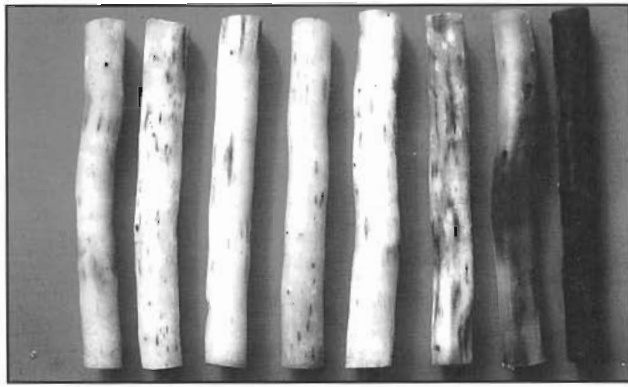


Plate 7.26: *R. similis* infested coconut root.

roots. *R. similis* infestation produces small, elongate, orange-coloured lesions on the tender, creamy-white roots. Consequent to nematode multiplication and parasitization, these lesions enlarge and coalesce to cause extensive rotting of roots. Lesions and rotting are confined to the tender portions of the root, which on heavy infestation become spongy in texture. Surface cracks develop on the semi-hard orange coloured roots.

Life cycle

The burrowing nematode is a migratory endoparasite and is capable of spending its entire life within the roots. The nematode takes 25 days at 25 – 29 °C to complete one life cycle.

Population dynamics

In Kerala, burrowing nematode is found throughout the seasons however, nematode population in roots is maximum during October to November and minimum during March to July. Factors favourable for nematode multiplication are, mean soil temperature below 25 °C and a light rainfall coupled with availability of tender fleshy roots.

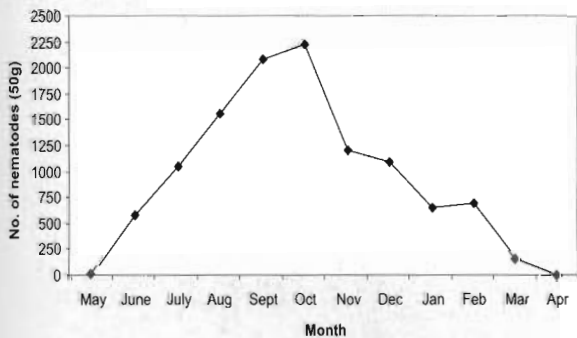


Fig 7.9: Population dynamics of *R. similis* in coconut roots.

Management

Integrated nematode management practices are to be adopted for the control of burrowing nematode.

Advice to farmers

What to do

- Use nematode-free planting materials of coconut and other crops, as the main method of nematode dissemination is by infested planting materials.
- Apply oil cakes, farmyard manure and green foliage to the basins.
- Grow intercrops like cocoa that enriches the soil with sizeable quantities of shed foliage which help in the build-up of beneficial organisms which may inhibit nematode.
- Apply phorate @ 10 g a.i./ palm in June/ July and in September/October.
- Collect soil and root samples during October – November at a distance of 100 cm from bole of the palm and at a depth of 50-100 cm, for detection of burrowing nematode. Tender, creamy white to orange coloured semi-hard roots showing lesions and rotting should be collected.

What not to do

- Avoid use of banana as shade crop in coconut nursery as it harbours large number of nematodes.

PESTS OF ARECANUT

Arecanut is affected by several pests such as spindle bug, grubs, mites, etc.

Spindle bug, *Carvalhoia arecae*

It is a major pest of areca palms. Adult bugs are bright red and black and are active during the morning hours.

Symptoms and nature of damage

Sucking of plant sap by the nymphs and adults of this bug result in typical linear, dark brown lesions which turn necrotic on the spindle and damaged open leaves and dry up and drop off resulting in holes. Severely affected spindle leaves fail to unfurl completely. Infestation in young exposed plantations

results in severe manifestation of symptoms during summer months.

Life cycle

Eggs that are laid into the spindle leaf hatch within nine days. The five nymphal instars are completed in 15-24 days.



Nymphs



Adult

Plate 7.27: Nymphs and adult of spindle bug.

Population dynamics

These bugs are present throughout the year. Peak incidence in Kerala is from June to October with maximum population in August and September.

Advice to farmers

What to do

- ❑ Spray of the spindle leaf and inner-most leaves of palms in infested plantations with dimethoate (15 ml in 10 litres of water).
- ❑ Place perforated poly-sachets containing two grams of phorate 10G granules in the innermost two leaf axils of infested palms during April. The same pair of sachets can be shifted to the inner -most leaf axils for five to eight months.

What not to do

- ❑ Avoid spray during the sunny hours of the day.

Root grubs or white grubs, *Leucopholis burmeisteri* Brens. and *L. lepidophora*

Root grubs are distributed in Dakshina Kannada, Uthara Kannda, Chikmagalur Districts of Karnataka, and in Kozhikode and Waynad Districts of Kerala.

Symptoms and nature of damage

Grubs feed on roots. Damage to roots results in yellowing of leaves, tapering of stem and reduction in the number of fruit bunches. Palms of all ages including nursery seedlings are damaged. Intercrops in the plantations like tapioca, banana, yams, sugarcane, cocoa and coconut are alternate hosts of this insect.

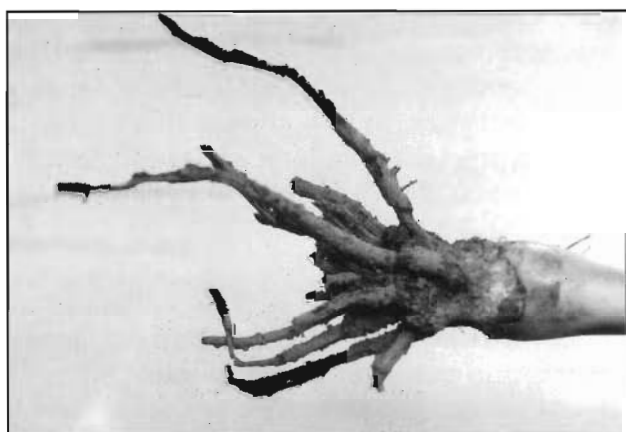


Plate 7.28: Grub affected roots.

Life cycle

Adult beetles emerge from the infested soils after 8-10 days of pre-monsoon showers in May/June in the evening hours after sunset. These beetles lay the eggs in the basin region of palms. After hatching, the young white grubs mainly feed on the humus and very tender roots of grasses. The U-shaped grubs have soft bodies with brown heads. Pupation inside earthen cocoons and the fully-grown adult emerge in May/June.



Plate 7.29: Adult beetles of *L. burmeisteri*.

Advice to farmers

What to do

- ❑ Collect adult beetles after 8 -10 days of pre-monsoon showers in May/June between 6.30 and 7.30 pm.
- ❑ Follow soil application of phorate 10 G at the rate of 15 g per palm twice a year (May to June and September to October) for a minimum of three years to reduce the grub population.
- ❑ Wet the soil before insecticide application.
- ❑ Follow cultivation practices like opening palm basins to kill and reduce grub population.
- ❑ Adopt soil amendment with oil cakes of neem/pongamia and apply organic manures to increase new root initiation in root grub infested plantations.

What not to do

- ❑ Do not harvest the nuts within 45 days of application of pesticide.

Phytophagous mites

The palm red mite, *Raoiella indica* and the cholam mite *Oligonychus indicus* colonize the leaves of palms of all ages.

Nature of damage and symptoms

Feeding results in yellow speckles that coalesce, become bronze-coloured and the infested leaves dry up. Attack severe in nursery seedlings and exposed young palms during the summer months.



Plate 7.30: Mite infested leaf.

Life cycle

Eggs, nymphs and adult mites are seen on the underside of leaves. Life cycle is completed in a short span of about two weeks.

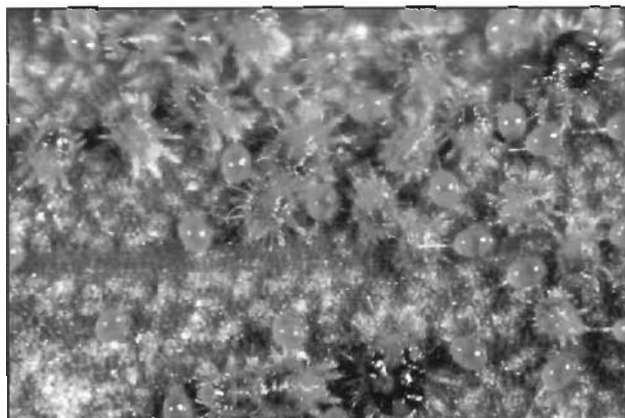


Plate 7.31: Colony of *R. indica*.

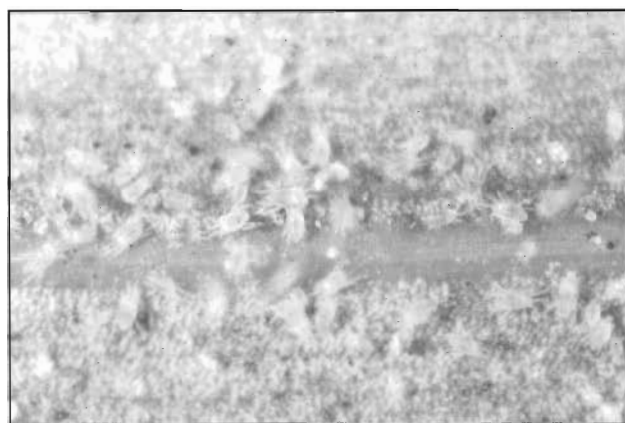


Plate 7.32: Colony of *O. indicus*.

Population dynamics

Population builds up after the monsoon months and is severe in summer months.

Advice to farmers

What to do

- ❑ Spray kelthane 1.8 EC (2 ml/litre of water) or dixmethoate 30 EC (1.5 ml/litre of water) to the lower surface of mite- colonized leaves.
- ❑ Remove and destroy seedlings with large mite colonies and severe infestation.

What not to do

- ❑ Avoid spraying when natural enemies like small coccinellid beetles are plenty.

Immature fruit drop

Feeding by pentatomid bug, *Halyomorpha marmorata* F. (Heteroptera: Pentatomidae) causes immature nut drop.



Plate 7.33: Adult bugs of *H. marmorata*.

Symptoms and nature of damage

Adults and mature nymphs suck the sap from the developing kernels of immature fruits of areca palm. Feeding results in immature fruit drop with shrunken and browning kernels. The pin-prick dots made by the insertion of proboscis of the insect on the surface of green fruits are the external symptoms of evidence of this insect feeding.



Plate 7.34: Pin-prick dot on the fruit surface.



Plate 7.35: Tender fruits showing symptoms of damage.

Life cycle

It is seen feeding on tender fruits of the palm from March-April in various places and continues to be there till July to early August depending on the availability of green fruits. Life cycle is completed in about a month's time.

Advice to farmers

What to do

- Collect and destroy various stages of this insect seen on alternate hosts like cowpea, bhendi, bitter gourd and chillies before these bugs shift to areca palms.

Nematode Pests of Arecanut

A total of 52 species of nematodes belonging to 33 genera have been reported from the rhizosphere of arecanut, but only burrowing nematode (*Radopholus similis*) is known to be an important parasite.

Symptoms and nature of damage

The main conspicuous symptom of *R. similis* infestation is the appearance of lesions and rotting on roots. The nematode produces small, elongate, orange-coloured lesions on the young, succulent, creamy-white to light-orange coloured portion of the main and lateral roots. Later these lesions coalesce and cause extensive rotting. The thick primary roots arising from the bole of the palm exhibit large, oval, sunken, dark lesions. The burrowing nematode infested areca palms exhibit non-specific above ground symptoms like general yellowing and visible reduction in growth, vigour and yield.



Plate 7.36: *R. similis* infested arecanut root.

Cultivars, Indonesia – 6 (VTL – 11) , Mahuva – 8 and Andaman – 5 (VTL-29e) are tolerant to *R.similis*. The hybrid VTL – 11 X VTL – 17 has been reported as highly resistant to *R.similis*. Whereas, the hybrids VTL – 11 x VTL-12 and Mohitnagar x VTL-11 were found to be moderately resistant.

Life cycle

At a temperature range of 21-31 °C , the burrowing nematode takes 25-35 days to complete one life cycle on arecanut seedlings.

Population Dynamics

The population density of *R. similis* in arecanut roots is maximum during October-November and minimum during March-June.

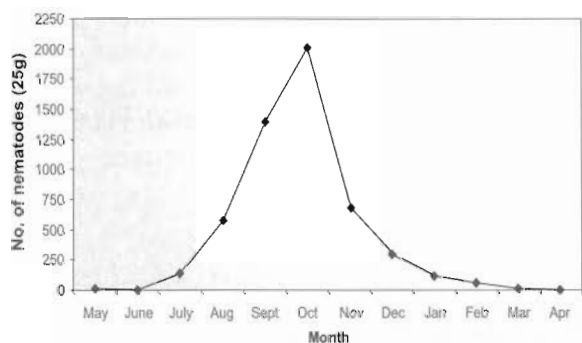


Fig. 7.10: Population dynamics of *R. similis* in arecanut roots.

Advice to farmers

What to do

- ❑ Use nematode-free planting material of arecanut and other intercrops.
- ❑ Apply phorate @50 g a.i./ palm during May / June and September / October.
- ❑ Arecanut being a masticatory and chewed directly by the consumers, the dosage, frequency and time of application of nematicides have to be carefully regulated to avoid residual toxicity in the nuts.
- ❑ Collect soil and root samples at a distance of 25 to 75 cm from bole region at a depth of 25 – 75 cm during October – November for nematode population estimation.
- ❑ Plant resistant/tolerant cultivars of arecanut and other intercrops.

What not to do

- ❑ Do not harvest nuts within 45 days of insecticide application in palm basin.

PESTS OF COCOA

Cocoa is mainly affected by mealy bugs and aphids.

Mealy bug, *Planococcus lilacinus* and *P. citri* (Pseudococcidae)

These are present on cocoa trees throughout the year. These colonize the tender shoots, flower cushions, cherelles and developing pods.

Symptoms and nature of damage

Continuous colonization by mealy bugs on flower cushions result in flower cushion abortion. The feeding on cherelles result in cherelles wilt. The colonies on developing pods serve as the center for further spread of the colonies by the ants attending to these mealy bug colonies. Severe feeding on apical shoots can alter the canopy structure of very young trees.



Plate 7.37: Apical stem with mealy bugs.



Plate 7.38: Cherelle with infestation.



Plate 7.39: Cherelle wilt due to mealy bug feeding.



Plate 7.40: Mealy bug infested cocoa pod.

Population dynamics

Though present throughout the year, the population peaks in April-May when high temperatures and low rainfall prevail in the Western Ghats region. These build up in high numbers in the moisture stressed plants at this time. With the advent of southwest monsoon the population decreases.

Advice to farmers

What to do

- ❑ Follow timely cultural practices like pruning of the cocoa trees to reduce the colony build up.
- ❑ Locate the foci of trees with initial colonies in plantations with perennial incidence and follow spot application of insecticide.
- ❑ Follow spot application of dimethoate (0.05%) to reduce the available colony in a locality.

What not to do

- ❑ Do not spray insecticides when predator is spotted.

Aphid, *Toxoptera aurantii*

This black aphid colonizes the flower buds, flowers, small cherelles, tender shoots and leaves.

Symptoms and nature of damage

The nymphs and adults of this aphid feed on the

tender plant parts. Feeding can result in flower shedding and crinkling and twisting of leaves.



Plate 7.41: Aphid colonies on flower bud and tender leaf.

Population dynamics

This insect is also present throughout the year but population was found to be low from February to July, with a peak from August to January.

Advice to farmers

What to do

- ❑ Release the natural enemies like the coccinellid beetles, green lace wings.

What not to do

- ❑ Avoid the use of insecticides when the natural enemies are spotted.



Chapter 8: Influence of Weather on Major Diseases of Coconut, Arecanut and Cocoa

Rohini Iyer and R. Chandra Mohan

Coconut, arecanut and cocoa are infested by several disease causing organisms like *Phytophthora*, *Ganoderma*, *Thielaviopsis*, *Colletotrichum*, *Exserohilum*, *Fusarium* and *Xanthomonas* causing economic loss to the farmers.

DISEASES OF COCONUT

Coconut is affected by several important diseases like bud rot, basal stem rot, leaf rot and stem bleeding.

Bud-rot disease

Bud-rot is the most important fatal disease of coconut. Plants of all ages and cultivars are susceptible to this disease. It has been reported from India, Sri Lanka, Indonesia, Philippines, Colombia, Papua New Guinea, Vanuatu, French Polynesia, The Dominican Republic and Cot'e-de-Ivoire. In our country this has been reported from all the coastal regions of Kerala, Tamil Nadu, Goa, Andhra Pradesh and Maharashtra. In non-traditional areas of Bastar, Raipur and Durg also this has been recorded. This disease is usually sporadic in nature. Occasionally, 30-40% palms in a given locality are affected and killed.

This malady is seen during the monsoon season when moderate temperatures and high levels of relative humidity prevail. The fungus survives in a quiescent form in the soil as well as in the leaf axils during the rain-free months and becomes active with the onset of rain when free particulate water is available.

In our country, this disease is caused by *Phytophthora palmivora*. Elsewhere, *P. katsurae* causes the disease. Even though there is one report from India on the occurrence of *P. katsurae*, this has not been widely encountered.

This disease attains its name from the way it attacks the growing apical meristem or terminal shoot-bud. Since coconut has only one apical meristem, a

successful infection ultimately results in the death of the palm. However, if the disease is detected well in time, the affected palm can be treated successfully and restored to normal health and productivity. Hence, it is most important that the growers are familiarised with the symptoms of the disease.

Symptoms

The first externally visible symptom is the withering of the spear leaf, the base of which rots and turns brown. In seedlings, this spear shoot comes away



Plate 8.1: Bud-rot affected coconut seedling.



Plate 8.2: Internal decay due to bud-rot.

with a gentle pull, signalling its death. In older palms it bends at the base and turns brown. A foul smell is emitted from the rotten tissue. Once the spindle drops, the subsequent leaves gradually wither. However, some of the bunches stay firm and the nuts mature in due course. The internal tissues show discoloration, assuming a pale pink colour with a brown border. As the disease progresses, the rot descends into the lower tissues, finally affecting the meristem and killing it.



Plate 8.3: Coconut palm dead due to bud-rot.

Weather and the disease intensity

This disease is generally noticed during South-West and North-East Monsoon periods when wet weather prevails. A combination of a temperature of 21-24 °C and 98-100% relative humidity have been found to be highly congenial for the development of *Phytophthora*- incited rots. Earlier studies have revealed that bud-rot has an incubation period of 35 days for the manifestation of visible symptoms. The microclimatic factors prevalent in the top leaf axils are also equally important. Recently, more information has been collected in this regard. It has been noticed that the number of palms with bud-rot incidence was higher in the hilly areas of Kasaragod, Kannur and Kozhikode districts compared to the plains where a warmer temperature regime prevailed.

Bud-rot incidence was high in the plateau region than in the plains in the non-traditional coconut growing regions of Madhya Pradesh. In the hilly areas it was also noted that the disease-prevalent season continued for a much longer period, i.e., up to the

month of January whereas in the plains, the bud-rot season ended by September.

Initial incidence of bud-rot was dependent on the monsoon showers. However, the occurrence of bud-rot in subsequent months from October to January could be attributed to the favourable microclimatic conditions inside the crown with consistently high humidity, low night temperatures and presence of water (particulate) from dewdrops.

Even though survival of the pathogen was observed in the leaf axils of healthy as well as diseased palms, the population of propagules was distinctly high in the case of diseased palms.

When recovery of *P. palmivora* from debris was attempted, the palm in hilly region readily yielded them since the debris was moist for a longer period while the debris collected from the plains had to be moistened and incubated at 24±1 °C for 6-12 days.

Disease incidence and the wetness of leaf axil debris of coconut palms observed in different months is given in Table 8.1.

Table 8.1: Moisture percentage in the crown debris of coconut palms in different locations (transformation used: $\sin^{-1} p$ where 'p' is the proportion of moisture).

Locations	Moisture % in the crown debris of coconut palms during				Mean
	April	July	October	January	
Kasaragod	19.00 (11.3)*	60.7 (75.6)	40.8 (42.9)	29.9 (24.9)	37.7
Mandapam	26.2 (20.0)	62.3 (77.3)	51.0 (60.4)	44.6 (49.3)	46.0
Josegiri	27.2 (21.4)	61.6 (76.4)	49.9 (58.5)	43.6 (47.5)	45.0
Mean	24.2	61.5	47.2	39.3	

*Figures in parentheses are the actual % values

From the foregoing, it is seen that *Phytophthora* infection on coconut occurs when the relative humidity is higher than 94% and temperature lower than 24 °C. While such conditions prevail at higher elevations for an extended period, duration of ideal situations is shorter in the plains. The mean macro- and micro-humidity and temperature levels recorded in the two endemic plots in hilly localities for two years showed variation compared with that of Bovikanam area (plain) with sparse incidence of disease.

Disease incidence was highly correlated with the macro- and micro-humidity of the same month and also with that for the previous two months. Correlation matrices could be calculated for endemic areas with this.

Table 8.2: Relationship between bud-rot incidence and macro- and micro-climate.

a) Correlation Matrix - Mandapam (Kasaragod District, Kerala).

Bud-rot incidence	Temperature		Relative Humidity	
	Macro	Micro	Macro	Micro
Same month	0.320	0.453	-0.802	-0.780
After 1 month	0.259	0.375	-0.820	-0.780
After 2 months	0.174	0.171	-0.707	-0.642
After 3 months	0.088	0.048	-0.602	-0.53
After 4 months	0.149	0.0076	-0.474	-0.417
After 5 months	0.104	-0.076	-0.388	-0.32
After 6 months	-0.20	-0.28	-0.06	-0.007

Table 8.3: Correlation of bud-rot incidence at montly interval with macro-and micro-climate at Josegiri (Kannur District, Kerala).

Bud-rot incidence	Temperature		Relative Humidity	
	Macro	Micro	Macro	Micro
Same month	0.488	0.23	-0.835	-0.84
After 1 month	0.43	0.149	-0.78	-0.79
After 2 months	0.24	-0.02	-0.65	-0.664
After 3 months	0.10	-0.18	-0.46	-0.48
After 4 months	0.23	-0.09	-0.47	-0.48
After 5 months	0.20	-0.129	-0.369	-0.38
After 6 months	-0.01	-0.23	-0.150	-0.18

A regression equation ($y=ae^{bx}$) could be fitted for forecasting the number of diseased palms in each location in different months with fair degree of accuracy.

Prophylactic measures

In nurseries and young plantations, prophylactic sprays with 1% Bordeaux mixture or 0.3% Mancozeb should be taken up at the onset of monsoon. Small perforated sachets containing 3 g of Mancozeb can be placed in the top two leaf axils as an alternative. Root feeding palms with Aureofungin sol (46.6%) @

36.4 g per palm or Tridemorph 80% (calixin) @ 21ml per palm can afford protection from bud-rot for a period of eight weeks.

Proper spacing should be adopted for planting since over-crowding helps to build up humidity and thus support disease incidence or development. Adequate spacing encourages air movement and dissipation of humidity.

Ensuring proper drainage and avoidance of water stagnation also ensures freedom from disease.

Phytosanitation

Removal and destruction by burning all the dead crowns is essential to reduce foci of infection and also to reduce breeding of pests. Crown cleaning before and after the rains also helps in reducing lurking inoculum and insect pests.

Forecasting disease onset is essential to take up control measures in vulnerable places.

Advice to farmers

What to do

- Adopt control measures in the early stage of the disease.
- Observe palms regularly to detect the ones with tell-tale symptoms of bud- rot.
- Remove all dead palms and burn them.
- When the disease is detected, using a sharp knife remove the rotten portions of the spindle and crown.
- Treat the wound with 10% Bordeaux paste or Mancozeb slurry. Cover with plastic sheets in such a way so as to prevent damage from rain and also to facilitate drainage and aeration.
- Burn all the infected material.
- Adopt proper spacing to facilitate free air movement and to prevent build up of nigh humidity in the garden.
- Take up axil filling to prevent the attack of rhinoceros beetle.

What not to do

- Do not retain infected dead trees in the garden.
- Do not allow organic matter to rot in garden.
- Do not plant seedlings at closer spacing.

Basal stem-rot

Basal stem-rot is a killer disease caused by a soil-borne bracket fungus. This has been reported from India and Sri Lanka. In India, the disease is prevalent in Tamil Nadu (where it was detected first in Thanjavur and hence called 'Thanjavur wilt'), Andhra Pradesh, Karnataka, Maharashtra and Gujarat states. The disease is endemic in nature and slowly spreads through soil to the adjacent trees. The spread is faster in sandy soils.

Symptoms

There are many symptoms associated with this disease. One or more of these may be present on a given tree. Exudation of a reddish brown, viscous fluid from the basal portions of the stem which gradually extends upwards, is a very important symptom. Severe root decay and discoloration of the bole region is seen. Drooping of the leaves of the outer whorl in quick succession followed by nut shedding is observed. Often, the dry top is blown off leaving a telephone pole-like decapitated trunk. When the palm is dead or just about to die, brackets of the fungus emerge from the base of the trunk.



Plate 8.4: Drooping of leaves in outer whorl due to basal stem-rot.

Etiology

The disease is caused by three species of a Basidiomycetous fungus *Ganoderma lucidum*, *G. applanatum* and *G. boninense*.

Weather and the Disease

In endemic areas of Thambikkottai in Tamil Nadu, disease incidence was more in summer i.e., from March to August. It was directly related ($r=0.27$) to the mean maximum soil temperature. It was not related to rainfall, humidity or mean minimum temperature. Mean maximum temperature of soil at 15-30 cm had a decisive role in the spread of the disease. Soil moisture on the contrary, had a negative correlation. Subsoil in the diseased areas of Thanjavur (Tamil Nadu) has a mixture of sand and yellow clay which hardens on drying in summer and forms a hard pan impeding root penetration which predisposes the trees to infection, due to stress.

Observations at Ambajipetta (Andhra Pradesh) also found the spread to be more when the rainfall was less. Linear spread was more during summer i.e., from December to May than during June to November. High soil moisture had an adverse effect on its spread.

Table 8.4: Relationship between temperature and incidence of Thanjavur wilt of coconut

Months	1 st year			2 nd year			3 rd year			4 th year			5 th year		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
January	0	0	29.6	1	2	31.0	2	0	27.1	1	2	27.3	0	2	25.7
February	0	0	32.6	0	0	31.4	0	5	29.7	0	1	29.2	2	2	25.8
March	0	0	34.0	0	2	32.1	2	1	30.6	1	0	30.9	1	10	29.8
April	7	32	35.4	1	0	33.5	1	1	32.4	0	0	32.1	2	3	30.8
May	4	19	33.9	2	4	34.0	1	1	33.7	0	0	34.2	0	3	33.4
June	3	2	36.6	3	8	33.8	2	2	33.9	0	2	33.6	1	7	34.4
July	1	5	35.9	2	4	33.7	0	1	31.9	0	2	31.0	2	1	36.5
August	3	1	35.8	0	0	32.3	0	3	31.4	7	0	31.4	1	4	36.2
September	1	1	34.5	1	1	31.6	2	2	31.2	6	0	30.5	1	8	34.8
October	0	0	31.6	0	0	30.8	0	2	30.8	3	0	30.1	3	1	34.6
November	1	1	30.3	0	1	28.8	0	0	30.1	3	7	27.7	0	7	31.0
December	1	1	29.8	0	1	27.4	0	3	27.7	0	2	26.1	1	1	28.4

Vertical Columns:

1. Number of trees wilted
2. Number of trees with bleeding symptoms
3. Mean maximum temperature ($^{\circ}\text{C}$)

Management of the disease

Being a soil-borne pathogen, eradication is not easy. Once the soil becomes 'sick' it will remain so. Hence, a multipronged integrated approach is needed to keep the disease in check. Management of the disease

has been attempted using organic matter, green leaves, bio-control agents like *Trichoderma*, phospho-bacterium, *Gigaspora calospora* (VAM) and *Azospirillum*.

Advice to farmers

What to do

- ❑ Remove dead palms and palms in advanced stage of the disease.
- ❑ Burn the bole of the dead trees and the planting pit to destroy remains of the pathogen.
- ❑ Isolate diseased palms from healthy ones by digging trenches one meter deep and 30 cm wide, 1 meter away from the infected tree.
- ❑ Irrigate regularly during summer (follow basin/drip method).
- ❑ Adopt moisture conservation measures to assure water availability by mulching and burying husk.
- ❑ Apply organic matter @ 50 kg/palm/year.
- ❑ Apply five kg neem cake enriched with *Trichoderma* along with regular application of organic matter.
- ❑ Raise banana as an inter crop as the root exudates of banana discourage the growth of *Ganoderma*.
- ❑ In heavily infested areas, drench palm basins with 40 litres of 1% Bordeaux mixture once in 90 days, thrice a year (avoid the rainy season) to reduce the pathogen population in soil.
- ❑ Root feeding with 2 g *Aureofunginsol* + 1g copper sulphate in 100 ml water, thrice a year at quarterly intervals (avoid rainy season) ; alternately, 100 ml of 2% 'Calixin' (Tridemorph 80%) in water can also be used. Fungicide treatment is very effective when adopted during the early stages of the disease.
- ❑ When weevil (*Xyleborus*) attack is noticed on the trunk, swab the portion with Sevin (Carbaryl) slurry.

What not to do

- ❑ Avoid flood irrigation to prevent spread of pathogen.
- ❑ Avoid ploughing and inter culture as this would produce injury to roots and also help the pathogen to spread.

Leaf-rot disease

Leaf-rot is a disease that appears super-imposed on root (wilt) affected coconut palms. Root (wilt) is a debilitating disease caused by *Phytoplasma*. Leaf-rot is a fungal disease attributed to three different pathogens.

Symptoms

The disease starts as minute water soaked lesions on the emerging spindle in different colours and shapes. These lesions enlarge, coalesce freely leading to extensive rotting. These portions dry, turn black and get blown away. Tips of leaflets and midribs become black and shrivel. As the leaves turn green, the progress of the disease stops. Because of this, a considerable portion of the lamina is lost, indirectly affecting the productivity. This disease is caused by *Colletotrichum gloeosporioides*, *Exserohilum rostratum* and *Fusarium solani*.



Plate 8.5: Leaf-rot affected coconut seedling.



Plate 8.6: Leaf-rot affected coconut palm. Note affected spindle leaf.

Weather and disease

Leaf-rot becomes severe during the monsoons. Severity of infection by *E. rostratum* (formerly referred to as *Helminthosporium halodes*) was correlated with monsoon. Similar was the case with *Colletotrichum* also with the infections reaching a peak in June-July. The disease incidence was positively correlated with rainfall and relative humidity and negatively correlated with maximum temperature and sunshine hours. *Fusarium* species were isolated most commonly during the dry season of January-May.

Advice to farmers

What to do

- ❑ Conduct regular surveillance to detect disease incidence.
- ❑ Cut and burn the rotten portions of the spindle and that of the adjacent two leaves.
- ❑ Pour 300 ml of fungicidal solution containing Contaf (Hexaconazole 5% EC) or 3 g Mancozeb around the spindle leaf.
- ❑ Apply 200 g maroti cake around the base of the spindle. Treat all palms twice a year, once before and once after the cessation of the rains.

What not to do

- ❑ Do not neglect treatment even if only one palm is affected.

Stem bleeding

Stem bleeding is a debilitating disease, which is prevalent in most of the coconut growing countries like Sri Lanka, India, Malaysia, Philippines, Trinidad, Papua New Guinea, Indonesia and Bangladesh. In India, it occurs in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa, Orissa, Maharashtra, Andamans and West Bengal.

Symptoms

Exudation of reddish brown gummy fluid from longitudinal cracks on the stem is the typical symptom of the disease. These exudations dry and appear as black streaks/patches. Initially these are seen at the base of the palm. Gradually, these bleeding patches progress upwards. When it reaches the middle of the trunk, the leaves in the crown begin



Plate 8.7: Stem-bleeding due to *Ganoderma*.



Plate 8.8: Stem-bleeding due to *T. paradoxa*.

to yellow and gradually the leaf size and number gets reduced. Nuts fall pre-maturely and production decreases drastically. The stem tapers like a 'pencil point'.

Internally, the tissues underlying the bleeding patches become water-soaked and decay sets in. In dry and warm areas, the decay is confined to the peripheral tissue. In cool weather and cool places, the decay extends inwards resulting in accumulation of much fluid in the affected tissues. This predisposes the palm to the attack of scolytid beetles. The disease is aggravated by nutrient and moisture stresses.

This disease is caused by a soil-borne fungus, *Thielaviopsis paradoxa*. The fungus enters through the



Plate 8.9: Internal water soaking due to *T. paradoxa*.



Plate 8.10: Stem-bleeding due to lightning.

natural crevices formed on the bark during the growth of the palm and attacks the underlying soft tissues. The fungus produces minute hyaline conidia that move upwards through vascular streaming and establish fresh infections in due course. The fungus also produces thick-walled, dark chlamydo spores that help in surviving through the harsh summer.

Symptoms of this disease become prominent during the cool post-monsoon period when assured humidity and a favourable temperature regime prevails. In cooler habitats like Karkala and Coorg in Karnataka and in Assam, the disease assumes severity during winter season and attacks soft tissues deep into the stem resulting in collapse and death of palms. As the weather warms up, the infection

subsides, again to flare up during the monsoon season.

This disease is amenable to management through a number of integrated control measures.

Advice to farmers

What to do

- ❑ Remove the affected portions, using a sharp knife or chisel and paint the wound with 5% Calixin (Tridemorph 80%) solution. After a gap of two days (to allow absorption of the chemical) apply hot coal tar to seal the wound.
- ❑ Root feed with 5% Calixin thrice a year at quarterly intervals avoiding the monsoon season, at a dose commensurate with the extent of infection.
- ❑ Provide summer irrigation in adequate quantities.
- ❑ Provide drainage during rainy season.
- ❑ Apply 50 kg organics/tree/year.
- ❑ Apply 5 kg neem cake fortified with *Trichoderma* sp.

What no to do

- ❑ Do not burn trash close to palm base.

DISEASES OF ARECANUT

Arecanut is affected by many diseases of which fruit-rot and yellow leaf disease (YLD) are the most important.

'Koleroga' or 'mahali' or fruit-rot

Fruit-rot caused by *Phytophthora arecae*/*Phytophthora meadii* is prevalent in all arecanut growing areas receiving heavy regular rainfall. Nuts at any stage of development are susceptible to infection. The disease causes both qualitative and quantitative loss by way of inferior quality kernel and also due to heavy shedding of nuts.

Symptoms

The disease is characterized by the appearance of dark green water-soft lesions on young nuts. These lesions may coalesce to form extensive patches. Slowly a white fluffy growth of the fungus appears on these lesions and covers the entire nut. Affected nuts fall off the bunch.

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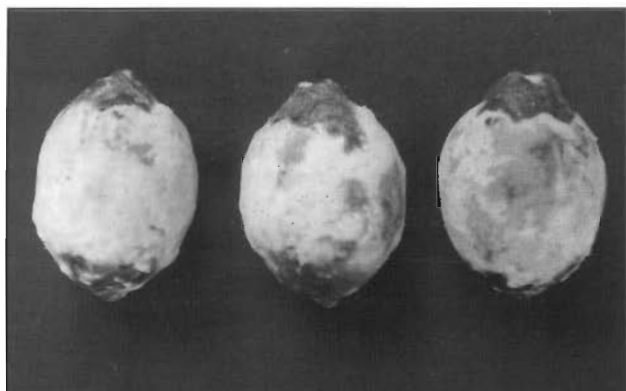


Plate 8.11: *Phytophthora* infected arecanuts.



Plate 8.12: *Phytophthora* infected areca bunch.

Some times, infection takes place late in the season. Infected nuts shrivel, become mummified and persist on the bunches. These bunches are often not harvested but retained on the tree. In the subsequent season, inoculum lurking in these nuts help to initiate fresh infection.

Weather and Disease

Disease is prevalent during South-West monsoon period and rains play a key role in disease development. Usually the disease makes its appearance about 15-20 days after the onset of South-West monsoon (May-June) and persists till the end of monsoon (Aug.-Sep.). High humidity and low temperature are congenial for the growth of the fungus. Heavy rainfall with constant humid conditions and low temperature, alternating sunshine and rain, favour the incidence of the disease. The maximum crop loss of 50-90 per cent was recorded when the rainfall was maximum with high humidity of more than 80 per cent throughout the season. Besides, the shorter duration of sunshine hours favoured the development of the pathogen. Heavy wind and, to a certain extent, birds and small

insects help in the spread of the disease as also the rainsplashes. There is no definite pattern in the spread of the disease. Based on epidemiological data, a linear model to predict the disease four days in advance has been developed. Zoospores released from the sporangia germinate in films of water and penetrate the nut surface through the stomatal openings.

Advice to farmers

What to do

- ❑ Collect fallen nuts, dried inflorescences and burn them before the onset of monsoon.
- ❑ Spray 1% Bordeaux mixture to all the arecanut bunches at the onset of monsoon and again at intervals of 45 days when sunshine is available for 4-5 hours after spraying.

What not to do

- ❑ Do not retain mummified bunches on the palm after the harvesting season.
- ❑ Do not use excess quantity of lime for making Bordeaux mixture since it will affect the fungicidal property of the Bordeaux mixture adversely.
- ❑ Do not remove the pin from the nozzle of the rocker sprayer to get a strong jet of spray. This will only flow down, without reaching the nooks and corners; whereas retaining the pin helps in producing a fine mist with very fine droplets of spray which would settle down into the nooks and corners of the crown and bunch, thus affording greater protection (with lesser amount of the fungicide).

Inflorescence dieback

Inflorescence dieback of arecanut caused by *Colletotrichum gloeosporioides* Penz. has been reported to be wide-spread in Kerala and Karnataka, which are the major areca growing States in India.

Symptoms

From the constant observations on initial stage of infection of inflorescences under natural condition,



Plate 8.13: The most susceptible stage of inflorescence to the fungal infection.



Plate 8.14: Infected inflorescence.

the most susceptible stage of infection was found to be immediately after shedding of all male flowers. The scars left after shedding of male flowers were found to be the main foci of infection. The infection spreads from tip of the inflorescence to the base and causes shedding of female flowers. Inflorescences are partially or completely infected. The infection is rarely initiated through female flowers. The green



Plate 8.15: Inflorescence die-back symptom.

fruits are resistant in the beginning and they become susceptible only when they turn yellowish-red during ripening.

Weather and Disease

Monthly observations on the disease incidence showed that inflorescence die-back is present throughout the year. The incidence of the disease becomes higher during February- March, reaches a peak during April-May and subsequently becomes low and insignificant during July- January. Though the annual mean RH was 76.13 to 82.08 per cent, the highest was 99% and the lowest was 45% during

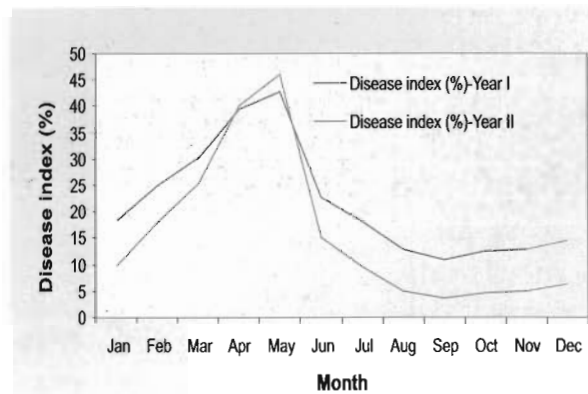


Fig. 8.1: Incidence of inflorescence die-back of arcanut.

March-May. The highest temperature, (28 to 34.5 °C) was recorded from 12.00 hr to 16.00 hr and the lowest (18 to 29 °C) from 2.00 hr to 8.00 hr during March to May. The maximum number of inflorescences of the susceptible stage (75-80%) was observed from January to May. In general, the disease appeared to be closely related to the production of inflorescences. The high humidity and low temperature prevailing

during the months of March-May in the early hours of morning followed by high temperature in the afternoon and the availability of inflorescences of susceptible stage during this period appear to favour disease development. The relationship between inflorescence produced and disease incidence was found to be highly significant ($r= 0.65^{**}$). The regression equation to determine the disease index

rarely produced and hence, the disease incidence in the garden is also very low. Thus, the abundance of inflorescence of susceptible stage and the prevailing climatic conditions during April-May are the deciding factors in the epidemiology of the inflorescence dieback of arecanut.

Advice to farmers

What to do

- Spraying 0.3% Mancozeb to check the spread and progress of the disease.

What not to do

- Do not retain dead and mummied bunches.

Bacterial Leaf-stripe

This is the only bacterial disease of arecanut, which is found in Tumkur district of Karnataka State. *Xanthomonas campestris* pv. *arecae* is the causal organism of the disease.

Symptoms

The disease appears as elongated water soaked lesions with a halo. The lesions coalesce and run as stripes as the disease progresses. Reddish ooze is also seen from these lesions in cooler weather.

Close planting of arecanut and application of higher levels of nitrogen and green leaf manure favour disease development and spread. Frequent irrigation (once in 5-10 days) also aggravates the disease incidence. Phosphorus and potash have no influence on disease incidence. Intercropping banana in arecanut garden with bacterial leaf stripe disease accelerates disease intensity and is thus detrimental to arecanut plantations.

Weather and Disease

Incidence of bacterial leaf stripe attains a peak during the active monsoon season (July-October) when the average monthly rain fall is 130 mm or above with more than 10 rainy days per month. Subsequently, the intensity reduces. Temperature above 30 °C and below 17 °C was found to slacken the disease spread. Soil is not considered as the primary source of inoculum because the bacterium does not survive for a long time in soil. Palms of younger age group (three to five years) were highly susceptible to the

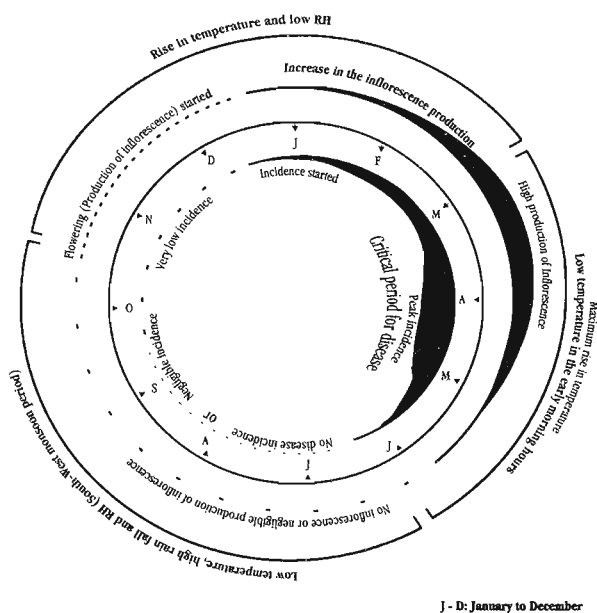


Fig. 8.2: Seasonal cycle of inflorescence dieback of arecanut in relation to production of inflorescence and climatic factors

Table 8.5: Temperature and relative humidity in cocoa- arecanut mixed garden during the peak incidence of inflorescence dieback.

Month	Temperature °C				Relative Humidity (%)	
	Minimum		Maximum		Mean	Range
	Mean	Range	Mean	Range		
Year 1						
March	21.96	18.0-24.0	32.00	30.5-34.5	80.50	50-99
April	22.30	19.0-25.0	32.87	28.9-34.5	82.08	64-98
May	24.88	22.0-27.5	35.68	29.5-33.5	79.88	59-99
Year 2						
March	21.26	18.0-23.0	31.85	30.0-33.5	76.13	20-96
April	23.97	22.5-25.5	33.50	31.5-36.0	81.06	50-99
May	25.18	24.0-27.0	37.86	35.0-42.0	78.70	45-97

from percent inflorescence produced is $y=1.625+0.305x^{**}$. During the South-West monsoon period (June-September), the inflorescences are very

disease than older palms. Susceptibility factor varied with age of the palm as well as with the age of the leaf.

Advice to farmers

What to do

- Spraying 1% Bordeaux mixture is effective.

What not to do

- Do not spray Bordeaux mixture when the temperatures are very high.
- Do not grow arecanut as an intercrop in disease-prone areas.

Yellow leaf disease

Symptoms

The disease is characterized by the yellowing of tips of leaflets and leaves of the lower whorl during the post monsoon period. As the disease progresses, lamina on either side of the veins alone remains green giving rise to the vein band symptoms. Gradually, the size of the emerging leaves diminish and the crown gets reduced in size. Symptoms appear on the nuts as blackening of the kernel and they turn spongy.

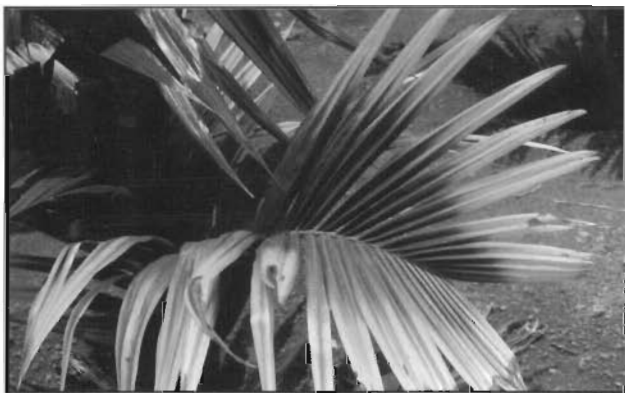


Plate 8.16: Yellow leaf disease affected areca seedling.

A survey in Thrissur District of Kerala revealed the occurrence of yellow leaf disease (YLD) of arecanut in varying intensities. Over 50 per cent of the total villages were found to be affected. A total of 40,061 palms were observed during this survey. Eighteen per cent of the observed palms were found to be affected. In areas, where the water table was above 1.5 m the disease was noticed in 20 per cent of the palms with 11 per cent in the early, 7 per cent in the middle and 2 per cent in the severe stages of intensity. The disease incidence in areas where the water table



Plate 8.17: Yellow leaf disease affected arecanut garden.

was 1.5 – 3.0 m below ground level, was also 20 per cent with 10, 8 and 2 per cent of the palms in diseased early, middle and severe stages of intensity, respectively, but only 12 per cent of the palms were found to be affected in localities with water table below three meters. Thus, it has been found that the incidence of YLD is not independent of water table and incidence was more in areas of high water table. Water logging was considered as one of the predisposing factors in the incidence of the disease. Water-logging in affected garden was generally high with 10 – 20 cm standing water during the period of symptom appearance. Water- table in affected gardens was within the root zone of areca palms and in Karnataka state, yellow leaf disease was generally seen in areas of high water table. Water table may be considered as one of the important factors while investigating the predisposing factors in the occurrence of yellow leaf disease. Since the disease cannot be controlled by any chemicals, management is the only alternative.

Advice to farmers

What to do

- Apply fertilizers and organic matter at prescribed doses.
- Regulate drainage.
- Irrigate during summer.

What not to do

- Do not use planting material from affected areas.

DISEASES OF COCOA

Black-pod disease

Black pod disease of cocoa caused by *Phytophthora palmivora* Butl. occurs in most of the cocoa growing countries. Among the diseases of cocoa occurring in India, *Phytophthora* diseases are found to be the major malady on the basis of the extent of damage caused and nature of the disease. Based on the survey of the diseases of cocoa occurring in South India, black-pod disease has been observed in 93.4 per cent of the gardens surveyed in Kerala, Karnataka and Tamil Nadu States. Thus, from the District-wise distribution of the diseases and the percentage of gardens showing the disease incidence, black-pod has been found to be the most important cocoa disease in India.

Symptoms

The disease starts as isolated chocolate colored lesions on pods. They enlarge in a circular fashion. The expanding spots coalesce and result in extensive patches of rotted tissue.



Plate 8.18: Disease affected cocoa pod.

Weather and Disease

Black-pod disease occurs in India during the South-West monsoon period (June-September) with the maximum disease incidence in July-August, when there is high humidity with little Sun-shine. A preliminary study on the incidence of black-pod disease during South-West monsoon period in Dakshina Kannada District of Karnataka State revealed that the disease incidence varied significantly from locality to locality as well as from garden to garden. The lowest disease incidence recorded during the study was 12.93% and the

highest was 29.78%. The variation in the intensity of the disease may be attributed to the prevailing climatic factors, especially low temperature, high humidity and availability of water in the garden or localities.

Advice to farmers

What to do

- ❑ Remove dead and mummified fruits regularly.
- ❑ Spray 1% Bordeaux mixture at the onset of the rainy season and subsequently at monthly/fortnightly intervals.

What not to do

- ❑ Do not allow over crowding of branches.

Leaf blight, shot hole, irregular spot and pod rot

Symptoms

The leaf blight, shot hole, irregular spot and pod rot in cocoa are caused by *Colletotrichum gloeosporioides*. *Colletotrichum* infection on cherelles and young pods mostly starts from the stalk as a dark brown discolouration with a diffused yellow halo spreading to the tip of the pod and stalk, but not to the cushion. Ultimately, the whole pod turns dark brown to black, shrinks and remains on the tree as mummified fruit. In some cases dark brown sunken lesions start any where on the pod surface. The shot hole symptom is mostly observed in cocoa monocrop, whereas the leaf blight is severe in cocoa-arecanut mixed garden and in heavily shaded gardens. The leaf blight symptom is more common on older leaves whereas shot hole symptom is usually confined to flush leaves.

Weather and disease

The intensities of leaf blight and shot hole increase from July reaching peak during September to November period and then decrease there after with the lowest level from April to June. Increase in infestation is associated with the period of rains (June to November). The phylloplane population of *Colletotrichum gloeosporioides* also increased during June to November period when the temperature tended to be low and constant with high rainfall and high humidity. During this period, cherelles and young pods are the susceptible ones. From January to May, when susceptible stages of pod are mostly

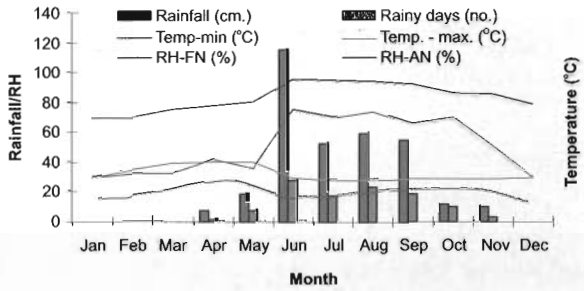


Fig. 8.3: Micro-climate in cocoa monocrop garden.

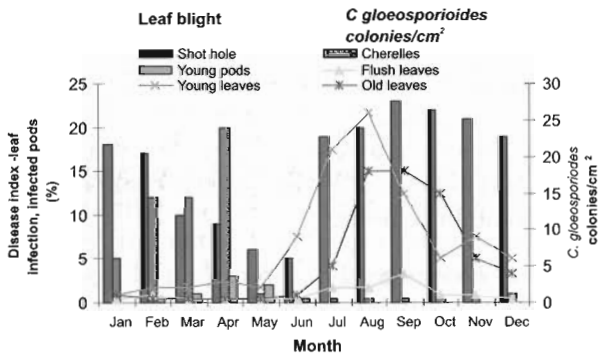


Fig. 8.4: Leaf blight and *C. gloeosporioides* population in cocoa monocrop garden.

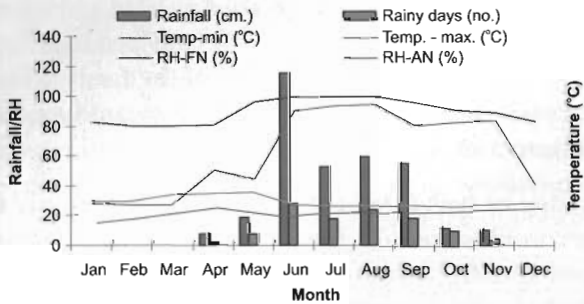


Fig. 8.5: Micro-climate in cocoa-areca mixed garden.

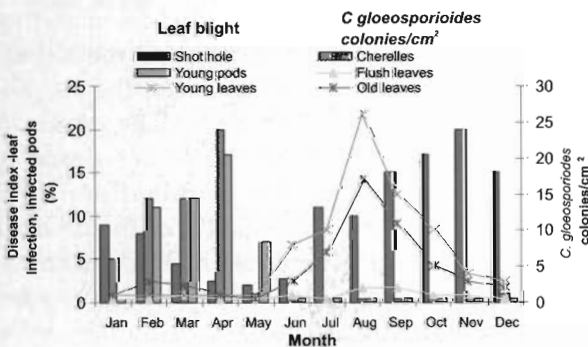


Fig. 8.6: Leaf blight and *C. gloeosporioides* population in cocoa - arecanut mixed garden.

prevalent the population of *Colletotrichum gloeosporioides* will be low due to the unfavorable climatic conditions. This seems to be the reason for the lesser incidence of pod rot when compared to foliar disease.

Advice to farmers

What to do

- Spray the leaves with 1% Bordeaux mixture just before the onset of South-West monsoon and continue at 15 day interval till November.
- Spray when maximum number of pods at cherelles stage and young pods are produced (during December to May period) to control the pod infection.

What not to do

- Do not allow infected pods to lie in the field.



Chapter 9: Weather in Relation to Processing

S.J.D. Bosco

Post-harvest processing determines effective utilization of harvested produce and the quality of the end product, which ultimately tells upon the consumption and acceptance of the produce. It has been estimated that there is considerable loss in many of the agricultural products after harvest. Weather plays a very important role in determining the magnitude of post-harvest losses by influencing the occurrence and intensity of pests and diseases. Further the post-harvest processing itself is highly influenced by weather where in the quality of final produce is determined.

COCONUT

The coconut reaches full maturity in about 11 to 13 months after the fertilization. Though the coconut palm produces an average of 12 inflorescences in one year, it is the ripe nut, which is the source of major coconut products. The stage of harvesting, and the duration and method of storage of coconut depends on the purpose for which the harvested coconut is used. For tender coconut purpose, harvesting is done when the fruits (nuts) are six to eight months old. For the production of copra and other kernel based products, fully matured coconuts are harvested. At this stage, the output of copra and oil as well as brown fibre would be the maximum.

It is estimated that nearly 50 per cent of the coconut production in India is consumed raw, 12 per cent for tender coconut purpose, while the remaining quantity is used in the copra industry and coconut fresh kernel based industry. The important fresh kernel based industries are desiccated coconut industry, coconut milk industry and coconut milk powder industry. In these industries the size of the nut is very important in determining the cost of production of the product. The nut size varies depending on the climate. The nut size is reasonably

good during July to October in central part of Kerala coincides with the South-West monsoon, while the nut size is reasonably good during November to March in the regions with North-East monsoon. Whereas, the nut size is reasonably good during April to June in central parts of Tamil Nadu where the coconut gardens are irrigated during the summer. Hence in a year, an industry located in a particular region usually transports coconuts at least from two other regions.

Storage of coconuts

It is a common practice to store harvested coconut in heaps under shade for a few days before they are further processed. This type of storing is also known as seasoning and has the following advantages: i) dehusking becomes easier, ii) shelling is cleaner and easier and the resulting shells are dry, hard and when used as fuel, burn continuously and produce less smoke, iii) the moisture content of the fresh kernel decreases and iv) the quality of copra produced is also superior.

Storage of harvested coconuts is beneficial only if the coconuts are fully ripe. If the nuts are fully ripe, good quality copra can be obtained from green coconut even if it is processed immediately after the harvest. The period of storage depends on the purpose for which coconut is used. If the coconut is used for the production of desiccated coconut, then it is stored for more number of days than the coconut used in the coconut milk industries for the purpose of getting high recovery of milk. The period of storage will be shorter during the winter season, as the climate will favour the germination of the coconut. To avoid the germination of the coconut, the height of the heap of the coconuts is also restricted to less than two meter. Due to variation in day and night temperature as well as direct sun light, stress crack will develop in the coconut which will spoil it within a day or two.

Advice to farmers

What to do

- Store coconuts in shade, avoiding direct sunlight.
- Cover coconuts with green coconut leaves, if stored in side the coconut garden.

What not to do

- Do not store the coconuts under direct sun light.
- Height of the heap should not exceed two meters.

Tender coconut water

In all the coconut growing countries, a portion of the coconut is harvested at the tender stage (5 to 7 months) for using the tender coconut water as beverage. In India alone, it is estimated that nearly 12 per cent of the production of coconuts is harvested and consumed in the tender stage. Due to variation in day and night temperature as well as direct sun light, stress crack will develop in the tender coconut which will spoil the tender coconut within a day. Hence tender coconut should be stored in the shade avoiding direct sun light. As mentioned earlier, if the tender coconut is stored in side the coconut garden itself, then it has to be covered with the green coconut leaves which will avoid the variation of the temperature. The shelf-life of the tender coconut will be more, if it is harvested and stored as whole bunch. This will also avoid the reduction in the quantity of water in side the tender coconut.

Advice to farmers

What to do

- Store the tender coconut in shade.
- Cover the tender coconut with the green coconut leaf, if it is stored in side the coconut garden.
- Harvest and store the tender coconut as bunch for longer shelf-life.

What not to do

- Do not store the tender coconut where sun light falls on it.

Tapping of toddy

In India, the interval between the beginning of tapping process and the commencement of sap flow is about 15 days extending to 21 days in summer months. The tapping is usually continued for a period of six months and sometimes three spathes are continuously tapped with a maximum toddy yield in the third month. The yield of toddy varies from tree to tree, season to season, day to day and even from spadix to spadix. There is also considerable variation between varieties.

Edible copra

The dried coconut endosperm is called copra. There are two types of copra – edible copra and milling copra. Edible copra is available in two forms – ball copra and cup copra. Ball copra is made from fully matured whole un-split nuts. The coconuts are stored for about 8-12 months on a raised platform, usually made of bamboos, inside a shed. In some



Plate 9.1: Good quality ball-copra.

places, during winter season drying process is hastened by occasional heating of the coconut by a slow fire set under the platform. Care should be taken to avoid over heating of the coconut which will spoil the taste of the edible copra. 'Big' and 'small' grades of ball copra are available in Karnataka. The weight of ball copra varies with respect to seasons and places. It is more in Karnataka than that from Kerala. In both the states, the weight is maximum in the month of July. Conversion of coconut into ball copra was faster during January to May when compared to June to November period.

Advice to farmers

What to do

- ❑ Store coconuts in shade.
- ❑ During winter season, heat the coconut by occasional firing under the platform for hastening of drying.

What not to do

- ❑ Do not over heat for hastening of drying.

Milling copra

Drying is an important post-harvest operation in the processing of coconut for the extraction of oil. For the efficient storage of copra and easy extraction of oil, fresh coconut kernel, which contains 45 to 55 per cent moisture, has to be dried to 5 to 6 per cent moisture level to obtain the copra. The conventional system of copra drying is by spreading the split coconuts on an open surface for sun drying. This



Plate 9.2: Sun drying of copra in drying beds.

operation takes 6 to 8 days and quality deterioration due to deposition of dirt and dust on wet kernel is unavoidable. Moreover, if the atmosphere is cloudy and the temperature goes down during the initial days of drying, the copra will get infested with mould. Copra obtained by this method is often of poor quality because of prolonged exposure to atmosphere resulting in microbial infection. During rainy season, with restricted sunshine, drying by

artificial method is the only possible solution for making copra. To obtain good quality copra, particularly during rainy season, a suitable dryer using indirect heating for drying is essential. Drying must be carried out within 4 hours of splitting since coconut kernel deteriorates very rapidly due to growth of mould and bacteria. During cloudy weather condition, it will be faster.

When drying is delayed due to uncertainty of weather conditions or for other reasons, pre-treatment of kernel by chemical means has been found to prevent deterioration of copra. Dipping the copra in dilute sodium carbonate and dilute sulphuric acid in conjunction with sun drying has been found to be successful. It is also confirmed that application of a coat of glacial acetic acid on the kernel surface prevented microbial growth during open sun drying. Treating the fresh kernel with shell ash prior to drying and dipping the fresh kernel in 1000 ppm propionic acid for 60 minutes have also been found successful in preventing mold growth. Though good quality copra could be produced by sun drying, the method is hindered during the monsoon. If proper care is not taken, the copra processed during the monsoon may become mouldy or discoloured. Even though mould growth does not appear on the fresh kernel until about three days, inadequate drying or intermittent drying develops sliminess on the surface of the fresh kernel resulting in subsequent discolouration. Copra drying can be carried out without interruptions during summer. Solar energy can be more effectively utilized for copra drying by using solar heat-collector type drying systems.



Plate 9.3: Small scale copra drier.

Advice to farmers**What to do**

- ❑ During cloudy weather condition, adopt any one of the drying methods for getting good quality copra.

What not to do

- ❑ Do not keep the split nuts for more than four hours without drying.

Quality of copra

The quality of copra is influenced by i) moisture content ii) colour and cleanliness iii) microbial load iv) rubberiness v) case hardening and vi) charring. Defective methods of processing and high moisture content of the copra are the major factors responsible for copra deterioration. Humid condition prevail in the coconut growing regions and as a result of this post harvest losses in copra due to the activities of microorganisms, are very high. Hence sun drying becomes very difficult during monsoon because of high ambient relative humidity and intermittent rains.

Copra with a moisture content of less than six per cent is considered good quality as it is not easily damaged by insects, moulds or microorganisms. With relative humidity of 80 per cent at temperatures above 30 °C, bacteria multiply rapidly and within four hours, a surface slime begins to develop on the wet kernel. The relative humidity in the coastal region during cloudy weather condition is more than 75 per cent. The equilibrium moisture content of copra at relative humidity of 75 per cent is 10 per cent. Therefore, even if the copra is dried below 6 per cent moisture content and stored in ambient relative humidity of more than 75 per cent, the moisture content of the copra will increase to more than 10 per cent.

Advice to farmers**What to do**

- ❑ Store the copra with the moisture content of less than six per cent.
- ❑ The relative humidity of the copra storage atmosphere should be less than 75 per cent.

What not to do

- ❑ Do not keep the copra on the wet floor.

Stored pests in coconut products

Excess moisture, mould, insects and rodents are known to be responsible for damage and loss to stored products of coconut and also for the deterioration in quality of stored material. At various stages of production, distribution and utilization, heavy quantitative losses occur due to insects, rodents, fungi and other micro organisms.

The general observation in India is that the copra storage is affected by excessive mould growth when the relative humidity is greater than 75 per cent at room temperature or greater than 85 per cent at 40 °C. In many milling establishments in India, it is a usual practice to dry the copra under the Sun for one or two days before bagging and storing. Painting of upper surface of the roof of the storage structure with white reflective paint has been reported to reduce temperature fluctuations within 10 °C thus preventing serious condensation effect. The walls also should be shaded from direct sunlight and should be provided with sufficient number of adjustable ventilators.

Sulphuring the copra is effective for storing for longer periods during rainy season. Fumigation of copra with methyl bromide at the rate of 3 kg/100 m³ for 48 hours with a gas proof sheet is recommended when copra is stored in godowns. Fumigation with sulphurdioxide or lindane smoke or pyrethrum and piperonyl butoxide as a fog is also resorted to. Fumigation with a mixture of carbondioxide and ethylene oxide (99:1) was effective against insects pests of copra.

Use of proper packing materials is also an important factor. Plastic lined gunny bags can be used for safe storage of copra even during the rainy season. Multi-walled paper bags could keep copra free from insects upto three months and those treated with pyrethrin could keep upto nine months. Storage of copra in tin containers and polythene bags, and fumigation with bio-gas, neem leaf-gas, carbondioxide and sulphur dioxide can effectively control microbial infestation during storage. Copra could be stored for more than six months by exposing it either to bio-gas for one to three days or to neem leaf gas for 15 days immediately after splitting, prior to storage in any air-tight container.



Advice to farmers

What to do

- Dry the copra under the Sun for one or two days before bagging and storing.
- Paint the upper surface of the roof of the storage structure with white reflective paint.
- Avoid direct sunlight on the copra storage room.
- Provide sufficient number of adjustable ventilators in the copra storage room.
- Fumigate the copra with methyl bromide at the rate of 3 kg/100 m³ for 48 hours with a gas proof sheet when copra is stored in godowns.
- When copra is stored in bags, use plastic lined gunny bags.

What not to do

- Do not use gunny bag for storing copra.
- Do not store the bags packed with copra on the wet floor.

Storage of coconut oil

The quality of oil mainly depends on i) quality of copra, ii) extraction conditions and iii) storage conditions. Unrefined coconut oil contains Free Fatty Acids (FFAs) and hence has a tendency to become rancid due to the hydrolysis and oxidation of FFAs. With storage time, the peroxide value and FFAs of oil increase thus developing rancidity. The shelf life of coconut oil can be improved by adding either citric acid (500 ppm), common salt (1 per cent) or tamarind (2 per cent) and packing it in plastic containers or brown bottles to prevent the rancidification of oil.

Table 9.1: Optimum storage conditions of copra and coconut oil

Treatment	Treatment period	Containers
Copra		
Biogas	1 or 3 days	Tins & polybags
Neem leaf gas	15 days	
SO ₂	} Saturation level	
CO ₂		
Coconut oil		
Tamarind	2.0%	Brown bottles
Common salt	1.0%	White bottles
Citric acid	} 500 ppm	Plastic cans
Sodium metabisulphite		

Source: Rajagopal and Ramadasan 1999. Advances in Plant Physiology and Biochemistry of Coconut Palm.

Table 9.2: Criteria for quality evaluation of coconut oil

Parameters	Critical values
Acid value	0.50-0.80
Iodine value	7.0-11.0
Free fatty acids (%)	0.03-0.10
Saponification value	250-264
Peroxide value	1.0-1.5
Refractive index	1.45-1.49
Viscosity	50.1-52.7
Specific gravity	0.915-0.922

Source: Rajagopal and Ramadasan 1999. Advances in Plant Physiology and Biochemistry of Coconut Palm.

Storage of coconut cake

The coconut cake easily absorbs moisture, making it prone to mould attack while in storage. The critical moisture content is 15.2% at which it could be stored free of moulds in conditions under 79% of relative humidity. The cake can be stored without any spoilage for a period of six months, if alkathene bags are used. The rancidity of the cake could be effectively checked if its moisture content is kept below the critical level of 15.2%.

Advice to farmers

What to do

- Store the oil cake in alkathene bags.

What not to do

- Do not use gunny bag for storing cake.
- Do not store the bags packed with oil cake on the wet floor.

ARECANUT

The stage of harvesting depends on the type of produce for the consumer markets. Mainly, there are two types viz., one prepared out of immature green nuts and the other from ripe nuts. Dry kernel obtained after drying and de-husking of ripe arecanut is called as '*chali*'. The processed kernel of the immature green arecanut is called as '*kali packu*' or '*supari*'. In each case, the maturity at which the fruit is harvested and the season of harvest affect the quality of the processed nut considerably.



Drying and storage of 'chali'

Fresh ripe areca fruits are dried under the Sun by spreading in single layers for 35 to 40 days. In Kerala and Assam harvesting season coincides with the monsoon and sun drying is difficult. Drying is the most important activity in tender arecanut processing industry also. Drying is carried out under the Sun in the open yard or in mechanical dryer.

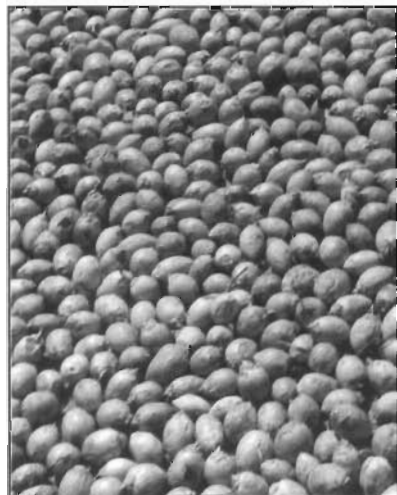


Plate 9.4: Ripe arecanuts.

The husked arecanut known as 'chali' is stored in godowns even upto one year in gunny bags before marketing. The moisture content of the stored arecanut varied from 8 per cent to 28.3 per cent. Insects damage nuts by feeding on the inner central core and due to this, holes appear on the surface of the nuts. More than 21 species of insects and mites are recorded infesting stored arecanut in the country. The insect damage is maximum during the rainy months when the humidity is high while damage is minimum during winter and summer months. The most important storage pest of arecanut is arecanut



Plate 9.5: Arecanut sun drying yard.

beetle (*Cocotrypes carpophagus* Horn), damaging even up to 100 per cent during November.

Lack of proper drying yards, improper spreading and turning of nuts and exposure to unexpected rains during the drying period lead to microbial infection of the husk as well as kernel. These infections affect the quality of the nuts rendering them unsuitable for consumption and thus lowering their market value.

The extent of damage due to fungi and other biological agents aiding deterioration depends upon the nature and season of drying. When nuts are stored for one year, the infection increased to 60.7%. It was observed that the fungal infection was highest in the nut dried during October (62%) and lowest in those dried during February (21%). The high incidence of fungal infection during October is attributed to the prevailing low temperatures and high relative humidity. Whereas, low infection in February is due to high temperature and low relative humidity. Majority of the nuts were infected during the first 5 to 10 days presumably from husk. The slow drying of endosperm coupled with its high nutrient content encourage the fungi to penetrate inside and attack the kernel.

Table 9.3: Mean percentage of fungal infection in processed arecanut during different months

Months	Infection (%)	Range of temperature		Relative humidity (%)	Total rainfall (mm)
		Max.	Min.		
October	61.5	26.0-35.0	19.1-22.3	56.8-92.4	156.8
November	52.8	31.0-34.5	15.4-22.6	46.9-87.7	454.4
December	43.8	31.0-35.0	12.7-22.9	49.6-86.8	0.0
January	31.5	31.4-35.8	14.9-18.6	33.2-85.7	0.0
February	21.0	32.5-36.5	16.0-20.9	48.1-91.9	0.0
March	25.7	33.8-37.8	19.1-24.1	50.7-90.2	1.2

Elimination of soil contact by the harvested nuts is beneficial in reducing nut infection since it is the prime source of infection. Harvested nuts treated with copper oxychloride showed less infection. Steeping the nuts in Bordeaux mixture followed by drying on cement floor reduced the percentage of infection significantly. Polythene lined gunny bags can be used with advantage over plain gunny bags for storing nuts. Storage of arecanut in air-tight bins also minimizes the fungal infection.

Advice to farmers*What to do*

- ❑ Spread the arecanut in thin layer while drying.
- ❑ Mix the arecanut randomly while drying.
- ❑ Eliminate soil contact by the harvested nuts since it is the prime source of infection.
- ❑ Use polythene lined gunny bags for the long period storage.
- ❑ Use air-tight bins to store arecanuts.

What not to do

- ❑ Do not dry the arecanut on the mud floor.
- ❑ Do not expose the arecanut to unexpected rains during the drying period.
- ❑ Do not use plain gunny bags for storage of nuts.
- ❑ Do not expose the arecanut to unexpected rains during the drying period.

Drying and storage of 'kali packu'

Tender arecanut processing is mainly done in some areas of Karnataka and Tamil Nadu where South-West monsoon is usually received late or not received. Harvest is done as per the daily requirement of the industry. If the rain is expected, then that day the processing is not done. The tender arecanut pieces show maximum resistance to infestation by insects.

Advice to farmers*What to do*

- ❑ During cloudy weather condition, adopt any drying method for getting good quality arecanut.

What not to do

- ❑ Do not process the arecanut during cloudy weather condition, if the artificial method of drying facility is not available.

COCOA

In cocoa, pods are processed to get the beans which are the economic products.

Pod formation and harvesting

The pods matures in about 150 to 170 days from the day of pollination. In the cocoa growing regions of India the days for maturity ranges from 135 to 170. This period varies depending on environmental conditions. A highly significant negative correlation between the number of days from pollination to harvest and the mean temperature during the period of fruit development has been established as $N = 2500/T - 9$, where N is the number of days from pollination to harvest and T is the mean temperature in °C.



Plate 9.6: Harvested cocoa pods.

Fruit production in cocoa is not uniform and there are often peaks in production. Harvesting of cocoa beans can proceed all through year, but the bulk of the crop is gathered in two flush periods from October to February and from May to August. For the Ghanaian cocoa, the peak harvest is in the month of November, the yields being high in October and December. The crop is spread more or less evenly in Malaysian cocoa. Occurrence of peaks in production is often related to environmental conditions and internal physiological factors. When wet and dry seasons alternate, there is often induction of flushing by the onset of the wet season, leading to increase in leaf area and enhanced photosynthetic activity in about a month's time when the leaves harden. Flowering flush commences by this time and peak harvest could be expected after about five months. Because of the fruit load, especially towards the later stages of development of pods, further flowering is inhibited and cherelle wilt enhanced. In addition to

this, there will be 'crazy' flowering and scattered harvests due to the prevalence of wet and dry periods, in between. Temperature also plays a role in inhibition of flowering in the cool seasons. When temperature remains high and rainfall is well distributed, harvests are more uniform throughout the year as in Malaysian cocoa.

In India also, there are peaks in cropping with the major peak in June to August and another minor peak from November to December. These are the general trends in the harvesting pattern. But there are obviously location differences, depending mainly on the rainfall pattern of the cocoa growing regions of the country. At Trichur in Kerala, following the pre-monsoon showers of April and May, there is peak flowering in May which results in the peak harvest in October and November, five months after. Even though flowering continues to be high in subsequent months except July and August, fruit set and development are inhibited by the fruit load. After the harvest of the main crop, there is another bout of successful fruit set and development resulting in the peak season during April and May.

Fermentation

Primary processing denotes production of dry cured beans for the market. This involves fermentation and drying. The climatic conditions during fermentation affects the process of fermentation. Temperature rises more slowly in wet weather in June and July. It is reported that volatile acid contents are higher in May than in June. Fermentation during the dry season was better than that during the wet season.

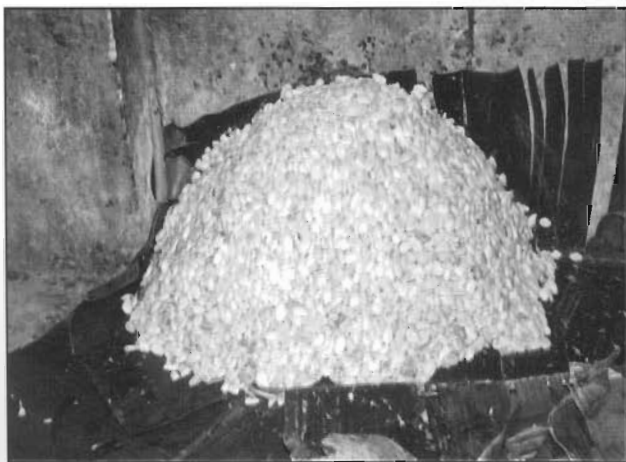


Plate 9.7: Cocoa pulp with beans heaped for fermentation.



Plate 9.8: Fermentation in box method.

Drying

The fermented beans will have a moisture content of about 55%. Such a high moisture content is unsuitable for storage of the beans as putrefaction may set in. The moisture content has to be brought down to about 6% for safe storage and transportation. This requires drying of the beans, which should commence immediately on cessation of fermentation. Unless the beans are skin-dry within 24 hours after fermentation, moulds set in and damage the beans. Sun drying is the simplest and the most popular method in most of the cocoa producing countries. Depending upon the climatic conditions, the beans are exposed to the Sun for about 12 to 20 days. This method generally gives good quality beans in traditional areas of cocoa production where the weather is sufficiently sunny.



Plate 9.9: Dried cocoa beans.

Advice to farmers**What to do**

- Dry the skin of the fermented bean within 24 hours after fermentation.

What not to do

- Do not dry the beans below 5 per cent moisture content.

Storage of dry beans

Dry cocoa beans can be stored for long under suitable conditions. However, the period of safe storage will depend on mainly the relative humidity and temperature of the atmosphere in which the beans are stored. In the temperate climates where humidity also is low the storage life is very long. In the tropical regions of high humidity, it will be difficult to store the beans for considerable length of time. For safe storage of the beans the moisture content should be 6 to 7%. When the moisture content is above 8% there is a danger of moulds developing within the beans; when the moisture content is below 5% beans become very brittle, hence the beans should be dried to the correct moisture content. The dried beans, when rubbed with fingers should produce a crackling sound. Cocoa beans can be stored safely for 2 or 3 months, however, if the cocoa is to be stored for much longer period special precaution must be taken to prevent deterioration. Cocoa beans are hygroscopic and hence absorb moisture under humid conditions.

The bean moisture content will exceed 8% when the relative humidity of atmosphere reaches 85%. Since, the moisture level of 8% in the beans is critical, as when it is above this level mould growth sets in, it will be difficult to store cocoa beans without damage in atmospheres with relative humidity exceeding 85% for a considerable period of the year. Hence, special precautions are to be taken to prevent contact of the dry beans with air.

In the cocoa-growing regions of India, the average relative humidity of the atmosphere remains high often exceeding 95%. Storage of cocoa beans is, thus, difficult in the producing regions of the country in the rainy months. The practice at present followed is to shift the beans to other regions of the country where atmospheric conditions are suitable. Another alternative would be to store the well-dried beans in

air-tight containers. Polythene or polythene-lined containers would come in handy for this purpose; but even such containers may not be very suitable for bulk storage of the beans during the continuously humid seasons.

A large number of mould species have been found in cocoa beans. These invade the cocoa beans before harvest, during fermentation and storage. Pods attacked by *Botrydiplodia theobromae* produce high percentage of beans with internal mould. If fermentation is prolonged beyond seven days, the percentage of internally mouldy beans increases considerably. When sun drying is prolonged due to dull weather, moulds get into the beans. Cocoa beans in storage are fumigated to kill off insects, in particular the cocoa moth, which can infest the beans. During the period from May to August of each year, each cocoa bean storage facility undergoes a total building fumigation.

Advice to farmers**What to do**

- Store the beans with the moisture content of 6 to 7 per cent.
- Store only well-dried beans in air-tight containers.
- Take special precautions to prevent contact of the dry beans with air, when the ambient relative humidity exceeds 85%.

What not to do

- Do not store the bags packed with dried bean on wet floor.

Storage of cocoa products

Chocolate and cocoa require storage conditions of 18 to 20 °C with relative humidity below 50 percent. High (27 to 32 °C) or widely fluctuating temperatures will cause fat bloom, a condition in which cocoa butter infiltrates to the surface, turning products grey or white as it recrystallizes. High humidity causes mustiness in cocoa powder and can lead to mould formation.

Advice to farmers**What to do**

- Store the cocoa products in low temperature and low relative humidity atmosphere.

What not to do

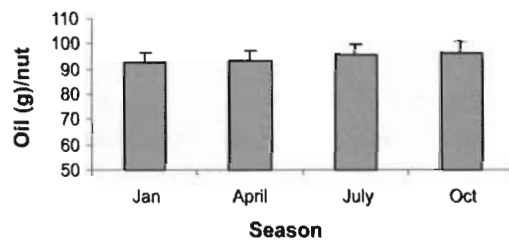
- Do not expose to high temperatures.

Yield and Quality of Coconut Oil in Relation to Season and Agro-climatic Zone

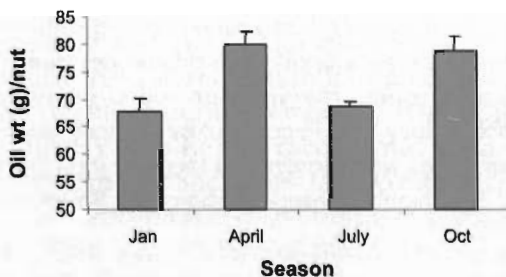
S. Naresh Kumar

The main economically important product from coconut is oil. Copra contains at least 63% of oil consisting mainly of lauric acid (48%) with the balance being myristic, caprylic and palmitic acids. In India, coconut oil is used for various purposes i.e., edible (39.4% of the total production), toiletry (46.5 %) and other industrial (14.1 %) uses. The coconut oil plays an important role as the raw material for the industries such as textile, soap, pharmaceutical, dye, lubrication, etc. The oleochemicals –oil based derivatives – are used in these industries. For industrial use the high content

of lauric acid is desirable for making high quality soaps, detergents, surfactants and shampoos. Moreover, based on the fatty acid composition of the oil, the chemical industry can produce various oleochemicals such as glycerol, fatty acid alcohols etc., from which various oleochemical derivatives can be prepared which are useful in various fields like textile, paints, petroleum, etc., including food industry. On the other hand, the most important use of the coconut oil is for human consumption. Coconut oil is a rich source of medium- chain- triglycerides (MCT) which are beneficial for human health and nutrition. It also is given to the patients as a source of fat and also to cure fat absorption disorders. The coconut oil is used as a base in making various pharmaceutical products. Further, the market economy of the coconut and its products is controlled by coconut oil industry.



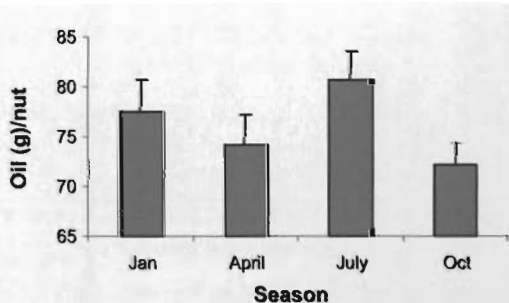
Seasonal variation in oil yield per nut at Kasaragod-Kerala (mean of 45 cultivars).



Seasonal variation in oil yield per nut at Ambajipeta-AP (mean of 42 cultivars and hybrids).

An elaborate study, conducted to analyze the copra and oil yields and fatty acid composition, indicated that external factors such as, growing seasons, agro-climatic zones found to influence copra yield, oil yield and the fatty acid content and composition in oil in coconut. Apart from these, variations also exist among the cultivars.

The mature nuts of all available cultivars and hybrids during January, April, July and October months from six centers (viz. Kasaragod -Kerala, Ambajipeta- A.P., Veppankulum – T.N., Ratnagiri - Maharashtra, Kidu and Arsikeri- Karnataka) and during January and July



Seasonal variation in oil yield per nut at Arsikeri-Karnataka (mean of 40 cultivars and hybrids).

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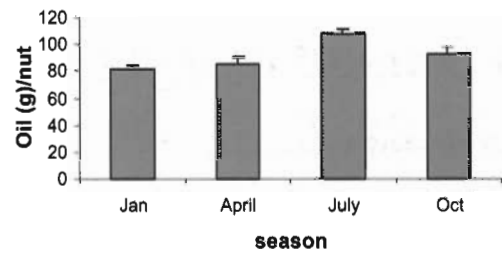
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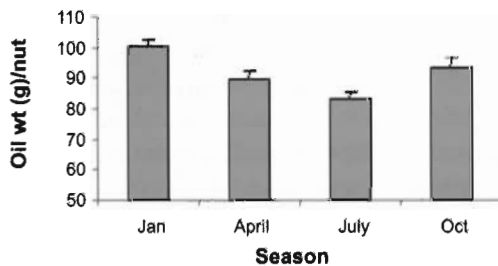


at five other centres (viz. Aliyarnagar – TN, Konark – Orissa, Kahikuchi – Assam, Mandouri and Mohitnagar – West Bengal) were analyzed for the above mentioned parameters.

The data indicated that the relationship between copra and oil concentration had seasonal variations. The copra yield/nut and oil yield/nut varied with cultivar, season and location. For example, the oil yield/nut was almost uniform throughout the year at Kasaragod, while at Ambajipeta the oil yield/nut was high in the nuts harvested during April and October. Similarly, at Arisikeri, the oil yield/nut was more during July and January harvests. In Veppamkulam, the oil yield/nut has shown an increasing trend from January to July and then it decreased. On the other hand, the oil yield/nut at Ratnagiri showed a decreasing trend from January to July and then increased in nuts harvested during October.



Seasonal variation in oil yield per nut at Veppamkulam-TN (mean of 62 cultivars and hybrids).

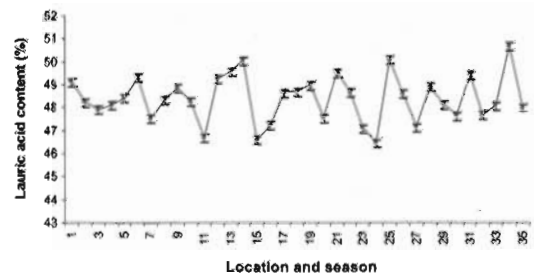


Seasonal variation in oil yield per nut at Ratnagiri-Maharashtra (mean of 48 cultivars and hybrids).

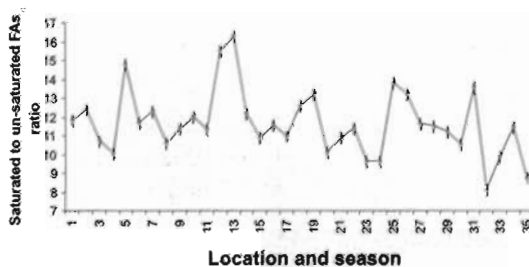
It is essential to note that these variations are contributed by seasonal differences in both copra weight/nut and oil percentage. These indicate that the copra and oil yields are having seasonal variations, which can be exploited for commercial purposes by the farmers.

The FA composition of oil also varied among cultivars and between seasons apart from differences due to agro-climatic zones. The variation found in Lauric acid, a major fatty acid in coconut oil, concentration is from 41% to 51%. The fatty acid profile of a given cultivar varies with season and location indicating the environmental impact to certain extent, even though it is a highly conserved character. Variations were more in the content of long chain fatty acids. Abiotic stress like water stress in rainfed palms adversely affected the copra yields, however, oil percentage was high in these nuts compared to those in irrigated palms. The profile of long chain fatty acids also varied due to rainfed and irrigated condition.

The FA composition of oil also varied among cultivars and between seasons apart from differences due to agro-climatic zones. The variation found in Lauric acid, a major fatty acid in coconut oil, concentration is from 41% to 51%.



Variation in mean lauric acid percentage in coconut oil across cultivars, hybrids, seasons and agroclimatic zones (each point represents mean of atleast 40 cultivars).



Variation in saturated to unsaturated fatty acid ratio in coconut oil across cultivars, hybrids, seasons and agroclimatic zones (each point represents mean of atleast 40 cultivars).

Biotic stress like *Eriophyid* mite infestation decreased the oil concentration in copra.

The spatio-temporal variations in quality of coconut oil in terms of fatty acid composition can be exploited for commercial purposes both by the farmers and industries.

Related Topic Oil & Season and Agroclimatic Zone



Chapter 10: Weather Data Based Forecasting: Case Studies on Yield and Bud-rot Disease of Coconut and Fruit-rot Disease of Arecanut

S. Naresh Kumar, Rohini Iyer and V. Rajagopal

With the advancement in knowledge on crop-climate relationship, weather data are increasingly being used to develop the models for forecasting the crop productivity and productivity reducers like pest and disease incidence. In many crop yield models, pest and disease modules are incorporated for effective simulation of system productivity. In coconut, efforts are being made to develop the descriptive models to forecast the yield and one of the diseases viz. bud-rot, under different agro-climatic zones.

Forecasting coconut yield

Weather variables play an important role in determining the coconut palm's growth, development and yield. The influence of weather on coconut yield starts from inflorescence initiation and lasts till nut maturity (44 months). Historical data on weather variables and coconut nut yield from different agro-climatic zones viz., Western coastal area – hot sub-humid-per-humid (Kasaragod – Kerala; Ratnagiri – Maharashtra), hot semi-arid (Arisikere – Karnataka) and Eastern coastal plains-hot sub-humid (Veppankulam- Tamil Nadu; Ambajipeta- Andhra Pradesh) of India were used for developing models for forecasting coconut yield. The weather parameters, which correlated significantly, were used for multiple regression analysis. In these models, one-year lag refers to the use of previous year's weather data for forecasting current year yield, two year lag refers to the use of weather data of year which is two years previous to the current year, to forecast nut yield of current year. Similarly, models were developed using lag periods up to four years. The forecast models with three- and four-year lag had high R² values. The models differed for usage of parameters in different agro-climatic zones, indicating the relative importance of these parameters in respective conditions for realizing the nut yield in coconut. Interestingly, the parameters used in models for Western coastal area – hot sub-humid-per-humid are temperature and relative

humidity, as indicated even in the classification of these areas. Models were verified for two years and forecast of yield during these two years was within 10% confidence level validated these models. The study indicates that the relative humidity and temperature play important role during the ontogeny of inflorescence and nut development. The descriptive models, developed based on weather data, can be used for forecasting coconut yield two to four years in advance within acceptable range of accuracy. The yields to be realized can be bracketed within forecasted range obtained from models using one, two, three, and four year lags.

Models for different agro-climatic zones

Forecast of weather data-based yield forecasting in different agro-climatic zones was done using descriptive models developed for specific agro-climatic zones.

Table 10.1: Weather data based yield forecasting regression models with four-year lag for different agro-climatic zones

Place	Regression equation	R ² value
Kasaragod	$Y = 860.26 - 12.56(T_{max_{11}}) + 0.90(T_{min_{11}}) - 1.924(RHFN_{11}) + 0.024(RHFN_{12}) - 1.574(RHAN_{12}) - 8.725(PE_1) - 25.005(PE_2)$	0.921
Veppankulam	$Y = 926.90 - 18.18(T_{max_{11}}) - 12.98(T_{min_{11}}) - 0.108(RF_1) - 0.107(RF_2) - 0.176(RF_3)$	0.992
Ambajipeta	$Y = -800.23 + 4.39(T_{min_{11}}) + 11.29(RHFN_6) - 4.89(RHFN_1) + 4.84(RHFN_2) - 13.36(RHAN_6) + 10.56(RHAN_{10}) + 0.15(RHAN_{12}) - 0.394(RF_3) - 1.08(RD_{10})$	0.948
Ratnagiri	$Y = -298.70 + 7.80(T_{max_{11}}) + 7.36(T_{max_{12}}) + 0.242(RH_{11}) - 1.287(RH_2)$	0.913
Arsikere	$Y = -128.25 - 12.48(VPFN_{10}) - 1.93(VPAN_{11}) + 8.48(VPAN_{12}) + 4.47(RHFN_{10}) - 1.19(RHFN_{11}) + 0.189(RF_1)$	0.997

where 1-12 indicate Jan to Dec.

The forecasted and actual yields were tested for two successive years. The tests were successful in one- to four- year lag period. Efforts are on to develop simulation models for forecasting the growth and yield of coconut in different agro-climatic zones.

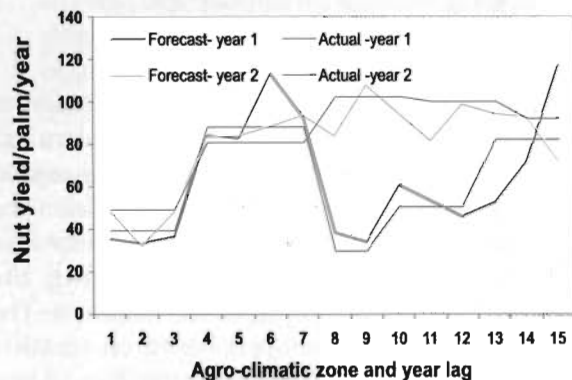


Fig 10.1: Forecasted and actually obtained coconut yields in different agro-climatic zones. The forecasting was done using 1-, 2-, 3- and 4-year lag periods in five agro-climatic zones. Values given are only for models with high R^2 at each zone.

Conditions for extrapolation of these models

With following conditions, these models can be used for wide areas

- i) Model developed for specified agro-climatic zone can be used for the fields falling in that area,
- ii) The crop should be under irrigated condition (at least a few summer irrigations),
- iii) Crop should be with recommended spacing (generally 7.5 x 7.5 m) and supplied with NPK at required amount
- iv) The plantation is of over 15 years old (stabilized yield stage).

In a well managed plantation the relative humidity and temperature played important role during the ontogeny of inflorescence and nut development. The descriptive models developed based on weather data can be used for nut yield forecast in coconut with fair amount of accuracy and the attainable yield can be bracketed within forecasted range obtained from models with one, two, three, and four year lags. These models can also be used for forecast of nut

yield in the situations similar to those in the present study. This will give an overall picture for nut yield, three to four years in advance.

Advice to farmers

- Ensure at least life-saving irrigation to palms during summer.
- Follow recommended management practices.

Forecasting coconut bud-rot disease

Among the diseases, next to stem bleeding and root (wilt), bud-rot and immature nut-fall caused by *Phytophthora* are the major diseases that affect coconut. The disease is generally noticed during South-West and North-East monsoon periods when wet weather prevails. A combination of temperature of 21-24 °C and 98-100 per cent relative humidity has been found to be highly congenial for the development of *Phytophthora*- incited rots. The microclimatic factors prevalent in the axil of leaves were equally important for the development of the disease. It has been reported that higher incidence of *Phytophthora*-incited bud-rot was always preceded by heavy rain fall. *Phytophthora* infection on coconut occurs when the relative humidity is higher than 94 per cent and the temperature lower than 24 °C. Epidemiological observations indicate that macro- and micro- temperatures and humidity in the coconut growing tracts of hilly areas of north Kerala are suitable for the survival of the pathogen in crown during almost all months, resulting in the high frequency of disease incidence during monsoon and continued infection up to January. Micro- and macro-level humidity and temperature of experimental plots at Mandapam, Josegiri and Bovikanum were recorded for two years. The micro-humidity was high and temperature was low when it was compared with that of the ambient. There is a high degree of correlation between disease incidence, micro and macro-humidity in Mandapam and Josegiri. Disease incidence was highly correlated with the macro- and micro-humidity for the same month and also that for the previous two months. Correlation matrices were calculated for endemic areas. Further, a regression equation ($y=ae^{bx}$) was fitted for forecasting the number of diseased palms in each location in different months with a fair degree of accuracy.

Table 10.2: Regression components with CGR in different bud-rot affected locations.

Location	a	b	Se (b)	R ²	CGR
Mandapam (300-1350M above MSL)	3.9110	0.0691	0.008428	0.9180	7.15*
Josegiri (300-1350M above MSL)	3.2783	0.0783	0.008475	0.9344	8.15*
Udayagiri (300-1350M above MSL)	3.1693	0.0609	0.006790	0.9306	6.28*
Kuttiadi (300-1350M above MSL)	3.0220	0.0563	0.008685	0.9355	5.80*
Bowikanam (150-300 M above MSL)	1.3863	0.0398	0.010288	0.7143	4.07*

Table 10.3: Regression models for different locations

Place	Regression equation	R ² value
Mandapam	$Y = (82.2) - 2.764 RH_{MACRO}^1 + 2.065 RH_{MICRO}^1$	0.856
	$Y = (72.455) - 4.315RH_{MACRO}^2 + 3.699RH_{MICRO}^2$	0.759
Josegiri	$Y = (36.5) - RH_{MACRO}^1 + 0.2578 RH_{MICRO}^1$	0.623
	$Y = (37.9) - 0.2629 RH_{MACRO}^2 + 3.699 RH_{MICRO}^2$	0.634

where

'Y' is the disease incidence (%) of particular month

RH_{MACRO}^1 is the average relative macro-humidity of the previous month

RH_{MICRO}^1 is the average relative micro-humidity of the previous month

RH_{MACRO}^2 is the average relative macro-humidity of the previous 2 months

RH_{MICRO}^2 is the average micro relative humidity of the previous 2 months

Forecasting disease incidence is very important for the management of the disease. Out of the models studied (same month, previous 1, 2, 3, 4, 5 and 6 months), the one using both macro- and micro-humidities of previous month and another using the same variable of previous two months gave the forecast equation with high R² at Mandapam and Josegiri. The difference between the forecasted and actual disease-incidence has been insignificant.

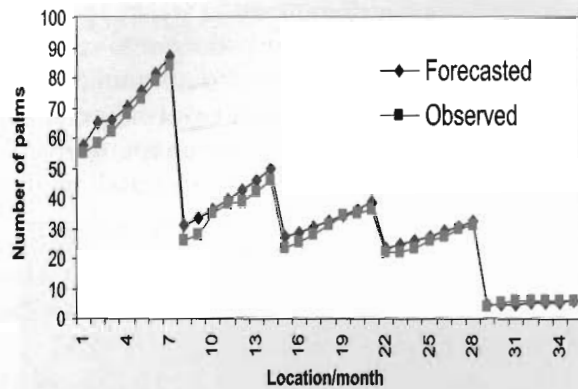


Fig 10.2: Forecasted and observed bud-rot incidence in terms of number of palms with disease at two locations in different months.

This is the first time a forecasting equation was developed for forecasting bud-rot disease in Kerala. This would help the farmers to take prophylactic measures before the disease outbreak and thereby save the palms from the lethal disease. Forecasting systems based on weather parameters well in advance can result in reducing crop loss, and adopting control measures at a reasonable time to avoid the recurrence of disease epidemics.

Advice to farmers

- Upon forecast of occurrence of the disease take prophylactic measures as suggested earlier in Chapter 8 for bud-rot.
- In forecasted areas avoid water-logging.

Forecasting fruit-rot disease of arecanut

Arecanut fruits are infected by *Phytophthora arecae* in high rain fall areas and cause fruit-rot commonly known as 'Koleroga' or 'Mahali'. Upon infection, the fungus grows as a white mat and produces sporangia which serve as inoculum for creating an epidemic. The tress will have five to six bunches at a time in various stages of development thus making it difficult to monitor the infected fruits at periodic intervals. Hence the fallen fruits in every day were used to score the tree for fungal infection level and to monitor the disease. Apart from this, the total number of fruits that have fallen is also counted. The epidemic growth was plotted on the X/1-X

transformed values to make the disease growth linear. Daily average temperature was made taking the incubation period of the pathogen to cause the disease as four days. Hence, four days running mean was calculated during the entire epidemic period for weather parameters such as maximum, minimum ambient temperature, amount of rainfall in mm, relative humidity and sunshine.

Multiple regression analysis was done and there was a linear relationship between the number of trees that had taken *P. arecae* infection and the total number of fruits that had dropped. A simple regression analysis done shows a very good fit ($r = 0.81$) between the two parameters. Hence, disease prevalence can be used as a parameter to arrive at the number of fruits that fall per hundred trees. When data of both the years were combined and MRA was run, these three variables still continued to be the most important ones, but the R and R^2 values were 0.81 and 0.65 respectively. The linear model given below that accounts for 81 per cent of the variation and will predict levels of disease severity in 65% of the cases attempted with a reliable level of accuracy is:-

$$Y = 131.45 + 1.53 X_1 + 23.9X_2 - 7183X_3$$

Where Y = Diseased palms forecasted to be infected 4 days in advance.

X_1 = disease prevalence 4 days ago

X_2 = four days running temperature

X_3 = four days running mean relative humidity

The relative humidity had a negative effect on disease growth. During epidemic phase relative humidity is above 95 per cent and when it increases beyond 98 per cent, spore production and release gets affected. The utility of the model can be enhanced through field tests so that this can be used for timing spray operations.

Advice to farmers

- Since inoculum load is one of the major factors contributing to repeated disease outbreaks, measures should be taken to reduce the inoculum load for controlling the disease, as suggested in Chapter 8.



Visuals on Some of the Technologies Adopted by Farmers



Plate 1. Seedling planted in pit and moisture conservation by placing husks.



Plate 2: Timely basin management.



Plate 3: High density multi-species cropping system in coconut gardens.



Plate 4: Inter cropping of arecanut and cocoa.



Plate 5: Intercropping of vegetables.



Plate 6: Mixed cropping of fodder grass in coconut gardens.

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Plate 7: Bunds formation in sloppy areas and planting across the slope.



Plate 8: Water-harvesting pond.



Plate 9: Basin mulching for soil moisture conservation.



Plate 10: Trench in between coconut palms filled with husk and basin mulching for soil moisture conservation.



Plate 11: Irrigation with basin mulching.



Plate 12: Vermicomposting of coconut leaves.

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Plate 13: Vermicompost ready to use for field application.



Plate 14: Pheromone trap being installed for pest control.



Plate 15: Integrated pest management being adopted in arecanut.



Plate 16: Covering inflorescence for disease control.



Plate 17: Drying of arecanuts.

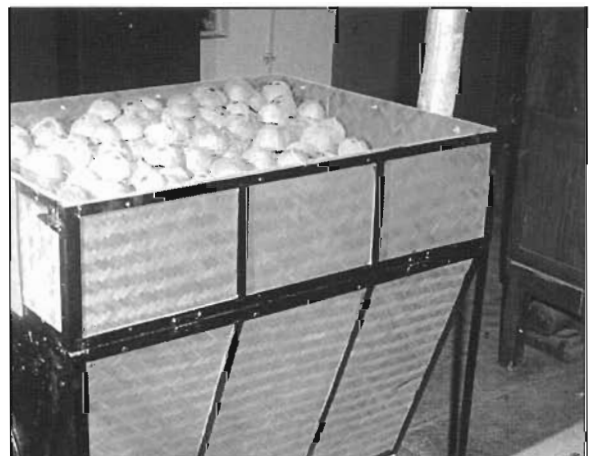


Plate 18: Use of copra dryer.

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