AGROCLIMATIC FACTORS AND COCOA PRODUCTION

Prepared by

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(CAgM Rapporteur on Agroclimatic Factors and Cocoa Production)
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# TABLE OF CONTENTS

**SUMMARY** .......................................................................................................................... VIII

**CHAPTER 1**

INTRODUCTION ....................................................................................................................... 1
1.1 Geographical Distribution ................................................................................................. 1
1.2 Biology of Cocoa Plant ..................................................................................................... 1
1.3 Genotype ............................................................................................................................ 5

**CHAPTER 2**

SEASONAL CLIMATIC PATTERN ............................................................................................... 7
2.1 Rainfall ............................................................................................................................... 7
2.2 Temperature ....................................................................................................................... 7
2.3 Sunshine ............................................................................................................................. 8
2.4 Wind ................................................................................................................................... 8

**CHAPTER 3**

ENVIRONMENTAL FACTORS AND COCOA PRODUCTION (YIELD) ......................................... 9
3.1 Soils ................................................................................................................................... 9

**CHAPTER 4**

CLIMATIC ASPECT OF LEAF PRODUCTION, GROWTH (FLUSHING) AND ABSCISSION ................ 11
4.1 Flowering .......................................................................................................................... 13
4.2 Pod set and Development ................................................................................................. 14

**CHAPTER 5**

CULTURAL PRACTICES .......................................................................................................... 17

**CHAPTER 6**

PESTS AND DISEASES ........................................................................................................... 19
6.1 Pests .................................................................................................................................. 20
6.2 Diseases ............................................................................................................................. 20
6.3 Control Measures .............................................................................................................. 20
6.3.1 Pests ............................................................................................................................. 20
6.3.2 Diseases ........................................................................................................................ 21

**CHAPTER 7**

STRUCTURE AND FUNCTIONING PROCESS ........................................................................... 23

**CHAPTER 8**

CONCLUSION AND RECOMMENDATION ................................................................................. 25

**CHAPTER 9**

REFERENCES ............................................................................................................................ 27
SUMMARY

The first chapter deals with a general description of climate and soil-types in typical cocoa growing countries. Rainfall distribution pattern is bimordial, in that, there are two distinct rainy periods. The first, which is the maximum rainy period starts from March to July, while the second and minimum rainy period commences from September to November each year. The dry-season, is from November to February, though in West-Africa, the onset of rains is highly variable while the end of rains can be abrupt and difficult to predict. A dry season of more than three months may not support cocoa production unless irrigation is practised.

Chapter 2 presents an analysis of temperature, sunshine and relative humidity in the region. It shows that an average annual rainfall varying between 1100mm and 2500mm and temperature ranging between a maximum of 30° and 32° and a minimum of 18° and 21° are optimum for the cultivation of cocoa crops. High levels of air and soil-moisture are required by many tropical plants, adapted to humid environments such as cocoa crop. The importance of cocoa crop as the mainstay of economy in many developing countries is highlighted, and because of this, research institutes have been established with the main purpose to improve the yield and qualities of the crop. The research workers have become aware of the role of weather and climate in cocoa production.

Chapter 3 and 4 discuss cultural practices of cocoa production. Cocoa is a shade loving and short-day plant. Its response to photoperiod is discussed with examples. In short-day plant, flowering and maturity (phenological stage) are stimulated by short-days. The same chapter describes briefly the phenological stages of the crop, and the techniques for selecting hybrids, based on the agroclimatic requirements using rainfall, sunshine, temperature and relative humidity.

Chapter 7 describes the main pests and diseases affecting the crops as well as the effect of meteorological aspect of crop protection.

The last chapter is on conclusion and recommendation. It summarizes the results of the study and recommends that research be continued in order to fully understand the biological response of cocoa plant to meteorological factors.
CHAPTER 1
INTRODUCTION

Cocoa (Theobroma cacao L) is a plant of tropical rainforest, where it is part of the lower or "C" tree storey (Richards, 1952). It grows in a more or less continuous stratum of trees of many other species, all of similar height, beneath the shade of an irregular canopy composed of the combined higher strata. It shows characteristics of other species of the stratum (Richards, 1952). Thus the trees have for a long time been accustomed to a relatively unchanging environment in which the upper storey vegetation and the vegetation beneath buffers them from the effect of climatic extremes. The rainforest tends, in general to have greater uniformity of rainfall and temperature than other plant communities (Richards, 1952). There may be diminution of seasonal variations of both rainfall and temperature and are higher in comparison with temperate climate. In these respects, cultivated cocoa must be very close microclimatically to the tropical rainforest.

However, the pattern of cocoa production has changed considerably over the past six decades with an increase in area of cultivation and in yield. New hybrids are being grown and cocoa is often grown without or with reduced shade, a departure from the original habitat. Failure to provide the necessary rainforest shade or canopy, where it is grown on clear-felled land even with subsequent emergence of shade trees, leads to water stress which gives rise to drought induced dieback; exposes the soil to destructive insolation and the direct effects of rainfall (Murray, 1964), encourages certain pathogens (Crowdy, 1947), and insect pests (Williams, 1953; Johnson, 1962). This paper reviews the climatic requirements of the cocoa tree and factors controlling growth and yield.

1.1 Geographical Distribution

Ecologically, all varieties of cocoa appear to be trees of lowland tropical forest (Cuatrecasas, 1964). The limits of cultivation are about 20°N and 20°S with the bulk of the crop within 10° of the equator (Fig. 1). Within these limits, most of the principal cocoa producing areas are at low elevation, usually below 300m (1,000 feet). Cocoa grows best in well aerated, moisture-retaining soil which is slightly acidic to neutral (pH 6.0 to 7.2) with a good organic layer. Rainfall as low as 1100 to 1250mm will support cocoa provided it is evenly distributed throughout the year (Murray, 1964).

The climates of different cocoa countries may differ from each other but the general pattern may be the same. The climatic requirements for cocoa production in Ghana is given as a typical example in Figure 2. Unfortunately, when the questionnaire was circulated no replies were received from any of the cocoa growing countries. Table 1 shows the major producing countries and their respective production.

1.2 Biology of Cocoa Plant

Theobroma cacao is, as stated earlier, a plant of the tropical rainforest, forming part of the lower or "C" tree storey where conditions are warm, humid and shady (Richards, 1952). It is indigenous to the forests of Central and South America and wild species occur in the Upper Amazon basin. Information on the worldwide history, agronomy and economy of the crop has been reviewed at length by Urquhard (1955) and Purseglove (1968). The origin of the cocoa tree as an under-storey species in a forest is probably responsible to some extent for the traditional method of growing it under the shade of larger trees.
FIG. 1 The Limit of Cocoa Cultivation
Total for year: 1.914h  Average for: 33 years

Total for year: 1.599mm  38 years

Fig. 2  Seasonal pattern of Ghana, Tafo
Total for year: 1.918h  Average for: 6 years

Total for year: 1.634mm  30 years

Fig. 3  Seasonal pattern of Nigeria, Ondo
Cocoa is a small tree attaining a height of about 10 metres. The seedling forms a straight main stem, 1-2 metres tall and then forks into 3-5 branches, "fans" or "jorquette". Further increase in height is by a sucker or "chupon" which arises later below the jorquette and grows vertically. The leaves, when mature, are dark green in colour and thin but firm in texture; the young are light green or of various shades of red and very soft. Cocoa grows intermittently and during the year there may be two main periods of leaf flush i.e. formation of new leaves (February and March, and August and September) and three or four minor ones, each lasting about eight weeks (Greenwood and Posnette, 1950; McKelvie, 1962; and Asomaning et al., 1971). Flowers and fruits are produced in place of leaf axils on the older parts of the stem and branches. There are two main flowering periods in a year, February (minor crop) and June-July (major crop) (Asomaning et al., 1971). Pods ripen 5-6 months after pollination and the very small pods (up to 2-3 months old and about 80mm (3.15 inches long) are called "cherelles". The size and shape of mature pods differ in different varieties and selections. The husk or "pericarp" consists of three layers: an outer thick parenchymatous layer, the "epicarp"; a thin woody zone, the "mesocarp" or "sclerotic layer", and an inner region, the "endocarp". Each pod contains 20-50 seeds enclosed in a sugary pulp.

1.3 Genotype

The type of cocoa grown is of prime importance in yield potential. The 3 main types of cocoa are the Criollo, Foresterio and Trinitario out of which hybrids have been bred. It is important that a hybrid distributed to farmers should combine high yielding characteristics with good bean size and quality, pod values, precocity, vigour, pests and disease resistance, and be easy to establish and to withstand adverse condition.

Studies have been conducted on the early growth of cocoa genotypes in relation to light in Ghana. A wide variation in the ability of certain seedling progenies to grow under full sunlight has been found. Most of the tested progenies grow poorly under full sunlight as very low rates of leaf expansion and high rates of leaf abscission led to low leaf area, photosynthesis and growth. The most sensitive progeny was Amelonado which became moribund or died on exposure to light of 70% or more daylight.

Nonetheless, there were others which could tolerate the high exposure to light. Predominantly among them were Scavina (as one of the parents) and some of the Nanays. As indicated above, this is one of the characteristics in selecting progenies to replant in exposed or denuded areas.
CHAPTER 2
SEASONAL CLIMATIC PATTERN

Seasonal climatic pattern for Ghana which is a typical cocoa growing area is given in figure 2. There are two main rainy seasons, March-July and September-mid November which are separated by a short dry weather in August. The dry season begins in mid-November to mid-February, lasting about 3 months. Similar season pattern occurs in Nigeria (Fig. 3).

2.1 Rainfall

Rainfall seems to be an important factor for the production of cocoa. As indicated earlier, rainfall as low as 1100 to 1250mm would support cocoa but majority of the cocoa growing countries have annual rainfall which lies between 1100 to 2500mm. The main cocoa growing countries of West Africa have rainfall between 1150 and 1800mm with the exception of Cameroon which has an annual rainfall of 2500 to 3000mm.

The annual rainfall in Ghana ranges between 1100 and 1800mm and in the marginal areas, it lies between 1100 and 1250mm.

The distribution is more important than the annual rainfall. As indicated, areas with dry seasons more than 3 months may not support cocoa unless irrigation is practised.

In Ghana, most of the rains fall between March and July with a short dull dry weather in August. A second rainfall peak occurs in September to mid-November after which the dry season begins; the dry season is never rainless but the average precipitation is about 250mm for the 3 month period.

High rainfall may result in heavy leaching of soil nutrients and under this condition, acidic soils which are poorer in exchangeable bases occur. Thus, most areas with high rainfall above 2500mm tend to have poorer acid soils as found in Malaysia. In areas where the soils were developed from alluvial soils, as found in the Eastern Cameroon, these soils will support cocoa as the fertility is replenished. Higher rainfall may also lead to other problems such as fungal diseases, particularly blackpod disease due to humid conditions as found in the Cameroon and the vascular dieback disease in Papua-New Guinea. The distribution of rainfall also affects flushing, flowering and pod setting of cocoa as well as the incidence of pests.

2.2 Temperature

Cocoa cultivation is limited to about 20°N and 20°S of the equator, and within these limits, the temperature lies between a maximum of 30° to 32°C and a minimum of 18° to 21°C. The lower limits will define the most northerly and southerly limits of cocoa growing and may also depend on the latitude.

Temperature seems to have an effect on vegetative growth, fruit development and to a lesser extent on flowering intensity.

Temperature has been found to affect both chemical and physical properties of cocoa butter. Relatively low temperatures during early fruit developmental stages result in a high proportion of unsaturated fatty acids and their accompanying low melting point of cocoa butter.
2.3 Sunshine

The amount of sunlight falling on cocoa has been shown to affect growth and yield through shade experiment. As a tropical crop, cocoa has been found to increase yield when exposed to certain hours of incident light energy. On the other hand, exposure by shade removal may result in heavy insect damage.

2.4 Wind

Severe wind storms normally do not occur in the cocoa growing countries. Cocoa, however, will recover from damages caused by severe wind by producing chupons. In areas where there are strong winds, such as in Malaysia and West Indies, wind breaks are at times planted to protect the cocoa.

In West Africa, where the dry harmattan wind blows from the Sahara desert, the humidity drops sharply and this may affect the growth of the plant. Establishment of cocoa becomes difficult when the dry harmattan winds are severe and the dry season is longer than 3 months.
CHAPTER 3
ENVIRONMENTAL FACTORS AND COCOA PRODUCTION (YIELD)

The purpose of this contribution is to present a general outline of the effects of agroclimatic factors on cocoa, showing the effect on the main physiological processes and conditions which control yield.

Yield is determined by the structure and function of the tree, which in turn vary with the growing conditions such as climate and management and also with the genotype. This is illustrated by the chart below:

![Chart Illustrating Environmental Factors and Cocoa Yield]

The yielding capacity of cocoa depends on the rate of dry matter production and on the way in which the tree partitions the assimilates between vegetative and reproductive growth - specifically the proportion used in producing beans. A higher rate of photosynthetic production is necessary for good establishment and early bearing and leads to a high yielding potential. Many climatic, environmental and agronomic variables such as shade intensity, soil fertility, water availability, radiation, temperature, etc. which affect yield do so largely by affecting photosynthesis.

The climate thus affects production (photosynthesis) and partition of dry matter by the tree.

3.1 Soils

As indicated earlier, cocoa grows best in a well aerated, moisture-retaining soil, which is slightly acidic to neutral (pH 6.0 to 7.2) with good organic matter. The best cocoa soils are aggregated clay or loamy sand. Very heavy soils impede root penetration while sandy soils have low moisture holding capacity, thus unabling cocoa to withstand dry seasons.

Soil fertility differs from place to place but cocoa does not tolerate low soil fertility. Areas with low soil fertility can be improved by fertilizers.
CHAPTER 4

CLIMATIC ASPECT OF LEAVE PRODUCTION, GROWTH (FLUSHING) AND ABSCISSION

Cocoa under the climatic condition of Ghana assumes two phases of active leaf growth during the year - one following the rains which ends during the dry season (February-March); the other during the sunny weather and ends in October.

The major flush is stimulated by the release from moisture stress usually at the transition period from dry-season to rainy season. If there is a long drought period, there is no flushing but when the rains start, a very long flush develops.

Flushing is basically an endogenous rhythm but temperature, radiation and water stress also affect the periodicity of flushing. Some flushes are the result of climatic factors such as rain and a drop in temperature after drought, a rise in temperature after a cool dull spell. There is available evidence which suggests that a rise in temperature and radiation after the cool dull season from June to September in Ghana appears to cause flushing on mature cocoa. (See Fig. 4).

It has also been shown that flushing intensities during the cool periods were lower than during the warm periods. Thus unshaded cocoa flushes more than shaded cocoa and that the enhanced flushing in unshaded plots is a direct effect of radiation (Fig. 5). Field records show that temperatures in unshaded cocoa canopies are higher than those on shaded cocoa.

Flushing intensity is low when the rainfall occurs during period of relatively low temperatures. There is the effect of a low moisture content on the availability and uptake of minerals. In fact, the effect of soil moisture shortage on vegetative growth, pod development and inhibition of flowering may partly be due to the result of decreased nutrient uptake. Thus soil moisture is an important factor in flushing behaviour.

Some authors could not find any correlation between flushing and soil moisture and suggested that the critical temperature for the bud burst and flushing by cocoa is 28.3°C. Others, however, later demonstrated flushing in young plants at 23.2°C and 22.8°C in constant temperature growth chambers. The two observations could not be compared as one dealt with mature trees under field conditions and the other, young plant in controlled environment. Results from studies in Ghana clearly demonstrated that plants in 31.1°C and 30°C growth rooms flushed more vigorously than those at 23.3°C and 22.8°C. There is no evidence to show that temperature determines the onset of flushing, although at periods of high temperature (28.3°C) and enough rainfall, flushing is regular at 6-8 weeks interval.

Recently, studies have shown that flushing occurred in the dry season in mature cocoa grown in the field well before the onset of the rains (See Fig. 6). Most of the flushing was observed in the drier months while during the main wet season months when conditions of water supply and moisture were most stable, little or no flushing occurred. They also confirmed previous reports that cocoa seedlings showed no marked periodicity in their flushing and tended to flush vigorously throughout the year provided they were exposed to radiation. Thus, early and frequent flushing was associated with no shade condition but not with the moisture status as indicated earlier.
Fig. 5  The flushing pattern in young cocoa (Ghana)
Sugars have been suggested to be involved in the stimulation of flushing in cocoa and there is a correlation between the amount of free indole-3-acetic acid (IAA) in the cocoa shoot tips and the onset of flushing, meaning, auxins are involved in controlling flushing. There is a close link between sunlight, free sugar levels, free IAA levels and flushing with the sugars activating or inducing bound IAA - hydrolysing enzymes as well as supplying energy and building blocks for growth. It was further explained that at the time of maximum growth, consumption of carbohydrate by the developing flush exceeds that available from current photosynthesis. During inter flush, the depleted carbohydrate store will be replenished and with the return to positive carbohydrate balance, a further flush of leaf growth can take place. Thus, for seedlings in constant environments, carbohydrate availability controls flush and it is a major factor for mature trees in the field.

Results from these recent studies also indicate that of all the factors commonly believed to affect flushing, only sunshine hours and free sugar levels have been shown to exhibit a positive correlation with flushing in field growing cocoa. (See Fig. 6)

It has been suggested that drought and other factors that stimulate flushing induce leaf fall. In Ghana, as leaf fall precedes flushing during the dry season, it may be assumed that leaf fall is a factor controlling flushing. The effect of defoliation, however, has been found to be transient with the trees quickly returning to flushing cycle synchronous with that of other cocoa trees. Thus early and frequent flushing was associated with no shade condition but not with the moisture status as indicated earlier.

4.1 Flowering

Flowering of cocoa in Ghana has a wide variation, depending upon the variety or progeny being grown but in all, the seasonal pattern seems to be similar. Several years data recorded in Ghana on both Amelonado and Upper Amazon cocoa have shown that Amelonado trees are normally out of flower from August till the end of the year while hybrid selections, such as T85/799 and T63/967 flower continuously throughout the year, but the peak periods are the same for both Amelonado and the hybrid.

Mature cocoa trees have the large proportion of flowers being produced in March-July period and a smaller number in the November period depending on the rainfall pattern. This is the “normal” flowering and appears to be related to nutrient uptake and photosynthesis. The other type, “Crazy” flowering is an immediate response to the removal of an internal moisture stress following a period of drought.

The peak of the natural flowering is usually in May or June, depending on the rainfall pattern at the end of the dry season. Early rains normally lead to an early and possible long flowering period while a long dry season leads to a late crop and a short late flowering pattern. The dull cool weather in July-August seems to be associated with decrease in flowering although competition from pods may contribute partly to the decreased flowering. This shows that flowering from July onwards becomes increasingly inhibited directly or indirectly by a less favourable weather condition, i.e. cool, dry, dull weather.

It, therefore, seems that the rhythm and intensity of flowering were closely linked to vegetative activity which is also dependent on the rainfall and the seasonal distribution of solar radiation. There is a relationship between flushing and major flower production and seems that normal flowering is associated with assimilate availability.
4.2 Pod set and Development

Pod set and pod development are more influenced by endogenous factors than by the climate. There is no seasonal pattern per se apart from the one due to or which can be derived from patterns of flushing. It may be assumed that if climatic conditions favour flowering, then pod set and development would be maximal. There is indication of a correlation between rainfall or any other climatic factors and actual yield. As such, it is not possible to forecast yield or the size of a crop from climatic data.

![Graph showing effect of shade on flowering of hybrid (Ghana)](image-url)

Fig. 6 Effect of shade on flowering of hybrid (Ghana)
Other authors, however, have found that seasonal variations in both rainfall and temperatures have an influence on pod setting. In Bahia, where there is no clear defined dry season, the relatively low temperatures during the months of June through August are responsible for the total lack of harvest during the period (January to March), i.e. 7 months after the cool period (mean temperatures lower than 23°C). The temperatures have an inhibition effect on cambium growth which is linked to flowering.

In regions where temperatures are higher, harvests are mainly influenced by rainfall distribution, and an interval of approximately seven months was observed between causes and effect. Variation in yield from year to year appears to be influenced by a greater extent by rainfall distribution and intensities than by any other climatic factor.

Water deficit, especially when very pronounced, reduced pod setting by its inhibitory action on flowering and can also cause loss of young pods (cherelles) through physiological wilt.

Water stress reduces crop yield below potential values through both direct and indirect effects. The high incidence of cherelle wilt and pod losses associated with water stress may be due to reduction in net photosynthesis or to inhibition of translocation of photosynthates to growing pods. Flowering and fruit set are maximal at the beginning of the wet season when the photosynthetic rate is high. Stomatal conductance decreased rapidly as leaf water potential dropped below -15bars. Further, water status was strongly related to the rate of leaf area expansion.

Water stress has profound effects on the photosynthetic performance of cocoa. As tissue relative water content begins to decline, net photosynthesis is often observed to be relatively independent of leaf water potential. But as water stress intensifies, net photosynthesis, CO₂ up-talk rate decreases, often reaching zero at high levels of stress. The threshold water potential below which photosynthetic CO₂ up-talk rate decreases, defines a range of soil and plant water contents that will likely result in large reduction in yield. Yield is therefore partially related to photosynthetic production.
CHAPTER 5

CULTURAL PRACTICES

Cocoa is now being grown without or with reduced shade, a departure from the original rainforest habitat. Numerous field trials have been undertaken in most of the cocoa growing countries which are aimed at obtaining optimum yield under suitable shade regime. The reports from these field experiments show that optimum and sustained yield is associated with reduced over-head shade but his in turn may change the other climatic factors.

The principal advantage of reduced over-head shade is to provide the optimum light intensity for optimal growth and yield. Adverse effects of reduced shade include rapid loss of soil fertility, increased wind velocity, excessive evapotranspiration leading to soil moisture depletion which causes water and nutrient stress with its attendant tree susceptibility to insect pests and diseases.

On the other hand, shade is essential at the initial stage of establishing cocoa. Temporal and permanent shade trees are grown, at least, one year before the cocoa is planted out into the field. In West Africa, the forest is cleared or thinned out but a number of the forest trees are left to provide the initial shade. In other cocoa growing countries, the forest is clear felled and temporal/permanent shade is planted. The most common plants used as temporal shade trees in Ghana are plantain, cocoyam, cassava and banana, which grow very fast and provide food as well. Permanent shade trees include *Glicidia, Terminalia* spp. and other forest trees.

The quantity of light is very important as shade would result in plants with long internodes and few branches while no shade results in poor slow growth due to low rates of leaf expansion with high rate of abscission leading to low leaf area, poor photosynthesis due to chlorophyll destruction and growth. Cocoa, being a shade plant, is unable to fully utilize high light intensities for photosynthesis. Light intensities above those which can be safely utilized by the plant result in photo-inhibition of photosynthesis and photo-oxidation of photosynthetic pigments which will lead to eventual leaf death. Seedlings in light of 70% daylight or more lose their leaves and become moribund or die. It is possible that the optimum light values may change with periods of adaption and vary with different progenies, but shade management will continue to play a major role at least for young cocoa unless new light stable progenies are produced.

Cocoa requires varying degrees of shade for optimal growth at different stages of plant development. It has been shown that 80% shade was the optimal during the first three months of growth, reducing to 55% during the fourth and fifth months. Some progenies, however, have been found to tolerate exposure to high light intensities.

Field trials have demonstrated that removal of shade, with or without fertilizer will result in yield increases but this increase is more pronounced when fertilizers are applied. It has been found that the light compensation point for photosynthesis is about six times higher for plants grown under no shade than for plants grown under shade. There was a clear relationship between the nutritional status of the tree and the light saturation point with the large flush leaves of plants with good nutrition being saturated at 300 microeinsteins m-2 sec-1 at 15% full sunlight and trees with poor nutrition and less vigour, at less than 10% full sunlight. It is concluded that the well known relationship between shade removal and fertilizer application and yield increase may be partially explained by light/nutrition interaction at the leaf photosynthesis level.

Apart from light or shading, rainfall or soil moisture is also an important component
during the establishment of cocoa. Normally, land preparation in Ghana starts during the dry season, January to February so as to plant out the nursed seedlings or the beans at stake between May and June, during the rainy season. This coincides with the period when soil moisture is maximal.

The application of irrigation water and mulch, sustained growth of cocoa seedlings during the dry season at a time when control-plants experienced minimal growth, leaf senescence, and even death. Although irrigation improved growth, the best establishment was obtained with mulch, possibly due to repeated replenishment by fresh, moist pseudo stems providing moisture and nutrients to the very uppermost layer of soil.

The application of mulch to cover mature cocoa trees has been shown to reduce the rate of soil moisture decline during drought and increase organic matter content of the soil. This could, therefore, prove beneficial to seedling establishment. There was also a positive effect of irrigation on the number of cherelles set and number of pods produced.

The potential harmful effects of a prolonged drought in Ghana and other cocoa growing countries on cocoa seedlings establishment could be successfully alleviated by irrigation and/or mulching.

Irrigation can also be used to increase yield and produce pods during the lean or dry season.
CHAPTER 6

PESTS AND DISEASES

**Pests:** The most important pests of cocoa in West and Central Africa are the capsids or mirids although the mealybugs are also of prime importance in the transmission of the cocoa swollen shoot disease. The two most important capsid species in West Africa are *Salbergella singularis* Hagl and *Distantiella theobroma* (Dist) which are plant sucking insects. Capsid damage is more severe on shaded than on unshaded cocoa where the damage is greater. “Capsid pockets” are typical of cocoa grown under dense shade where there is an increase in chupon growth which provides breeding and feeding sites for the capsids. On the other hand, stag-headed damage is more prevalent when shade is sparse or absent due to greater production of fans, which when dead, give rise to stag-headed appearance.

Thus, breaks in canopy, particularly in shaded cocoa, lead to chupon growth and formation of pockets. In unshaded cocoa, the damage is more frequent but less severe, that is, capsid distribution in shaded cocoa is highly aggregated and less aggregated in unshaded cocoa. It is clear from the above that light affects food abundance or availability.

The significance of over-head shade on cocoa has been discussed in connection with yield and flowering. The removal of shade, however, can easily reverse the results expected as certain pests may become serious later. It was found that defoliation and loss of terminal buds occurred within two months of removing shade from Amazon cocoa. The damage was attributed to *Earias biplaga* and *Mesobatoma tessmani*. A break in the canopy has been said to lead to “capsid pocket” formation.

On the other hand, some cocoa pests such as *Bathycoelia thalassina* have been found to be associated with shaded cocoa. It was observed that moderate temperatures (25° - 30°C) coupled with a mean monthly rainfall less than 130mm might cause an increase in the population of *B. Thalassina* in the field. Conversely, high rainfall plus high (35°C+) or lower (20°C-) temperature might result in a decrease in the population of the pest. Other pests, such as aphids, *Toxoptera aurantii* and psyllids, *Tyora tessmani* were very abundant in shaded cocoa during the first rainy season when cocoa forms young leaves.

Rainfall has also been found to affect the abundance of these pests. Heavy rainfall tend to have deleterious effect on *B. Thalassina* and mirid populations. Nonetheless, during the dry season, water stress in cocoa trees could seriously retard the development of mirid nymphs and female ovarirole development. As the cocoa plant nears wilting point, Osmotic pressure of about 15 atmospheres or more are produced on fan and chupon tissues and at this level, capsid nymphs are unable to feed and develop normally.

A relationship was found between the seasons and insect activities. These were:
(a) The dry sunny period (November to March): Period of maximum fruiting and ripening with abundant fruit and seed feeding insects.
(b) First wet sunny period (April/May): Maximum leaf production with abundance of leaf feeders and their predators.
(c) First wet dull period (June/July): Maximum litter breakdown with high numbers of litter and fungal feeders and tree but a decline in leaf feeders and their predators.
(d) Dry dull period (August): Biologically similar to (c) but decline in tree borers.
Second wet dull period (September/October): Biologically similar to (d) with a second peak in tree borers.

These observations showed that most cocoa insects occurred throughout the year but their distribution and peak occurrences were related to the climatic parameters.

6.2 Diseases

Various diseases have been found to attack the cocoa trees and have caused a reasonable loss of the crop to the farmer. Different geographical areas may have different diseases and in West Africa the most important diseases of cocoa are the “blackpod” and the “Cocoa Swollen Shoot” diseases.

The Cocoa Swollen Shoot disease is caused by a virus which has the mealybug as the vector. The blackpod or pod rot is caused by fungus of the genus *Phytophthora*, which is said to be represented in all cocoa growing areas. The level of disease incidence varies from one country to the other. The source of inoculum or infection is either from the soil or the cushion, depending on the species concerned.

In Ghana and the other West African countries, the blackpod disease appears at the start of the wet season in April but remains low until the heavy rains in July. The short dull dry spell in August-September may halt the disease incidence but rises again as a result of the heavy rains that follow. Thus, blackpod development and the isolation of the pathogen are associated with the frequent and heavy rainfalls which occur in July and October.

Studies carried out in Ghana concluded that the occurrence of the two peaks was caused by changes in rainfall, while a fall in the amount of rainfall caused a reduction in the activity of the fungus; the drop in the rate of disease development was associated with a fall in both the frequency and amount of rainfall. Blackpod disease developed best when the outside maximum temperature was between 29.4°C and the corresponding under-canopy temperature was 23.9°C to 26.7°C. The disease developed in June and then declined in September when the afternoon under-canopy relative humidity was not less than 85% and the outside humidity was not less than 75%. It appears that frequent rainfall with a fall in the maximum temperature and a corresponding rise in the relative humidity favoured development of the disease.

Nonetheless, the amount of rainfall per se would not be a reliable parameter on which a spraying schedule could be based in Ghana as correlation between disease incidence or pod production and amount of rainfall were unreliable.

6.3 Control Measures

6.3.1 Pests

Capsid control in West Africa is mainly by chemical means and in Ghana lindane and propoxur are currently being used. As indicated, canopy breaks attract capsids, resulting in the formation of “capsid pockets”. In order to avoid capsid invasion when the canopy breaks, fast growing trees such as plantain or *Gliricidia* are to be planted to close up the open canopy. The maintenance of inter-lacing canopy is a useful cultural control method.

Heavy shading gives rise to very low yield while inciting of cocoa results in increase in yield but this has been found to increase thrips and aphid damage. As such, it has been recommended that 15-18/ha permanent shade trees should be provided. In planning pest
management strategies, rainfall, temperature and shade regimes are to be taken into consideration as these are the main factors which affect the insect species attacking the cocoa tree and the extent of their damage.

Biological control has not been successful in capsid or mealybug control at present.

6.3.2 Diseases

There are no control measures for the viral disease of cocoa in West Africa yet except the unpopular removal of infected and contact cocoa trees.

In Ghana and the Cote d'Ivoire, the most predominant species of Phytophthora pod rot is caused by P. Palmivora. The more virulent type, P. Megakarya, is mostly found in Cameroon and Nigeria. It has recently been in Ghana but its occurrence as at now is sporadic.

P. Palmivora does not need any expensive chemical control measure, for cultural control measures like reducing the humidity under the cocoa farm and to allow air circulation can reduce the disease incidence considerably. This is achieved by regular reduction of shade to allow the penetration of sunlight, regular weeding and tree pruning, removal of infested pods and regular (3-weekly) harvesting. Stagnant pools of water within a farm should be drained by drenching to reduce the immediate humidity. Piles of discarded husks should be removed or sprayed as these form a source of inoculum.

Where the damage is severe, treatment with fungicide should be used to control the disease at the beginning of the rainy season. The fungicides act as prophylactic as such once the disease has appeared, the fungicide has no effect. In the case of P. Megakarya chemical control is presently the only method of control although the cultural methods mentioned above may partially reduce the incidence of the disease.
CHAPTER 7

STRUCTURE AND FUNCTIONING PROCESS

The size of the leaf canopy, usually expressed by the ratio leaf surface to ground surface or the leaf area index (LAI), the rate of photosynthesis per unit area and the partitioning of photosynthates between the fruits and other parts of the tree are the main physiological determinants of yield.

Research on young cocoa indicated that genetical differences in leaf growth rate can be associated with yield among some cocoa types.

The yielding capacity of cocoa depends on the rate of dry matter production and on the way in which the tree partitions the assimilates between vegetative and reproductive growth - specifically the proportion used in producing beans. A higher rate of photosynthetic production is necessary for good establishment and early bearing and leads to a high yielding potential. Many climatic, environmental and agronomic variables such as shade intensity, soil fertility, water availability, radiation, temperature etc. which affect yield do so largely by affecting photosynthesis. The climate thus affects production (photosynthesis) and partition of dry matter by the tree.

Cocoa has been found to have a relatively low net assimilation rate (NAR) and it has been observed that photosynthesis of cocoa increased from 7 to 22mg CO₂ dm⁻² as the light intensity was increased from 2 to 25% of full sunlight. Further increases of light intensity resulted in very little increase in the rate of photosynthesis. Further experiments showed that NAR increased from 4.5mg dm⁻² day⁻¹ to 15.2mg dm⁻² day⁻¹ when light intensity was increased from 5 to 60% of full daylight and showed no further increases at higher light intensities.

These observations show that some degree of shading appears to be beneficial for photosynthesis. Yield, however, increases in proportion to increased illumination up to a maximum light intensity as shown by shade experiments.
CHAPTER 8

CONCLUSION AND RECOMMENDATION

The discussion has shown that the most important climatic factors that control the growth and yield of the cocoa plant are rainfall, temperature and radiation (shade). These factors affect the growth and yield of cocoa through their respective effects on potential photosynthesis production of the plant and the partitioning of photosynthates. Other ecological factors that were considered include, shade, soil-moisture and fertility. The wrong exploitation of some of these factors may earn adverse effects such as increase in pest and disease infestation. These, however, can be partially reversed by the correct manipulation of microclimatic factors.

Previous chapters in this report confirm that cocoa plant is vulnerable to a large number of pests and diseases, which affect the health of the plant with consequent loss in quality and yields. Cocoa, being an important economic crop, and source of earning foreign currencies in most developing countries, there is need to maximize production with minimum resources through the establishment of an operational crop protection scheme. Agrometeorology forms an important part of the scheme by signalling the timing of spray, the most suitable weather condition for spraying in order to achieve maximum result with minimum cost.

The direct benefit of this scheme includes saving on the costs of chemical when spray applicators are reduced. Good agrometeorological advice based on historical records can also help to locate new varieties in areas where climate is unfavourable for the development of particular pests. Other indirect benefits of the scheme is the reduction in soil, air and water pollution. There is no doubt that the benefits of an Agrometeorological Service required in the operational cocoa crop protection scheme vastly outweigh the costs. It is also desirable to establish an organization structure and good communication system that permit operational interaction between agrometeorologists, entomologists, plant pathologists and environmentalists for the purposes of issuing reliable advice and warning to cocoa farmers on a timely basis.

Where in-crop data cannot be measured, or have not been as in retrospective studies of the past outbreaks, it is necessary to infer climate in the crop from the nearest weather station using a linking model. Such models involve crop temperature, windspeed, humidity, radiation and surface wetness duration. Automatic weather station may be installed close to cocoa plantation where crop observation such as phenological data, and pest and disease measurement are required. This will afford continuous monitoring of relevant weather elements to fight against pest and diseases.

The collection of phenological observations for cocoa crop or any other perennial crops should be a permanent activity in operational agrometeorology. Knowledge of crop phenology is mandatory. Procedure and techniques for phenological observation for cocoa crop and other tropical crops are contained in the manuals prepared by Todorov (1982) and Villalpando and Ruiz (1993).
CHAPTER 9

REFERENCES


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*Forecast

Source: Gill & Duffus
Cocoa Market Report, No. 343, May 1992