UNIVERSITI PUTRA MALAYSIA

THE EFFECTS OF WATER AVAILABILITY ON MATURE COCOA PLANT

IBROHEM YEEDUM

THE EFFECTS OF WATER AVAILABILITY

ON MATURE COCOA PLANT

by

Ibrohem Yeedum

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Agricultural Science in the Faculty of Agriculture, Universiti Pertanian Malaysia

April 1988

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Associate Prof. Dr Raja Muhammad Raja Harun my supervisor, for the interest and guidance throughout the duration of this study. My sincere thanks is also extended to the following persons and institutions:

The South East Asia Ministry of Education Organization - South East Asia Regional Centre for Graduate Study and Research in Agriculture (SEAMEO-SEARCA) for providing financial support.

The Faculty of Natural Resources, Prince of Songkla University (PSU) with Prof. Sujin Jinayon and Dr Prasert Chitapong (former dean and present dean, respectively) for allowing me to go on study leave.

Sime Darby Plantation Sdn. Bhd., for allowing me to conduct the field experiment at Seafield Estate and to Mr. Peter Lim of Ebor Research for his guidance in some part of the field experiment.

Finally, I dedicate this thesis to my family; father, mother and especially Sumsiyoh and Muneeroh (wife and daughter, respectively) for their encouragement, patience and understanding throughout the years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE		Page

An abstract of thesis presented to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirements for the degree of Master of Agricultural Science

THE EFFECTS OF WATER AVAILABILITY

ON MATURE COCOA PLANT

by

Ibrohem Yeedum

April 1988

Supervisor : Assoc. Prof. Dr Raja Muhammad Raja Harun

Faculty : Agriculture

In Malaysia cocoa is usually grown in areas where prolonged drought is absent in Malaysia. In order to increase cocoa acreages, it may be necessary to extend cocoa planting to the northern areas of the Peninsular Malaysia where prolonged dry period occurs for several months in a year. A study is therefore carried out to observe the effects of reduced water availability on growth and productivity of mature cocoa.

The results of the experiments showed that flowering in cocoa is not dependent on soil water availability. Mild water stress at 75 to 80 percent of available soil water for one month, reduced leaf water potential, but not the yield of mature cocoa.

When the mild water stress was prolonged to two months, the effect was similar to that exposed to 30 to 70 percent of available soil water for shorter periods. Yields were reduced through an increase in percentage cherelle wilt which comes about from reduced photosynthate production. Water stressed condition results in highly negative leaf water potential which brings about stomatal closure and reduced photosynthesis.

It can therefore be concluded that under conditions of reduced water availability, irrigation is necessary to maintain sufficient water supply to maintain plant growth and productivity of the cocoa plant at the optimum level. Irrigation however has to be managed to prevent over supply of water which also is deleterious to plant growth and productivity.

Abstrak tesis yang di kemukakan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi sebahagian daripada syarat-syarat untuk mendapatkan ijazah Master Sains Pertanian.

KESAN PARAS AIR TERHADAP

TANAMAN KOKO MATANG

Oleh

Ibrohem Yeedum

April 1988

Peyelia : Prof. Madya Dr. Raja Muhammad Raja Harun

Fakulti : Pertanian

Koko ialah satu jenis tanaman tanah rendah yang ditanam di kawasan tidak mengalami kemarau di Malaysia. Untuk meningkatkan luas kawasan pengeluarannya, koko mungkin perlu ditanam di kawasan utara Semananjung Malaysia yang mengalami musim kemarau selama beberapa bulan pada tiap-tiap tahun. Satu kajian untuk menentukan kesan keadaan kemarau keatas tumbesaran dan pengeluaran koko telah dijalankan.

Kajian ini menunjukkan bahawa pembungaan tidak dipengaruhi oleh keadaan tahap kelembapan tanah. Kekurangan tahap kelembapan tanah ke paras 70-80 % memberi kesan kepada kandungan air dalam daun, tetapi tidak mempengaruhi hasil koko, dibandingkan dengan rawatan kawalan. Apabila keadaan kekurangan lembapan sederhana diteruskan selama dua bulan, kesan yang terdapat adalah sama

seperti kesan kekurangan lembapan ke tahap 30-40 % dalam masa yang singkat/pendek. Kekurangan hasil disebabkan oleh peningkatan peratus " cherelle" layu akibat daripada kekurangan daya pengeluaran fotosintate. Kekurangan lembapan juga menurunkan potensi air dalam daun kepada tahap yang rendah. Keadaan ini menyebabkan penutupan stomata dan menghadkan pengeluaran fotosintate.

Sebagai rumusan, pengairan adalah mustahak bagi keadaan yang berkurangan air supaya bekalan air mencukupi untuk menampung tumbesaran dan daya pengeluaran ke paras optima. Pengairan mestilah diurus supaya tidak berlebihan kerana ini boleh menjejaskan daya pengeluaran tanaman koko.

CHAPTER I

INTRODUCTION

Water availability which is related to soil properties, is commonly considered as one of the most important factors in controlling plant growth and yield. Either too little water or too much water causes a water stressed condition which is a serious problem that limits plant development and yield. Generally, when assessing the suitability of a region for growing a given crop, special attention is always given to its rainfall pattern.

The effect of water stress on perennial crops such as rubber, oil palm and coconut is influenced by climatic factors such as the intensity and duration of dry seasons. Compared to other tree crops the cocoa plant appears to be more sensitive to changes in the environment, particularly water availability. Alvim (1978) asserts that when rainfall exceeds 2,500 to 3,000 mm/year, cocoa yield will be reduced due to water-logged soil for part of the year and incidence of black pod disease caused by *Phytopthora palmivora*. In places where rainfall is less than 1,200 mm/year, cocoa can be grown successfully if proper irrigation facility is provided. Alvim (1981) further added that yield variability from year to year is more affected by rainfall distribution than by any other climatic factors. Nieuwolt et al (1982) also suggests that the suitable area for cocoa growing should have a dry season not more than one month in a year.

Growth and development of cocoa in relation to water availability has been studied by many researchers, such as Alvim and Alvim (1975); Hutcheon (1975); Sale (1970); Boyer (1973, 1974) and Jadin et al (1976). These studies mainly emphasized on growth and development of the cocoa plant in relation to the agroclimatic factors, particularly the rainfall patterns. Only few studies have, however, reported on the relationship of soil water availability to yield patterns and factors such as flowering, pod development and cherelles wilt (Hutcheon et al, 1973; Jadin et al, 1978 and Lim et al,1986). The optimum soil water availability for each yield pattern has not been fully determined. Alvim and Alvim (1978) put the necessity of such information in the following way:

> "It is necessary to recognise that more experimental information is needed to demonstrate the hydro-periodicity hypothesis and therefore to define the most suitable water regimes for cocoa growth and yield. The absence of clear cut evidence still prevails, primarily due to the difficulties found in applying different water regimes to mature cocoa plants. Juvenile plants cannot be used because they flush at a more or less fixed interval of approximately two months and usually do not show any synchronism among themselves with regard to their growth periodicity"

In Malaysia, a similar view was expressed by Neiuwolt (1982) who noted that relatively little local research has been carried out on the optimum water requirement for cocoa and most information regarding to the climatic needs for cocoa are obtained from abroad, especially South America and Africa. Certainly those information can be used as a guide but may not be directly relevant to the conditions in Malaysia.

The distribution of cocoa plantation areas in Malaysia is shown in Table 1. As was also pointed out by Nieuwolt (1982) the limited acreage of cocoa in Kedah/Perlis, Penang and Kelantan is attributed to the discouraging yield caused by the long dry periods in these states. In some parts of Terengganu good yield is limited not only by a long dry period but also by flash-floods and serious wind damage during northeast monsoon season.

Clearly from these observations it can be seen that water availability plays an important role in production. The extent of this role in relation to plant development, flowering and production under the local conditions need to be quantified and understood.

TABLE 1

TOTAL PLANTED AREA BY STATE
AS AT 31ST DECEMBER, 1985

State	Area (ha)
Johore	11,816
Kedah/Perlis	804
Kelantan	308
Negri Sembilan	990
Pahang	13,372
Penang	304
Perak	27,059
Sabah	135,114
Sarawak	15,670
Selangor	23,394
Terengganu	1,620
Total	232,149

from: Malaysia Agricultural Directory and Index, 1986

With the above in mind this project was initiated using mature plants with the following objectives:

1. To study the physiological responses and adaptibility of mature cocoa trees to different levels of water availability under the field conditions.

2. To study the yield patterns of cocoa as affected by the different levels of water availability.

3. To study the effects of the length of dry period on flowering and subsequent yield in cocoa.

CHAPTER II

REVIEW OF LITERATURE

THE IMPORTANCE OF WATER IN PLANT

Water is the main constituent of plant tissues, making about 50 percent of fresh weight of woody plants and as high as 80 to 90 percent of fresh weight of herbaceous plants (Kramer, 1983). It is an important component of protoplasm where plant chemical reactions take place. As most of the plant chemical reactions are related to water, water is therefore necessary for plant growth and development. The importance of water in plants can be summarized by listing its important functions under four general headings (Kramer, 1983):

Constituent

Water is an important constitutuent of plant tissues playing as important a role as that of the protein and lipid molecules. The reduction of water content below some critical level will be accompanied by changes in cell structure and ultimately death of the plant tissue.

Solvent

Water is known to be a good solvent for gases, minerals and other solutes. Because of this property, mineral ions contained in the soil solution can be taken up by the plant roots. Gardner (1985) describes that the primary process of mineral translocation from the soil to plant is by the mass flow by water.

Reactant

Water is the reactant or substrate in many important processes including photosynthesis and hydrolytic processe such as the amylase mediated hydrolysis of starch to sugar in germinating seed.

Maintenance of Turgidity

Turgor is an important factor in the opening of stomata and movement of leaves, flower petals and various specialized plant structures. Turgidity is essential for cell enlargement in order to increase cell size for cell division.

The water relations of plants is dominated by cell water relations because most of the water occurs in cell, chiefly in the vacuoles. Thus the best measure of the energy status in plants is the water potential (Ψ). Water potential (Ψ) is defined as a free energy of water and Ψ of any system is the amount by which chemical potential is reduced compared to that of pure water (Kramer, 1983). Generally, the water potential value is the result of solute potential, pressure potential, matric potential of that system.

Any condition that affects plant water status leads directly to changes in the plant which alters the physiological environment of the crops, and these changes may subsequently affect the physiology of the crop which is reviewed in the following sections.

SOIL WATER AVAILABILITY

The main source of water for plants is soil water. Water from rainfall or precipitation is collected by the soil, stored and released to the plant for its growth and development. Water that can be taken up by plant from the soil is defined as "available water" of the soil. Generally, the available water range is the soil water content between field capacity (FC) and permanent wilting point (PWP) or between -0.33 and -15 bar[1] in terms of soil suction. Soil water content exceeding FC and below PWP is defined as an unavailable water.

Soil water available range is determined by the texture and structure of the soil. Clay soils have small pores and a lot of pore volume while sandy soils contain large pores but small pore volume. Thus, clay soils have higher water holding capacity

---

[1] 10 bar = 1MPa

than that of sandy soils. In other words, clay soils have a wider water available range than sandy soils.

When the soil is at FC, all of its pores are full of water, and is supposed to be at the maximum water holding capacity because the water above the FC is drained down by gravity, also known as deep percolation. Initial water uptake by the plant is water from the large pores and when these get depleted the absorption of water occurs from smaller pores. This becomes relatively more and more difficult because of the increasing surface tension and soil particle attractive forces. Thus as the soil gets drier it will get progressively difficult for the plants to extract water from the soil. At PWP the plant can no longer extract any water from soil and the plant wilts and may not recover even if water availability is resumed.

SOIL WATER BALANCE

Rainfall intercepted by the soil surface infiltrates and is distributed through the soil volume. If the rainfall is greater than the infiltration rate, water loss by surface run off will occur. Deep percolation and evapotranspiration are also the other processes of water loss from the root zone. A mathematical model of soil water balance as given by Kramer (1983) is as follows:

$$W = P - (O + U + E)$$

Where W = change in soil water storage (initial water content minus the final soil water content)

P = precipitation

O = run off

U = deep percolation beyond the root zone

E = evapotranspiration

PLANT WATER BALANCE AND SOIL-PLANT-ATMOSPHERE CONTINUUM

The main source of plant water is the water absorbed from the root zone. Water is also absorbed through lenticels and leaf scars on stems; however, such pathways are of little importance as the water absorbed through them constitutes very small portion of the total amount of water absorbed by the plant. Water absorbtion through lenticels and scars occurs only during the wetting from precipitation and/or water application (Kramer, 1983). Thus water absorbtion through leaf and stem seems to be important in mineral and pesticide studies. It is of little significance in plant-water relationship study.

In soil-plant water relation study, the water status of soil and plant are preferably explained in terms of water potential (ψ). Water will be moved from regions of high water potential to regions of low water potential, along the water potential gradient. Water is absorbed by plants from the soil as a result of water potential gradient between root and soil and is then translocated from the root epidermis to the xylem vessel and leaves. Some amount of plant-water is used to maintain the plant cell water status and bio-chemical processes, such as photosynthesis and respiration and some amount of water is lost by transpiration through the stomatal pores. Water movement from soil to plant and from plant to atmosphere can be explained in terms of "water potential gradient".

In soil-plant-atmosphere system, the Ψ is highest in soil and decreasing from root to the leaf, being minimum in the atmosphere. This potential gradient results in the transport of water from soil to plant and subsequently lost through the leaf into the atmosphere. This concept, known as "soil-plant-atmosphere continuum (SPAC)", provides a theoretical basis for a general approach to the water relation of plant-environment interactions. Kaufmann and Hall (1974) cited that under steady state conditions the flux of water through any part of continuum may be expressed as a driving force or water potential gradient divided by a resistance since the flow through each segment is equal. Mathematically, this expression can be written by Van den Honet equation as follows:

$$\text{Flux} = \frac{\Psi\text{soil} - \Psi\text{root}}{\text{r soil to root}} = \frac{\Psi\text{root} - \Psi\text{leaf}}{\text{r root to leaf}} = \frac{\text{e leaf} - \text{e air}}{\text{r leaf+r air}}$$

Where "Ψ" is water potential, "e" is vapour pressure and "r" is resistance to flow. According to this concept, it can be summarized that: