DAILY CHARACTERISATION OF AIR TEMPERATURE AND RELATIVE HUMIDITY PROFILES IN A COCOA PLANTATION[1]

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ABSTRACT – The behaviour of daily cycles of air temperature and relative humidity outside and inside a Brazilian cocoa (*Theobroma cacao* L.) plantation was studied under contrasting conditions, for one week in both the wet and dry seasons. It was found that temperature, relative humidity and rainfall are interrelated in affecting the seasonality of the microclimatic conditions inside the plantation. Rainfall was associated with rapid drops in temperature at all canopy levels immediately after a shower and a rise in relative humidity one or two hours later.

Index terms: dry season, wet season, rainfall, *Theobroma cacao*

CARACTERIZAÇÃO DO CICLO DIÁRIO DOS PERFIS DE TEMPERATURA DO AR E UMIDADE RELATIVA EM UMA PLANTAÇÃO DE CACAU

RESUMO – O comportamento sazonal do ciclo diário da temperatura do ar e da umidade relativa dentro e fora de uma plantação de cacau (*Theobroma cacao* L.) foi, durante uma semana, estudado considerando-se os efeitos causados pela presença da chuva. Foi observado que a temperatura do ar, a umidade relativa e a chuva estão interrelacionadas, afetando a sazonalidade das condições microclimáticas dentro do plantio. As chuvas se associam às quedas instantâneas da temperatura e ao aumento dos padrões de umidade uma ou duas horas mais tarde nos diferentes níveis da copa do cacaueiro.

Termos para indexação: estação seca, estação úmida, precipitação pluvial.

INTRODUCTION

To understand the interrelations between vegetation and its surroundings, it is necessary to consider how sources and sinks of heat, mass and momentum are distributed within a canopy (Elston & Monteith, 1975).

In temperate climates, information collected (Roberts et al., 1984) suggests that variations in the character of microclimate above and within a stand are small. Furthermore, the daily amplitude of temperature and humidity at the bottom of dense planted crops is generally lower than that of uncropped land because of shading (Shoubo, 1989).

On the other hand, in tropical environments, Shuttleworth et al. (1985) pointed out that in daylight conditions, that temperature and humidity of the top two-thirds of the canopy are similar to those of the surrounding atmosphere, but these properties in the air at the base of the canopy are strongly decoupled. At night the behavior is reversed and air in the lower two-thirds of the canopy is partly decoupled from that of higher levels.

In defining a suitable climate for understorey crops, such as cacao trees, it has been observed that microclimatic variables may be quite different from the standard weather data (Bonaparte & Ampofo, 1977; Gerard, 1967). Furthermore, there were also indications that the structure and dynamics of the cacao agroecosystem would exert some influence on the microclimate (Beer, 1987) and are also related to cocoa diseases (Monteith & Butler, 1979; Butler, 1980 and Rudgard & Butler, 1987).

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This paper presents results for the space and time variations of temperature and humidity above and within a cacao plantation under dry and wet conditions.

MATERIALS AND METHODS

The meteorological data were collected, at the Research Station of the Cocoa Research Centre situated in Ilhéus, Bahia, Brazil (14° 31'S, 36° 16'W and 55 masl).

The area was planted with 15-year-old cacao (*Theobroma cacao* L.) trees, growing on well drained, undulating ground, heavily shaded by *Erythrina fusca* Lour. Temperature and humidity were recorded using a scaffolding tower located at a site selected as representative of the natural vegetation and topography.

The measurements above, within and below the canopy, of temperature and humidity, were taken using "Fuess" thermohygrographs. Calibrations of all temperature and humidity sensors were checked periodically by comparison with an Assman psychrometer at 09:00 and 15:00 hours.

Records between 18:00 h and 06:00 h of the following day represent the overnight weather conditions, and those between 06:00 h and 18:00 h reflect the weather conditions for the day.

RESULTS AND DISCUSSION

Standard meteorological data recorded for the two weeks, within contrasting seasons, are summarized in Table 1. The magnitude of the meteorological parameters was less variable in the hotter week (18 to 22.02.86) than in the winter (14 to 17.07.86). The predominantly clear summer (9 daily mean sunshine hours) and cloudy winter (5 daily mean sunshine hours) regulate, to a large extent, the behaviour of microclimatic parameters above and within a cacao plantation.

Characteristic daily profiles showing variations of temperature and humidity at different heights, and rainfall, for the two different periods are presented in Figs. 1 and 2.

TABLE 1. Standard meteorological data parameters data recorded for two contrasting weeks in Itabuna (BA), Brazil.

Parameters	18 to 22.02.86		14 to 18.07.86	
	Max.	Min.	Max.	Min.
Max. Temperature (°C)	32.0	31.0	27.8	24.8
Min. Temperature (°C)	23.7	20.0	18.0	16.7
Wind Speed at 2m (m/s)	0.6	0.2	0.5	0.1
Radiation (Ly/day)	505.4	367.3	333.3	196.7
Sunshine (Hours)	11.4	7.6	9.1	0.9
Pan Evaporation (mm)	6.1	4.6	4.3	1.8

Temperature and Humidity Time - Height in the Summer

In the summer (Fig. 1), the daily pattern in temperature measured during the week of analysis reveals that temperatures outside the research site were, in the dry daylight hours, always higher than those recorded underneath the shelter trees. Furthermore, changes in one generally reflected the changes in the other, although not to the same extent.

In a cacao plantation, as well as for other understorey crops the temperature cycle in the layers responds to a vertical and temporal distribution of the fraction of the direct radiation transmitted into the different layers within the canopy. From sunrise to midday, air temperatures at different heights, may be up to 5 °C lower than those measured at the meteorological station (Fig. 1). However, in the afternoon, the variation of temperature showed clear characteristic amplitude reductions compared with the air temperature at the meteorological station. Shuttleworth et al. (1985) report in top environments, incoming solar radiation peaks before midday and then falls slightly in the afternoon in response to the increasing cloud cover. In cacao plantations, the shelter trees are also a dominant influence on incident radiation and consequently the trends in air temperature at different heights tend to be more emphatic in the morning.

At night, the temperature cycle responds to long wave radiation cooling from the bottom layers of the cacao canopy (the lower 2/3). The noc-

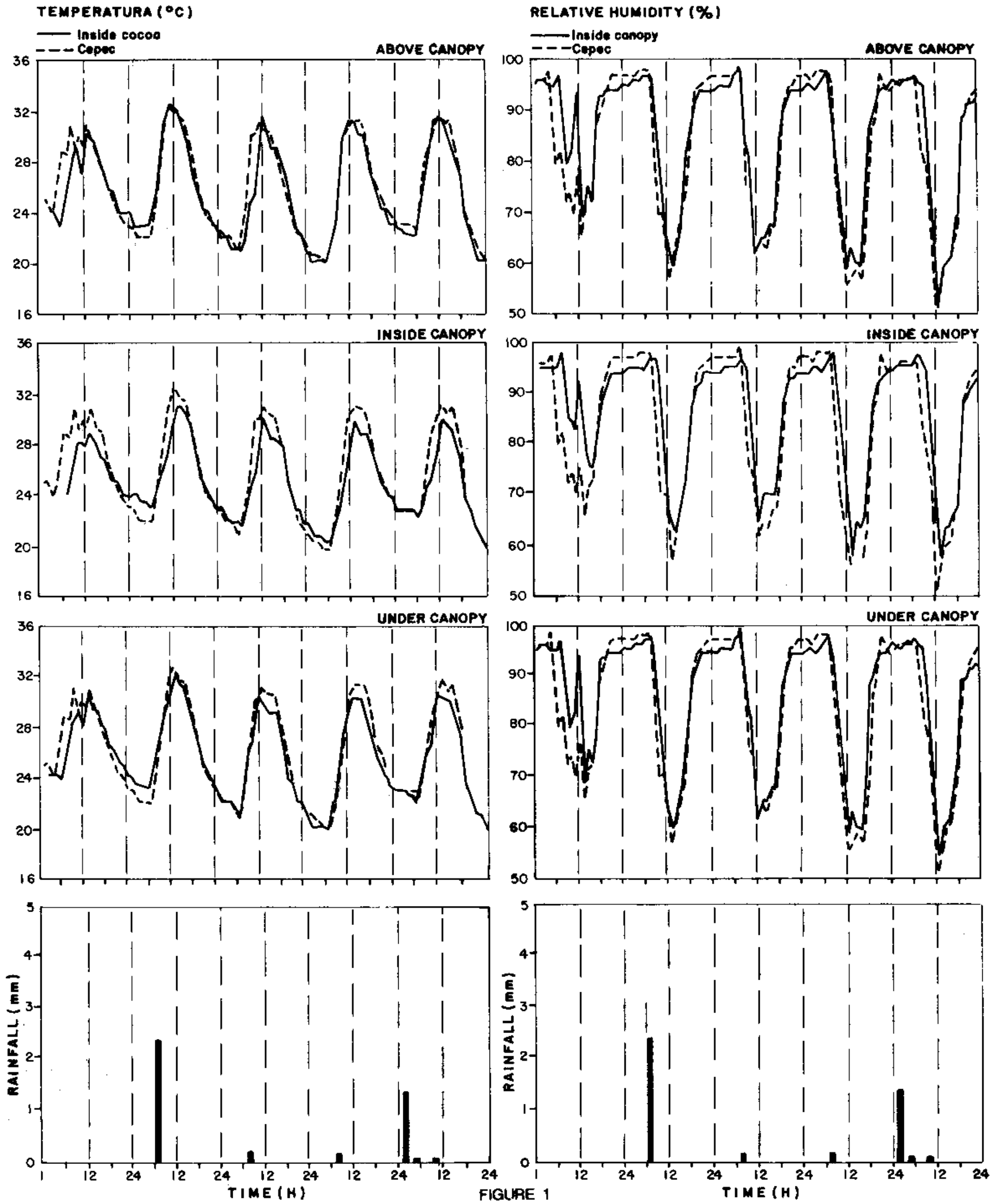

FIG. 1. Daily variation in temperature and humidity at three heights in a cocoa plantation rainfall, for summer week.

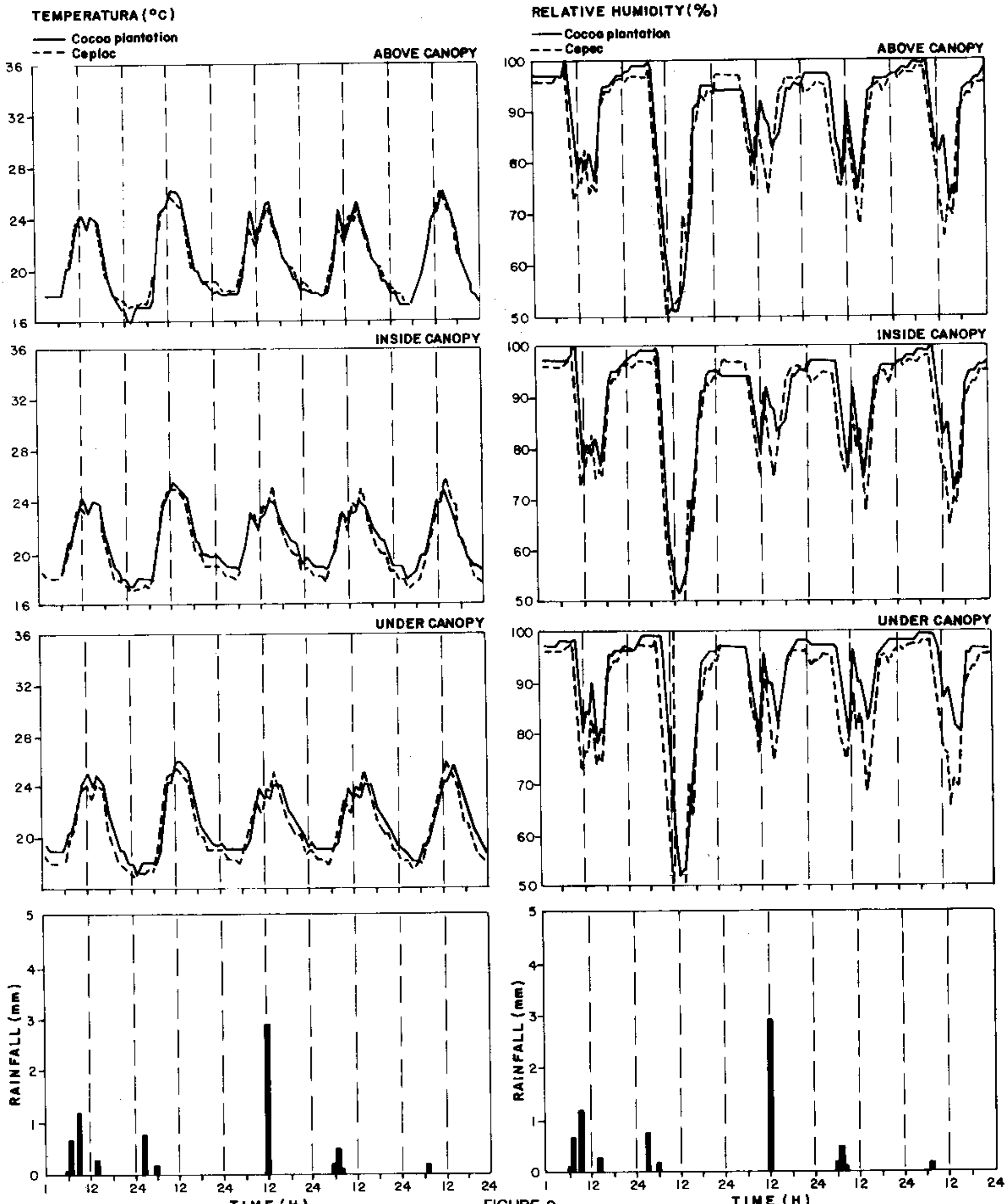

FIG. 2. Daily variation in temperature and humidity at three heights in a cocoa plantation and rainfall, for winter week.

turnal air temperature trend is reversed and reflects a difference in energy storage and its dependence on height. Air temperature is sometime decoupled from that at the lower levels of the canopy attributed to the decrease in turbulence exchange as the atmospheric stability increases.

Unlike temperature, the relative humidity cycle tends to decrease progressively from the undercanopy layer upwards over the whole daily cycle, and in both wet and dry conditions.

During the overnight period, conditions inside the cacao plantation were different from those from the meteorological station. Changes detected at the meteorological station were reflected in the plantation, without a time lag. The relative humidity under the canopy never fell below 85%; however, values for humidity outside the plantation were consistently greater than 90%. The maximum relative humidity, which represents conditions during the daylight hours, did not fluctuate as much as the minimum humidity. Inside the canopy, the minimum relative humidity was very similar to that at the reference station, particularly in the last two days of the investigated week (Fig. 1). The lowest humidity value of 57% (within the cacao canopy) and 52% (outside) were recorded after a period of rain.

Temperature and Humidity Time - Height in the Winter

The profile of the air temperature and humidity time-height cross section is shown in Fig 2. The extent of daily distribution and gradients of temperature and humidity differentials were a function of solar radiation intensity and mixing effectiveness.

The maximum difference in temperature measured outside and inside the layers in the cacao plantation was around 2 ± 0.5 °C. However, values lower than those, were recorded during the summer week (Figs. 1 and 2). Independently of prevaling weather conditions, the temperature gradients recorded from early evening to sunrise were positive at the 1.5 to 3.0 m layers. At night, the trend was for air temperature above the canopy to be lower than that measured in the bottom layers of the canopy. This is almost certainly due to the decrease in turbulent exchange as the atmosphere stability increases within the period. Temperature at the meteorological station was usually higher than that measured at 6 m and remained 0.2° to 1.0 °C below the temperature measured at the lowest layers of the cacao canopy. For the exceptions, it was observed that the temperature profiles reveal very variable behaviour, with no distinct trends.

From early morning to noon, under dry weather conditions, the air temperature profile inside the cacao plantation was almost identical to the profile measured at the meteorological station. After midday, the air temperature at the meteorological station decreased progressively in relation to the temperatures measured at the lowest layers of the cacao canopy. With the incoming solar radiation decreasing, the cacao canopy loses more energy than it receives, reaching lower temperatures than air at 6.0 m.

Conditions of relative humidity during a winter week were significantly different from those observed in the summer (Figs. 1 and 2). For the week in winter, overnight humidity conditions above and under the cacao canopy never fell below 95%. Minimum relative humidity did not fluctuate as much as in the summer. This minimum represents humidity conditions during day time. Over the period, the minimum relative humidity under the cacao canopy was above 80%, but the minimum relative humidity recorded at meteorological station remained at about 70% for the most of the time. The below canopy minimum relative humidity was very unstable, particularly after noon, when lowest humidity (58%) was measured. In contrast, the value measured at the meteorological station was 48%. Similar increases in humidity value outside a cacao plantation, compared with humidity within the plantation were also detected in Ghana, by Dakwa (1977).

Showers and their associated down-draught influence the daily cycle of temperature and humidity measured outside and inside the cocoa canopy. When showers occur, temperature tends to fall both inside and outside the plantation, in response to the presence of free water. Also humidity increases in response to the advent of free water on the vegetation surface. Figs. 3 and 4, show the daily cycle of temperature and relative

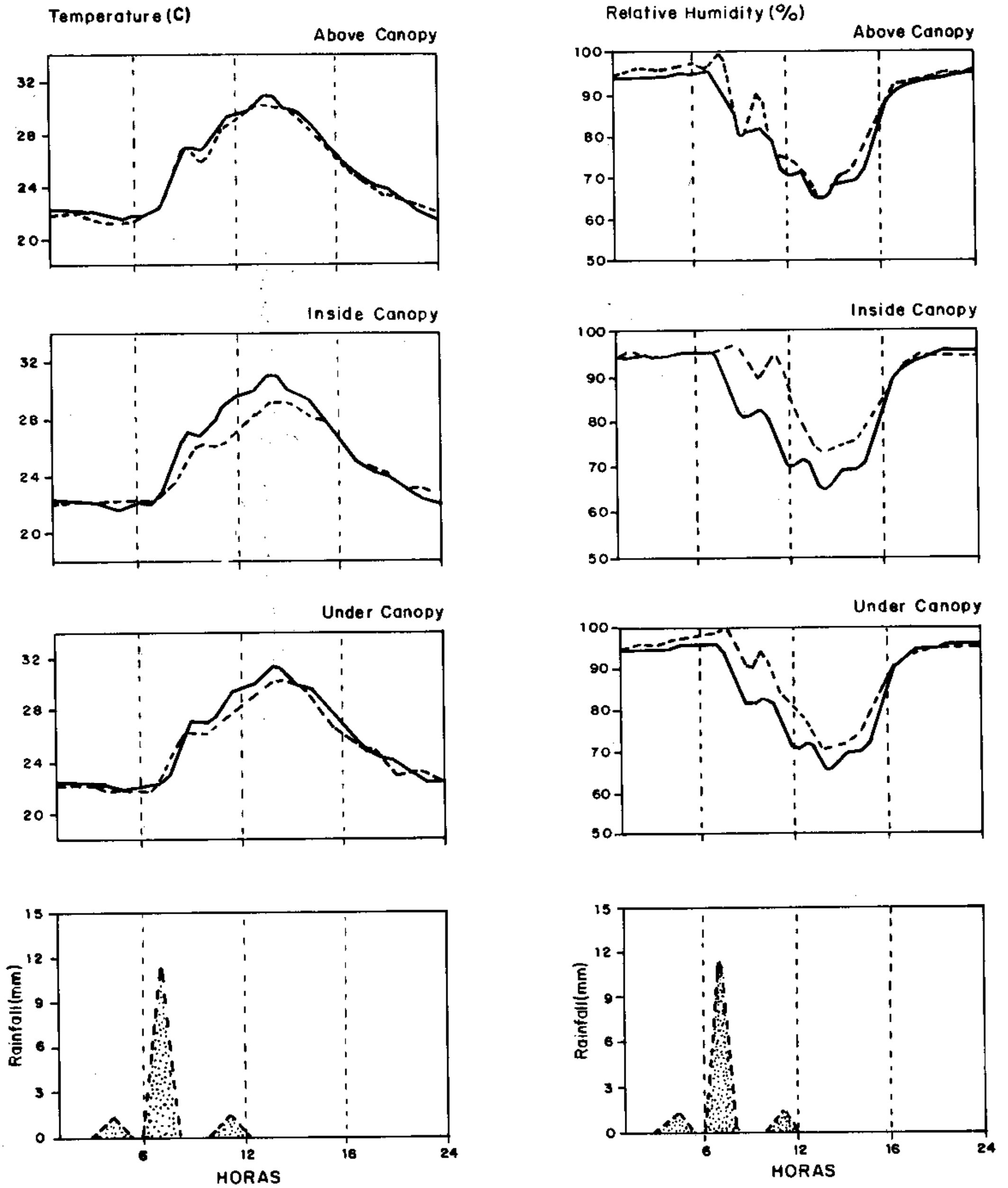

FIG. 3. Daily cycle of air temperature, humidity and rainfall recorded outside and inside a cocoa plantation

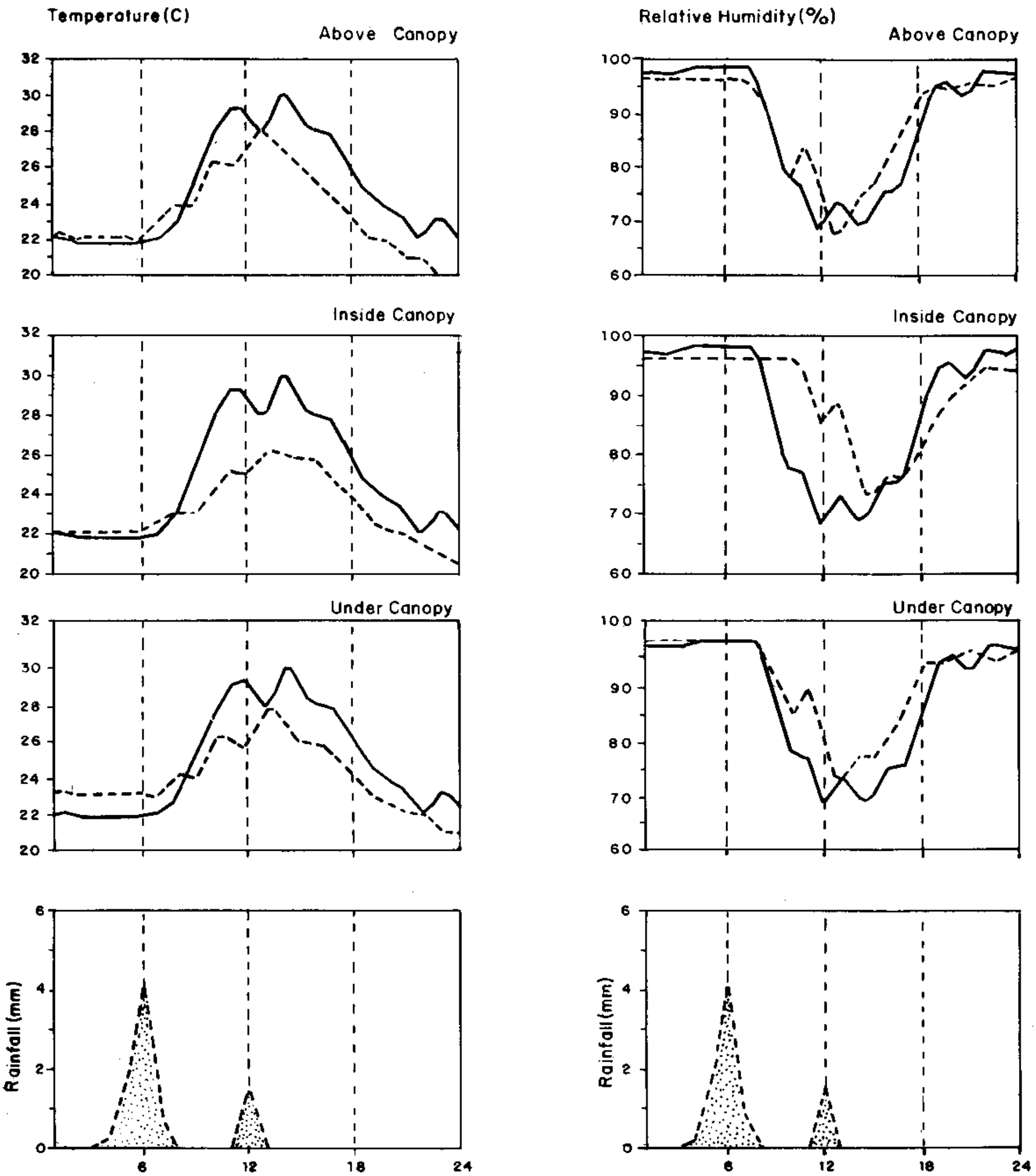

FIG. 4. Daily cycle of air temperature, humidity and rainfall recorded outside and inside a cocoa plantation

humidity during randomly chosen days within the seasons. During the morning, when air temperature inside and outside the plantation are expected to increase rapidly (Butler, 1980), the temperatures in the three canopy layers lag, remaining some degrees (1.0 - 4.0 °C) lower. If a rain event occurs, and if it is sufficient to wet the vegetative sub-layers of the cocoa canopy, temperatures recorded within the plantation undergo the same changes as those recorded at the meteorological station, but not to the same extent. The differential gradients of temperatures decreased proportionally with the amount of rain, and remained at this level until each canopy sublayer was completely dried off. The undercanopy maximum temperature were characterized by drops varying from 1.0 to 3.0 °C. Inside the canopy temperatures differences varied from 2.5 to 4.0 °C, while the above canopy maximum temperature decreased from 1.5 to 3.5 °C. Unlike temperature, the relative humidity becomes higher than that recorded at the meteorological station following a shower. Immediately after showers of 10 mm and 5 mm, maximum relative humidity remained steady at 18% and 11%, respectively. At the same time. It was observed that, on both days, the gradient of humidity was very unstable over the cocoa canopy, particularly when isolated showers occurred subsequently to the main rainfall period. This, in part, reflects an increased evaporation rate from the upper wet parts of the cocoa canopy. However, this interpretation is complicated, as pointed out by Shuttleworth et al. (1985), by the coincident temperature gradient reversal, which reduces the effectiveness of the turbulent transfer and reverses atmospheric stability.

CONCLUSIONS

It is clear that air temperature, relative humidity and rainfall are interrelated, and affect the seasonality of the microclimatic conditions inside a cocoa plantation. The weather inside the cocoa canopy was slightly different from the outside plantation. Temperatures outside the cocoa plantation always remained higher than inside during the summer week. Nevertheless, during the winter week, temperatures inside and outside were not observed to fluctuate very much. The temperature measured at the bottom of the cocoa canopy was decoupled from that recorded at the meteorological station. Relative humidity inside the cocoa plantation was higher during the summer week, and did not fluctuate as much as the outside relative humidity during daylight hours; outside the plantation, relative humidity was higher than inside the cocoa canopy and fluctuated enormously. mously.

Over the whole daily cycle, it appears that rainfall has an influence on temperature and relative humidity from the bottom of the cocoa canopy upwards. Rainfall, whether heavy or light, was always associated with a rapid drop in temperature and also with the rise in relative humidity 1 or 2 hours later, particularly inside the cocoa canopy. Relative humidity at the top of the canopy exhibited a small response to the advent of free water retained on the cocoa canopy. In the lower layer, a rise in relative humidity was observed, mainly if the incident rainfall was enough to saturate the canopy.

The measurements reported here were made in two contrasting weeks, and, therefore, reflect only a limited range of conditions. Nevertheless, they provide valuable information on the behaviour of cocoa trees and their response to weather, and on the variability which can be expected when using modelling techniques for the study of plant disease. They should lead to a reliable guide for plant control of cocoa disease as the microclimate of the cocoa plantations can be modified and also estimated from data obtained from a standard meteorological station.

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