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Epidemiological studies of *Colletotrichum gloeosporioides* disease of cocoa*

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Summary

The intensities of foliar infection (leaf blight and shot hole) and pod rot, caused by *Colletotrichum gloeosporioides*, were recorded from a cocoa-areca mixed garden and a cocoa-monocrop garden during 2 years. The intensity of pod rot was recorded from both the gardens. The intensities of leaf blight and shot hole gradually increased from July, reached a peak during September-November, decreased thereafter and reached the lowest level during April-June. Increase in leaf infection was associated in both plantings and in both years with the period of rain (June-November). The phylloplane population of *C. gloeosporioides* also increased during June-November when the temperature tended to be low and constant with high rainfall and relative humidity. During this period there were few susceptible stages of pods (cherelles and young pods) and pod infection was very low. Nearly mature pods were free from infection. In both years, pod infection was more in the cocoa-areca mixed garden than in the cocoa-monocrop; it was observed during January-May, when the susceptible stages were mostly prevalent but when the *C. gloeosporioides* population was low and the climatic factors appeared to be relatively unfavourable. This may be one reason for the lesser incidence of pod rot when compared to foliar disease.

Introduction

Cocoa (*Theobroma cacao* L.) cultivation in India is mainly concentrated in Kerala State, Dakshina Kannada district of Karnataka State and Kanyakumari district of Tamil Nadu State. Arecanut or betelnut (*Areca catechu* L.) and coconut (*Cocos nucifera* L.) are the principal plantation crops of this tract and cocoa is cultivated as an important mixed crop.

Among the diseases of cocoa so far reported from India, those caused by *Phytophthora palmivora* (Butl.) Butl. (Ramakrishnan & Thankappan, 1965; Chandra Mohanan, 1978) and *Colletotrichum gloeosporioides* Penz. (Chandra Mohanan & Kaveriappa, 1981; 1983*b*) have

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been recorded as the major diseases. Besides pod rot there are three kinds of foliar symptoms *viz.*, blight, shot hole and irregular spot caused by *C. gloeosporioides*. *Colletotrichum* infection on cherelles and young pods mostly starts from the stalk end 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 have been found starting anywhere on the pod surface (Chandra Mohanan & Kaveriappa, 1983*a*). Leaf blight, shot hole and pod rot were found to be widespread in Kerala, Karnataka and Tamil Nadu whereas irregular leaf spot was confined to Karnataka (Chandra Mohanan & Kaveriappa, 1983*a*). The shot hole symptom was mostly observed where cocoa was raised as a monocrop, whereas the leaf blight was severe in cocoa-arecanut mixed gardens and under heavily shaded gardens. The leaf blight symptom was more common on older leaves whereas the shot hole symptom was usually confined to flush leaves. In recent years leaf blight, shot hole and pod rot have been increasingly noticed in different localities of the cocoa-growing areas of India. The present investigations were therefore undertaken to study the epidemiological aspects of *Colletotrichum* disease of cocoa.

Materials and Methods

Disease incidence. Observations on the intensity of leaf and pod infection were made from a cocoa-areca mixed garden and a cocoa-monocrop garden, both in Vittal, Dakshina Kannada district, Karnataka, India. These gardens had 12-yr-old cocoa plants (cv. Forestero) which were not sprayed with plant protection chemicals. In the mixed garden, areca was planted at a spacing of 2.7 m × 2.7 m and cocoa was planted in the centre of four areca palms in alternate rows at a spacing of 2.7 m × 5.4 m. In the monocrop garden cocoa was planted at a spacing of 2.7 m × 2.7 m. Data were collected from three replicate plots of 25 plants at monthly intervals throughout 1981 and 1982. For recording the incidence of leaf blight and shot hole, one of the main branches from the jorquette of each plant was randomly selected and every 5th leaf starting from the base of the branch was assessed using a five-point rating scale (Table 1).

Table 1. *Rating system used for leaf disease assessment*

Per cent leaf area infected/no. of spots	Rating
0	0
1 - 10	1
10 - 25	2
25 - 50	3
50 - 75	4
75 - 100	5

The mean disease index (McKinney, 1923) was calculated and expressed as % maximum rating. The incidence of pod rot on cherelles, young pods and nearly mature pods of each plant was separately recorded at monthly intervals and expressed as a percentage of the total number of pods present at the time of observation.

Climatic data. Thermohygrographs, kept in Stevenson screens fixed 1.5 m above the ground at the canopy level in the centre of each garden, were used to record temperature (±1°C) and r.h. (± 5%). Rainfall was recorded with an automatic recording rain gauge located 10 m away from the experimental sites. From these, the following data were determined: (i) monthly mean, minimum and maximum temperature; (ii) monthly mean, minimum and maximum r.h., (iii) number of rainy days and total rainfall per month.

Phylloplane population. Leaf samples were collected from five plants from each garden. Five apparently healthy leaves each of old, young and flush growth were separately collected at random from the canopy of each plant on 15th of every month from January 1981 to December 1982 as described below:

1. Old leaves – Lowermost leaves of the branches excluding the lowest
2. Young leaves – Leaves at the middle portion of the branches
3. Flush leaves – Leaves at the tip of the branches which are coppery or bronze in colour.

Discs 1 cm in diam. (one per leaf) were cut randomly from each leaf avoiding the midrib and margin and each set of 25 discs was transferred to a 100 ml conical flask containing 10 ml sterile water. The flasks were shaken on a mechanical shaker for 10 min and dilutions were then prepared in sterile water. Dilutions of 10^{-1} for flush leaves and 10^{-2} for young and old leaves were found to be the most satisfactory from a range of dilutions (10^{-1} to 10^{-5}) studied. One ml from the respective dilutions was pipetted out and mixed with 15 ml of cooled potato dextrose agar medium supplemented with 100 units per ml streptomycin in a sterile Petri plate (9 cm diam). Five replicates were prepared for each dilution tested, the plates were incubated at room temperature (29 ± 2°C) and *Colletotrichum gloeosporioides* colonies were counted after 72-96 h based on the cultural characteristics and microscopic examination.

To detect any fungal propagules adhering to the mucilage at the cut surface of the leaf discs, all the 25 discs from each flask were washed in sterile water and plated on PDA medium (five discs/9 cm plate). The plates were incubated at room temperature for 96 h and *C. gloeosporioides* colonies growing around each disc were counted. The total number of colonies from both the dilution and disc plating experiments was considered as the phylloplane population of *C. gloeosporioides* and was expressed as number of colonies per unit area of the leaf surface.

Results

Disease incidence in relation to climatic factors. The number of rainy days and rainfall per month are given in Fig. 1. The rainfall was intense between June and September (south-west monsoon): during this period there was rain most days of the month (average rainfall/day 23 mm in 1981 and 29 mm in 1982). In October-November there were fewer rainy days (average rainfall/day 4 mm in 1981 and 3 mm in 1982). There was somewhat more rain in 1982 (3952 mm) than in 1981 (3246 mm). The number of rainy days was the highest in the month of June (28 days) in 1981 and August (29 days) in 1982.

Records of r.h. and temperature are shown in Figs 2 and 3. During June-November, the r.h. remained high with a mean r.h. of 90-99% and 88-95% in the cocoa-areca mixed garden and 85 to 95% and 90 to 95% in the cocoa-monocrop garden in 1981 and 1982 respectively. Within both plantations there were periods of very high relative humidity associated with the monsoon rain. However, the range of minimum to maximum humidity tended to be greater in the monocrop than in the mixed crop. This was particularly marked in 1981 where in the monocrop, minimum r.h. was about 70% from June to October compared with 80-90% in the mixed crop. Even in the wetter 1982, mean minimum r.h. only went above 70% in the monocrop in August but was above this level from June to September in the mixed crop.

Temperature in both the gardens was low and almost constant from June to November. The mean temperatures from June to November were 24.2-24.8°C and 22.4-25.7°C in the mixed garden and 24.5-26.0°C and 22.0-27.0°C in the monocrop garden in 1981 and 1982 respectively. In both the years from December to May, though the mean temperature was not very high, the maximum temperature was higher and the minimum temperature was lower than June-November in both the plantations. The maximum temperature gradually rose from

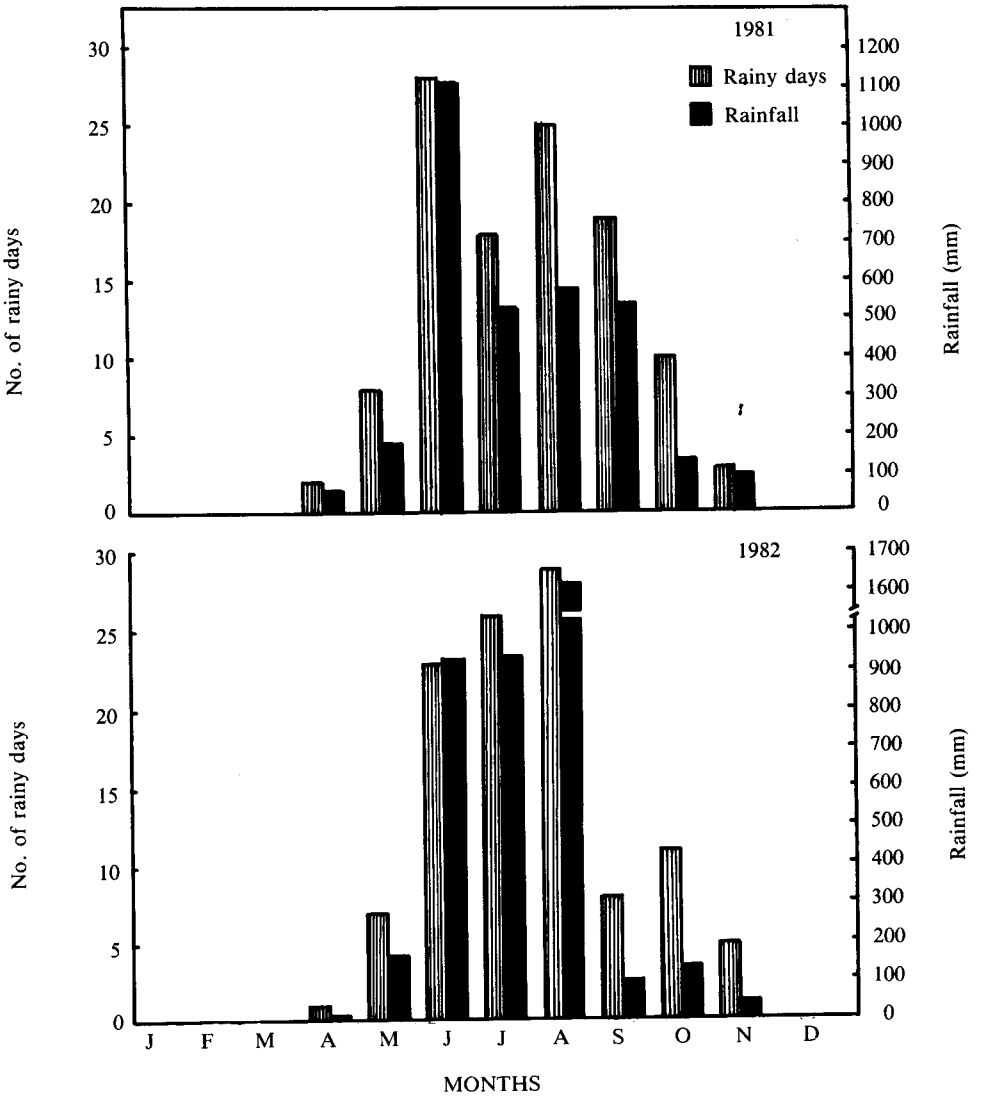

Fig. 1. Monthly rainfall data.

December and the hottest months were April and May with maximum temperatures of 36°C and 28°C in the mixed garden and 41°C and 36°C in the monocrop during 1981 and 1982 respectively. Thus during summer months the temperature in the cocoa-monocrop garden was higher than that in the mixed crop in both years. During this period the temperature in both the gardens was lower in 1982 than in 1981.

In both gardens and in both years the intensity of foliar infection increased during the south-west monsoon period (July onwards) and attained a peak immediately after the south-west monsoon (September-November), gradually decreased as temperature rose from December onwards and became very low during the dry weather period (April-June) (Figs 2 and 3). Thus the increase in leaf infection was associated in both years and in both plantings with the period of rain, when there was higher r.h. and constant low temperature. However, the initial (June) levels of foliar infection tended to be higher and the rate of increase was greater in the monocrop than in the mixed crop. Thus in 1981, 20% disease was attained in the

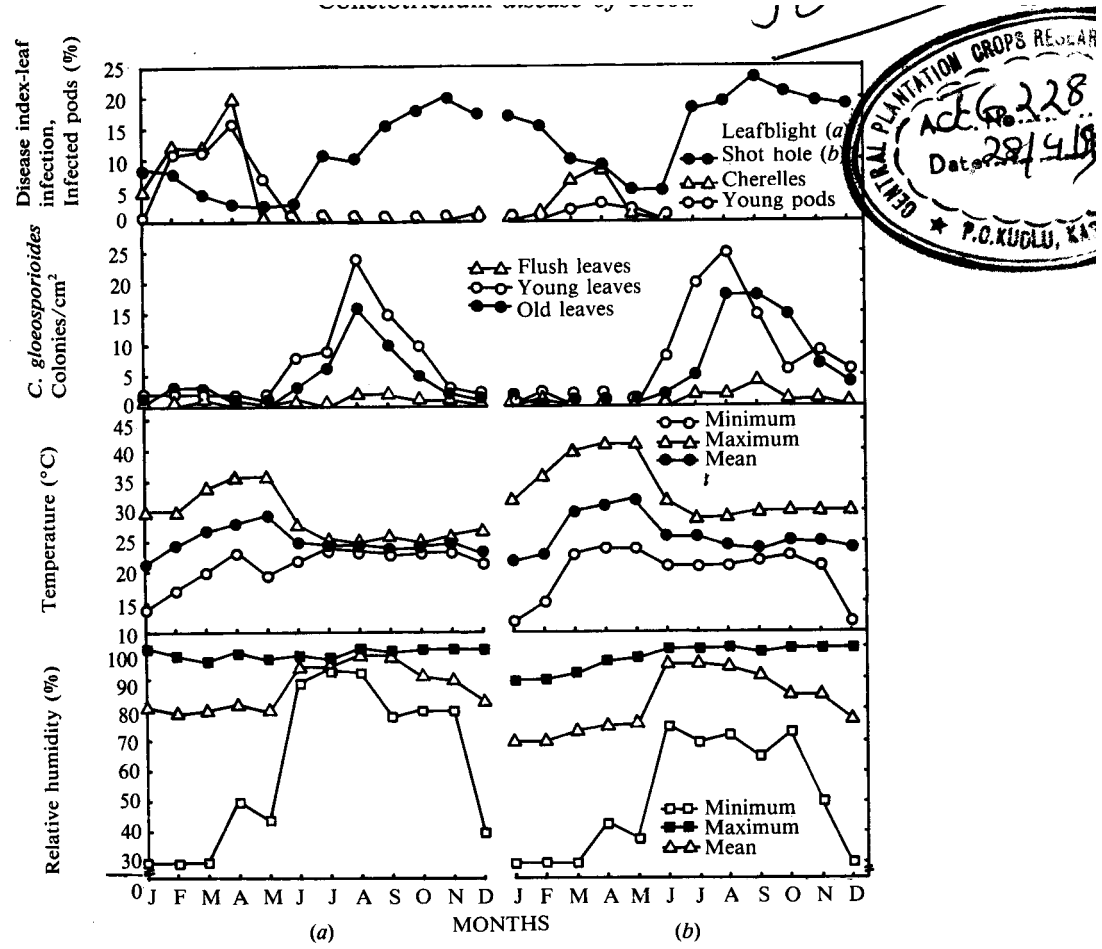

Fig. 2. Monthly disease incidence, phylloplane population, temperature and relative humidity in a cocoa-areca mixed garden (*a*) and a cocoa-monocrop garden (*b*) in 1981.

monocrop by July whereas in the mixed crop, this level was not reached until November. The same was true in 1982.

Colletotrichum gloeosporioides infection was observed on cherelles and young pods whereas nearly mature pods were free from infection. The intensity of infection was more on cherelles in both gardens and in both years.

Disease on pods was generally observed during January-May in the mixed garden and February-May in the monocrop in both years, when pods of susceptible stages were mostly available. The infection on pods reached a peak in April in both gardens and in both years. It was very low in the monocrop (maximum 10% in 1981; *c.* 5% in 1982) but almost twice as severe in the mixed crop (with maxima of 20% in 1981 and 15% in 1982). When the environmental conditions appeared to be favourable for foliar infection during July-November, cherelles and young pods were very rare.

Disease incidence in relation to phylloplane population of Colletotrichum gloeosporioides. The phylloplane populations of *C. gloeosporioides* in mixed and monocrop gardens showed a similar trend in 1981 and 1982 (Figs 2 and 3). The population was very low on flush leaves and high on young leaves; it increased in June with the onset of the south-west monsoon, reached a peak in August and thereafter declined considerably to be at its lowest in April-May. With the increase in the population from June, there was also a corresponding increase in foliar infection, and the symptoms of this infection became apparent from July in the mixed

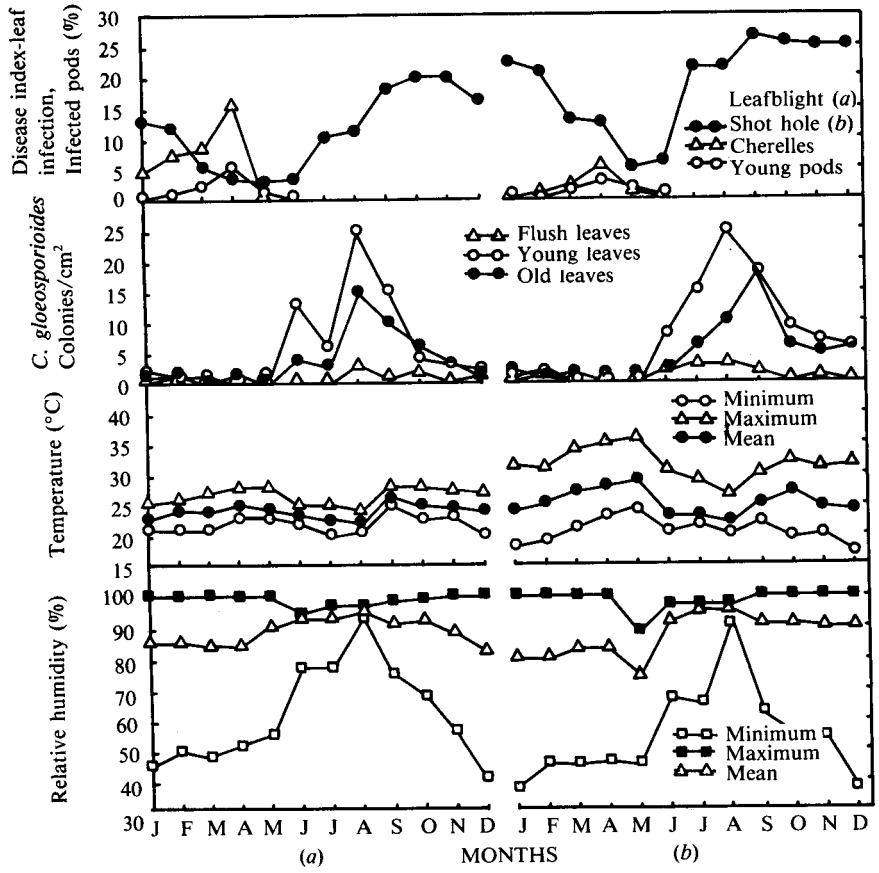

Fig. 3. Monthly disease incidence, phylloplane population, temperature and relative humidity in a cocoa-areca mixed garden (*a*) and a cocoa-monocrop garden (*b*) in 1982.

crop and the monocrop in both years. During this period cherelles and young pods were rare in both gardens and hence little disease developed on them. From December-January there was a decrease in the *C. gloeosporioides* population and a corresponding decrease in foliar infection.

Discussion

Foliar infection caused by *Colletotrichum gloeosporioides* was noticed throughout the year. Sarma & Nambiar (1976) also reported the occurrence of shot hole symptoms throughout the year in Kasaragod district of Kerala State, India. However, foliar infection in both the cocoa-areca mixed crop and the cocoa-monocrop increased substantially from July, following the frequent rains which started in June, and reached a peak during September-November. During this period there was rainfall associated with constant low temperature and high r.h. It is likely that the water available on leaf surfaces during the south-west monsoon period facilitated conidial germination and infection. It has been reported that a rapid increase in the intensity of post-bloom fruit drop disease of citrus caused by *C. gloeosporioides* occurred after the periods of major rainfall during June-October associated with periods of prolonged wetness (Denham & Waller, 1981). It is well known that diseases caused by *Colletotrichum* and other related fungi are favoured by rain. The conidia require water for dispersal and

infection and often infection is most severe when rain water soaks young tissue. It is therefore to be expected that leaf infection is mainly associated with periods of rain as observed in the present investigation.

During June-November, there was also a corresponding increase in the *C. gloeosporioides* population on the phylloplane with a peak in August. The constant low temperature, high r.h. and availability of free water from June may have facilitated germination, infection and sporulation of the pathogen resulting in a heavy inoculum build up on the phylloplane. Thus the foliar infection became more apparent from July. Similarly, from the studies on leaf blight disease of cocoa in Ghana, Dakwa & Danquah (1978) reported that initial infection might have started in late May so that the lesions became apparent in July. In the present investigation the inoculum for the main infection was available from the leaves infected during the dry weather period in the previous season.

From December/January when the temperature rose, with a low mean r.h., there were corresponding decreases in *C. gloeosporioides* populations and foliar infection in both plantations although infection remained slightly greater in the monocrop than in the mixed garden. The low inoculum concentration, absence of rainfall and low r.h. appeared to be the factors responsible for the decrease in foliar infection, while dew drops dripping from infected leaves to healthy leaves within and between the canopy in the monocrop might explain the differences between the two gardens. Thus during this dry period the overhead shade of areca palms in the mixed garden prevented dew formation on cocoa leaves to a greater extent than in the more open monocrop. The slightly greater increase in foliar infection in the monocrop as compared to the mixed crop during the rainy season in both the years is probably related to the differences in disease incidence during the preceding dry weather period.

The presence of low number of susceptible stage of pods when climatic conditions were favourable for disease development (June-November) and prevalence of unfavourable climatic conditions when the pods of susceptible stages were abundant (December-May) appeared to be the reason for the low disease incidence on pods in general. In the post-bloom fruit drop disease the intensity of infection was reported to be related to the availability of susceptible blossoms (Denham & Waller, 1981). In the present investigation the dew periods during the dry weather might have been expected to favour the infection of pods in the monocrop. However, more pods were infected in the mixed crop in both years perhaps because the micro-climate, especially high humidity and lower temperature resulting from the overhead shade of areca palm, favoured infection as compared to the monocrop.

The critical period for disease development may vary slightly from year to year owing to variations in climatic conditions such as rainfall, temperature and r.h. However, the information from this study suggests critical periods for the application of fungicides. In general, spraying of the leaves with a suitable fungicide should begin just before the onset of south-west monsoon and continue at regular intervals until November. Similarly to control pod infection, the spraying is needed when the maximum number of pods of the susceptible stages (cherelles and young pods) are produced, i.e., December-May in this study.

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