THE INTERACTION BETWEEN SWOLLEN SHOOT DISEASE AND MIRIDS ON COCOA IN NIGERIA

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INTRODUCTION

Cocoa in Nigeria is heavily attacked by Mirids (capsids), principally *Sahlbergella singularis* Hagl., which damage the young shoots when feeding by injecting a toxic saliva. The resulting necrotic patches are commonly invaded by *Calonectria rigidiuscula* (Berk & Br.) Sacc., and this fungus may affect the canopy to such an extent that the trees sometimes die. Crowdy (1947) showed that Mirid feeding damage alone killed only green tissue, but when the lesions became infected with *C. rigidiuscula* woody tissue could also be killed.

The swollen shoot condition of cocoa was shown to be caused by a virus in 1939 by Posnette (1940) in Ghana. Previously this disease was considered to be of minor importance in the general problem of cocoa die-back caused by Mirids and by adverse environmental conditions (Voelcker & West, 1940). Until recently, effective control of Mirids has not been possible and they are so ubiquitous as to occur frequently in farms also affected by the viruses causing swollen shoot disease. As a result, the effects of virus have been confounded with Mirid damage and the associated die-back fungus.

Observations in Ghana (Williams, 1953) and in Nigeria indicated that a virus infection predisposed trees to subsequent attack by Mirids. In fact wherever the growth of the cocoa is weak, or the canopy is broken there is a tendency for "capsid pockets" to form (Williams, 1953, Hoblyn, 1956). In such areas where the canopy has been reduced, increased exposure leads to adverse changes in the microclimate within the crop, and to invasion by a ground vegetation of grasses and herbaceous weeds. Under these conditions farms which are attacked by both Mirids and virus may become unproductive within a few years. This decline can be accelerated by the peasant farmers who often interplant with food crops.

Investigations into this complex interaction were greatly assisted by the application of the chemical control measures introduced against Mirids in 1956. Naturally infected cocoa farms, sprayed with B.H.C. showed spectacular improvements (Thresh, 1960), and these results prompted the suggestion that these insects largely determine the

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effect of swollen shoot disease on cocoa in Nigeria. Further aspects of the situation were examined in formal statistical field trials. The present paper discusses the results of these trials which were intended to examine this important interaction.

EXPERIMENTAL WORK

1. The interaction of Mirids and Virus

a) Koroboto observation plot

The spread of swollen shoot disease has been observed in peasant cocoa at Koroboto since 1953, and since that date the number of infected trees has risen from 49 to 606 in August 1959; almost 85% of the trees in the farm are now infected, and the effects of the complex of viruses at Koroboto are typical of others in the Area of Mass Infection. Individual tree yield records have been taken since 1954. B.H.C. spraying started in March 1956 to control Mirids.

The effect of virus on yield is difficult to estimate because the condition of the trees is only partly caused by the length of time they have been infected with virus. Nevertheless there were significant negative correlations between the number of months the tree had been showing symptoms and the yield in pods per tree per year for the crop seasons 1954 - 55 and 1955 - 56. Yields in each season were also correlated with girth, and partial correlations between yield duration of infection were obtained using this relationship.

Table 1 Correlations between Yield, Girth and Duration of infection at Koroboto Swollen Shoot Observation Plot

Crop Season	Yields x Virus	Yield x Girth	Girth x Virus	Yield x Virus Eliminating Girth	N
*1954-55	+ 0.1997	+ 0.2285	+ 0.0756	+ 0.1879	157
*1955-56	+ 0.3214	+ 0.3226	- 0.0195	+ 0.3462	274
1956-57	+ 0.1872	+ 0.3092	- 0.0450	+ 0.2116	386
1957-58	- 0.0279	+ 0.3808	- 0.1760	+ 0.0430	524
1958-59	- 0.1376	+ 0.4148	- 0.1803	- 0.0701	606

* = Before Mirids were controlled.

The relationship between yield and duration of infection became less marked in the crop season when control measures were applied, and has since disappeared. Indeed, in the 1958-1959 crop season there was a slight tendency for the oldest infections to outyield the most recent. Furthermore, in an adjacent farm, which was in a similar condition in 1953, and did not until recently receive insecticidal sprays, the level of virus infection is now high and the cumulative effects of virus, Mirid damage, and die-back over the years have made the farm unproductive. Thresh (1958) stated that the infected trees were more susceptible to Mirid attack. Many of the trees are moribund and a dense under-growth of grasses and small shrubs has followed the destruction of the canopy. There is no indication of soil or other environmental differences between this site and the one described above. In the sprayed plot, regeneration has proceeded without checks by further Mirid damage, and much of the present crop is borne on growth made since 1956. The yield in the 1958-1959 crop season was 800 lb. of dry cocoa per acre. This should be compared with the national average production which is less than 300 lb. of dry cocoa per acre.

b) Oluwo observation plot

Regular symptom observations were started in 1957 on a plot of randomly planted cocoa at Oluwo in the Ibadan Area of Mass Infection. The number of infected trees increased from 51 trees at the outset to 153 in August 1958. Most of the infected trees showed symptoms typical of virus infection and were usually in worse condition than their neighbours. Mirids were universally present though virus infected trees were more severely attacked than healthy ones.

Regular spraying with gamma B.H.C. was started in 1958 to control Mirids, and most trees have since made excellent growth. The condition of each tree was assessed before spraying began and at regular intervals after spraying, using a simple scoring system (Lister & Thresh 1955). Yields for the crop season August 1958 to July 1959 were recorded for each tree, and these yields were significantly correlated with girth, and with the condition of the canopy as recorded in August 1958. There was a significant correlation between yield and duration of infection similar to that at Koroboto, but after eliminating the effects of canopy condition this correlation disappeared. By comparison, at Oluwo the correlation between yield and canopy condition remained significant after eliminating variation due to girth, and duration of infection. Thus canopy condition is the most important of these factors, and whilst this can be influenced by virus infection, it appears that the condition of the tree is largely determined by the effects of Mirids, for at Koroboto the relationship between yield and infection ceased to exist after canopy conditions improved following Mirid control.

Table 2. Correlations between yield, girth, canopy condition and duration of infection at Oluwo Swollen Shoot observation plot

Correlation	Healthy Trees (N = 230)	Infected Trees N = (160)
Yield x Girth	+ 0.4667***	+ 0.3429***
Yield x Canopy Damage	- 0.4752***	- 0.5600***
Yield x Virus	-	+ 0.2575**
Yield x Virus. Canopy Damage	-	- 0.0745
Yield x Canopy Damage. Virus	-	- 0.5185***
Yield x Canopy Damage. Girth	-	- 0.5545***

*** = Significant at P = 0.001

** = Significant at P = 0.01

2. The interaction of virus and Calonectria

Four cocoa farms which were naturally infected with virus were chosen at Offa-Igbo near Ibadan, and two were sprayed with gamma B.H.C. to prevent further Mirid attack. In each of these farms selected fan branches on virus free and virus infected trees were inoculated with Calonectria. The technique used (Kay, 1960a) closely simulated Mirid damage and subsequent die-back. Both spread of die-back in the inoculated twigs, and the number of twigs which died to the point of inoculation were greater in virus infected trees. Moreover the results indicate that spread of die-back was greater in virus infected trees in the unsprayed plots, which were subject to continual Mirid damage. At Oluwo similar trials have shown that the spread of die-back is affected by the length of time the tree had been infected with virus, and upon the phase of virus infection. Kay (1960b) has shown in Ghana that there was a direct relationship between the spread of die-back and the virulence of the infecting virus. Preliminary investigations suggested that an adequate water supply reduced the spread of die-back (Kay, unpublished information). An inadequate supply did not stimulate the spread of existing inactive die-back, but promoted the spread of active die-back sites.

3. The effect of virus upon growth

Experiments on young trees at Agodi

A population of 240 young trees was divided into four groups as nearly equivalent in size and condition as possible. Two groups were inoculated with a combination of virulent viruses from Abaku and Egbeda. The flushes on one inoculated group of controls have been damaged each fortnight to simulate Mirid damage. Records of stem diameters indicated that virus inoculated plants had made significantly less growth in eight months than the controls. Most of the inoculated trees had shown the characteristic leaf symptoms of both viruses, and the swellings associated with Egbeda, and in many cases terminal swellings had destroyed the growing point. Virus infection had a striking effect on flushing as the number of new shoots had decreased by 60% in July 1959 and by 80% in August, when compared with controls. The artificial damage treatment has so far had little effect on growth. The difference in rate of flushing between treatments was most striking at the major growth periods in October and April.

4. The effect of environment on virus and Calonectria

A number of experiments were designed to give precise information on the effects of virus on cocoa under different cultural conditions (Longworth, 1960).

The first experiment consisted of a factorial combination of presence and absence of irrigation, and fertilizer application, and each plot contained healthy plants and others inoculated with mild, and severe virus. The area was heavily mulched, and shaded for the first dry season after planting, and these two factors were apparently sufficient to preclude any effect of irrigation. The reduction of growth caused by virus was significant and virus has also supressed height of the seedlings and the number of leaves produced. When most of the infected plants were showing symptoms, half of the plants in the virus treatments were inoculated with Calonectria. Eight months after inoculation the seedlings were removed and the length of the lesions measured. It was noted that lesion length was significantly greater in virus infected plants ($P = 0.01$). Mean lesion length in healthy controls was 29.9 mm. and in mild and severe virus infected plants was 31.0 and 38.8 mm. respectively. This has obvious relevance to the situation in the field as Thresh (1960) has shown at Koroboto and elsewhere that virus infected mature cocoa will regenerate and yield satisfactorily if maintained free from Mirids and associated die-back fungi.

The second experiment consisted of similar virus and Calonectria treatments superimposed upon the plots of a factorial layout involving shade and fertilizer treatments. After planting and throughout the first dry season shade promoted growth, but later the situation was reversed, and the greater growth in exposed conditions has continued. Virus supressed growth, and significant reductions in stem diameter, seedling height and leaf number were recorded. However, the supression was greatest under exposed conditions (Table 3). The Calonectria lesion lengths were greater in the virus treatments, but in this case the differences were not significant.

Table 3 Effect of mild and severe isolates of virus on stem diameter under exposed and shaded conditions

Category	Healthy	Mild	Severe	Total
Mean Stem Diameter (cm.) in Shaded Plots	2.36	2.22	1.98	6.56
In unshaded	2.84	2.64	2.00	7.48
Total	5.20	4.86	3.98	14.04

In both experiments, the number and length of lateral roots was recorded on seedlings which were removed for observation of the Calonectria lesions. Whilst root length and number of roots were reduced by virus ($P = 0.1$), in the second experiment the supression was relatively smaller under shade than in exposed plots. This interaction was significant though the reduction in total root length in shaded plants was not.

5. The effect of virus on growth of young cocoa in the field

The second seedling experiment described above involved a large number of guard plants, and in November 1958, 360 of these were selected and used in an ancillary experiment. The seedlings were divided into three groups, at random, and one group was retained as the healthy control. A second group was inoculated with a virulent isolate of cocoa swollen shoot virus from Egbeda in November 1958 (T1) and the third group was inoculated in February 1959 (T2), when most of the seedlings inoculated at T1 were showing symptoms.

Frequent records were made of leaf number, stem diameter, seedling height, and on the appearance of symptoms. Further, half the plants were removed in July 1959 for a detailed record of air-dry weights of stem, taproot and lateral root, and the number of lateral roots.

By May 1959, the seedlings infected with virus were significantly smaller than the healthy controls. The early inoculations caused the greatest reduction in growth, and the mean monthly increase in height since T1 was 7.6 cm. compared with 10.4 cm. for the seedlings inoculated at T2 and 12.9 cm. for the controls. Similar effects were noted on stem diameter and leaf number.

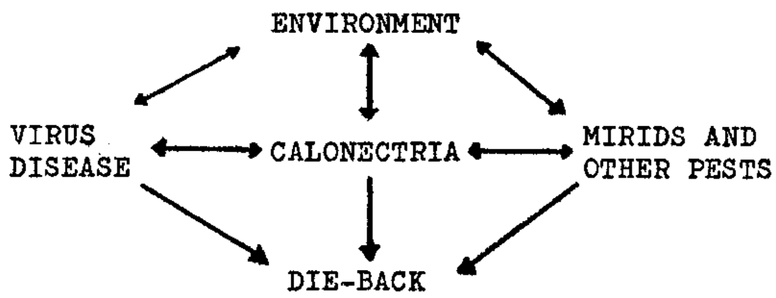
Table 4 — The effect of a virulent isolate of Swollen Shoot virus on stem and root growth

Category	Mean Wt. of Stem	Mean Wt. tap root	Mean Wt. Lateral roots	Mean Wt. Total root	Stem/ Root Ratio
Healthy Controls	248g.	74g.	16g.	90g.	2.76
Inoculated at TI (Nov. 1958)	174g.	53g.	11g.	64g.	2.72
Inoculated at T2 (Feb. 1959)	195g.	63 .	11g.	73g.	2.67

The results for the sample of trees which were uprooted and weighed indicate that virus caused a general reduction in growth, and there was no change in the stem/root ratio. Whilst there was no marked reduction in number and weight of lateral roots in the virus inoculated seedlings as was indicated in the previous experiments, the mean weight of total roots was reduced.

DISCUSSIONS AND CONCLUSIONS

Many factors contribute to the unthriftiness of cocoa in Western Nigeria. Among these are the viruses causing swollen shoot disease of cocoa, and Mirids principally Sahlbergella singularis Hagl. Their interaction in causing die-back of the cocoa tree has been the subject of investigation at W.A.C.R.I. Ibadan. The results obtained so far have greatly assisted in resolving this problem, and the following diagram is proposed to illustrate the interplay of factors leading to die-back:



The application of insecticidal sprays to cocoa farms infected with virus brought about striking improvements in growth and yield. This led to the suggestion that Mirids and the associated Calonectria die-back largely determined the condition of virus infected cocoa. In fact Thresh (1957) stated that in the observation plots at Koroboto, and elsewhere in the Area of Mass Infection, virus is rarely, if ever, solely responsible for the death of trees. Moreover in the areas of Mass Infection where eradication measures were abandoned in 1950 (Lister & Thresh, 1957) the cocoa has not died out as was expected.

At Koroboto and Oluwo there was a significant correlation between decrease in yield with duration of infection, and this relationship was reduced and finally eliminated at Koroboto after two years following Mirid control measures, and at Oluwo by removing the effects of canopy condition in analysis of the data. These results emphasize the importance of Mirid spraying, and indicate that the combined damage caused by Mirids and virus is greater than that caused by either occurring alone.

Mirids when feeding may kill young green tissue by injecting a toxic saliva (Goodchild, 1952) and in woody tissue these lesions provide entry points for C. rigidiuscula. Williams (1953) suggested that virus infection may predispose trees to attack by Mirids. Continued Mirid attack destroys the young regenerating tissue, and introduces further Calonectria. This cumulative process (Clayton, 1958) severely weakens the canopy and may destroy it completely, particularly in combination with other factors. Virus infection, for example, increases leaf fall, and generally reduces growth, (Posnette, 1948. Goodall, 1949). The present studies have shown that virus infection reduces the number of growth flushes produced. The greater numbers of Mirids on infected trees are therefore concentrated upon a smaller number of flushes and this further weakens the regenerative capacity of the tree. Longworth (1960) and Kay (1960) have shown that the spread of Calonectria is greatly influenced by the presence of the infecting virus and its virulence and also by the phase of its action upon the cocoa tree.

Where virus infection, Mirid damage and Calonectria infection occur together the direct effects upon the trees are severe, and in addition there are indirect effects which combine to aggravate this situation. Increased exposure to light intensifies the effect of virus upon the tree, and also encourages the formation of a ground vegetation, and the cocoa root system which had been weakened by virus must compete with this for nutrients and soil water.

The cocoa growing areas of much of the Western Region can be considered marginal. The mean annual rainfall at Ibadan is less than 50" and the decline of virus infected cocoa in this Region which is attacked by Mirids is particularly severe in the dry season, and Mirids are present in quite large numbers at this time (Williams 1954, Donald 1957). Kay (unpublished information) has shown that the spread of active Calonectria die-back is increased by an inadequate water supply, and the competition between the reduced root system and the ground vegetation is intensified at this period of water stress.

The cumulative effects of these factors over several seasons combine to cause severe die-back and often death of the cocoa tree. This decline is often accelerated by farmers whose cultivation of the crop may be confined to harvesting periods, and in absence of proper maintenance the farm may become unproductive especially if the area has been interplanted with food crops.

These preliminary results afford some explanation of the poor condition of much of Nigerian cocoa, and suggest the syndrome which has been described. The most important contribution is a realisation of the relative importance of Mirids and virus in this situation, and it is clear that in Nigeria, and particularly in the areas of Mass Infection, great benefits would accrue from general application of Mirid control measures.

SUMMARY

Until 1956 it was almost impossible to separate the effects of Mirids and virus in causing dieback of cocoa, and the degeneration of Swollen Shoot outbreaks was attributed to virus. It was not until chemical control measures were introduced against Mirids in 1956 that it was realised that Mirids and the associated dieback fungus Calonectria rigidiuscula (Berk & Br.) Sacc., largely determined the condition of virus infected cocoa farms in Nigeria. Spectacular improvement in growth and yield followed control operations.

An important part of the research programme at WACRI, Ibadan, has been a study of this problem, and its inter-relation with the environment. This has involved in part a combined approach of the pathology, mycology and agronomy sections, and the present paper outlines results obtained to date.

RESUMEN

Hasta 1956 fue casi imposible separar los efectos de los Miridos y los virus como causantes de la muerte regresiva del cacao, y el empeoramiento de los brotes de "Swollen Shoot" se atribuyó a virus. No fue sino hasta 1956 cuando se introdujó medidas de control químico contra los Miridos que se tuvo conocimiento que éstos y la muerte regresiva causada por el hongo Calonectria rigidiuscula (Berk & Br.) Sacc., determinaban en su mayor parte el estado de las fincas de cacao afectadas de virus en Nigeria. Se obtuvo mejoras espectaculares en crecimiento y rendimiento después de las operaciones de control.

Una parte importante del programa de investigación de WACRI en Ibadan ha sido el estudio de este problema y su inter-relación con el medio ambiente. Esto ha requerido en parte un enfoque combinado de las secciones de patología, micología, y agronomía, y este articulo presenta los resultados obtenidos hasta la presente fecha.

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