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Cacao virus research in Nigeria*.

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COMPENDIO

En 1953 se estableció en Nigeria una sub-estación del West African Cocoa Research Institute. Las investigaciones hechas desde esa fecha han demostrado la presencia de tres diferentes virus del cacao. Los virus de la necrosis del cacao y de la hoja moteada del cacao tienen una distribución limitada y no tienen importancia. Por el contrario, los virus de la hinchazón de los brotes (swollen shoot) están muy esparcidos y ocurren en numerosos tipos. Estos difieren mucho en sus efectos sobre el crecimiento, los que no son acumulativos salvo en los casos en que han sido obtenidos del mismo árbol o de árboles y localidades cercanas.

La hinchazón de los brotes del cacao se difunde lentamente y sobre distancias limitadas comparada con virus trasmitidos por vectores alados activos. Esto los hace fáciles de controlar mediante medidas de erradicación. En Nigeria éstas se aplican apenas se encuentran brotes de la enfermedad fuera de las dos zonas abandonadas de infección masiva. Así se ha interrumpido la dispersión del virus, aunque aparecen brotes en proporción creciente. Esto implica que las medidas de control deben continuar y que pueden ser más eficientes por el uso de insecticidas, cultivos de barrera y variedades resistentes. — El Autor.

Introduction

VIRUS diseases of cacao were found in Nigeria in 1944, soon after the start of the first intensive survey of the growing areas. At the outset, only limited investigations were carried out within the country, although Nigerian virus isolates were used in experiments at the West African Cocoa Research Institute in Ghana. A Substation of the Institute was established in Nigeria in 1953 and the present paper summarises the results of the most recent experimental work.

The viruses occurring in Nigeria

Survey Officers in the field soon realised that the symptoms of virus disease are not the same in all localities. Indeed, stem swellings may be rare or even absent and the leaf symptoms also differ in type and severity between and within outbreaks. The differences are usually maintained when uniform seedlings are inoculated with isolates collected from the different areas and more than fifty symptomatically distinct isolates have been made already. Even more could be collected if sufficiently detailed attention is given to symptom expression. The interrelationships between the different isolates are complex and equivocal due to the limited criteria for classification, but Thresh & Tinsley (14) have used symptoms and other features to distinguish three distinct viruses, whose main features are now summarised.

Cacao Mottle Leaf Virus: Isolates of cacao mottle leaf virus cause an extensive transient red vein banding and mottle caused by an abnormal accumulation of anthocyanins in the immature leaves. Clearing and chlorotic banding of the veinlets then appears between, but not alongside, the principals veins of older leaves. These isolates differ from most others from cacao in not causing swellings and they are transmitted by mealybug species, excluding *Ferrisiana virgata* Ckll.

The baobad, *Adansonia digitata* L. appears to be the usual host of cacao mottle leaf virus and most isolates have been obtained from this tree and also from cacao in the savanna areas of Ghana and Togoland (1). What appears to be the same virus has also been isolated from an outbreak in cacao near Alaparun, north west of Ibadan (6). This locality is near the boundary of the lowland forest and adjoins areas where baobads occur and in which suspicious symptoms have been reported (4).

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Figure 1.—*Leaf distortion and translucent patches caused by an isolate of cacao necrosis virus.*

Cacao Necrosis Virus: Isolates of cacao necrosis virus cause an early acute phase of infection, with extensive veinal necrosis in the leaves of graft-inoculated seedlings. The later so called "chronic" phase symptoms are relatively mild, with limited translucent clearings along the principal veins (Figure 1). Swellings, red vein banding, mottle and mosaic are not caused at either phase. The isolates also differ from those of the other cacao viruses by the apparent inability of mealybugs to transmit them. Indeed, isolates of cacao necrosis virus have not been transmitted experimentally, except by grafts and attempts at sap and soil transmission and with different insect species have been unsuccessful, although naturally occurring outbreaks seem to spread.

The inconspicuous chronic symptoms of cacao necrosis virus are difficult to detect during the routine inspections for swollen shoot disease, but nine small outbreaks have been found. They are all in Nigeria, where infection is apparently confined to adjacent parts of Ijebu-Ode, Abeokuta and Ibadan Provinces. The edible *Cola acuminata* (P. de Beauv) Schott. et Endl. is widespread in these areas and may be the alternative or even the usual host of cacao necrosis virus (5).

Cacao Swollen Shoot Viruses: Most of the isolates from Nigerian cacao belong to the complex of viruses causing swollen shoot disease (13). They cause a transient red vein banding in immature leaves, and this is followed by a reticulate mosaic of clearings and banding of the veinlets between and alongside the principal veins (Figure 2). With a few inadequately studied exceptions, the isolates cause swelling (Figure 3), at least on the roots, and they are transmitted by mealybugs including *F. virgata.*

Figure 2.—*Conspicuous vein clearing and banding caused by an isolate of cacao swollen shoot virus.*

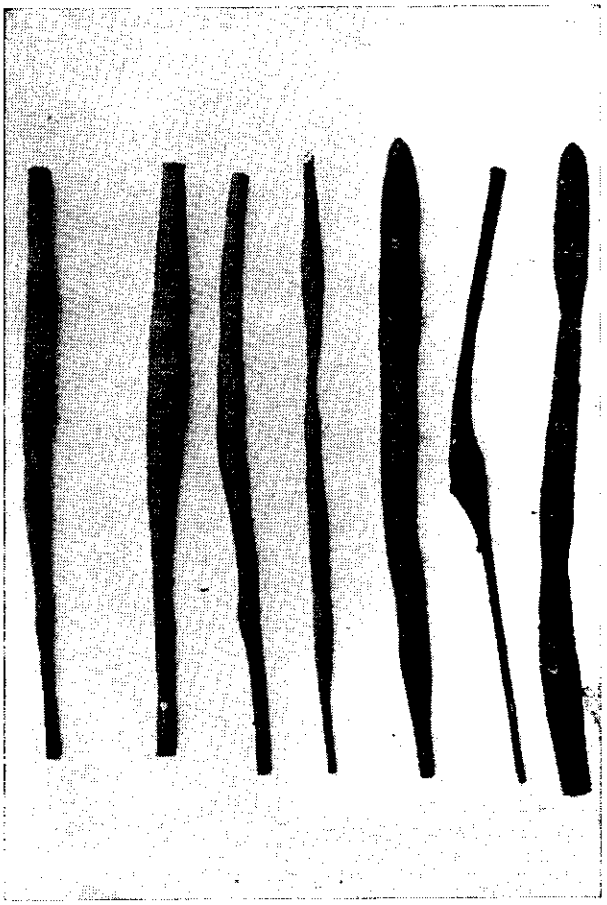

Figure 3.—*Stem swellings caused by an isolate of cacao swollen shoot virus.*

Isolates from the same outbreaks or localities often differ in their virulence to seedlings, but cause symptoms of a similar type. These isolates usually interprotect, do not have cumulative effects on growth and are assumed to be closely related strains. By comparison, isolates from dissimilar areas often differ in virulence, and also cause dissimilar symptoms. The isolates do not usually interprotect, have cumulative effects on growth and are not closely related.

The precise significance of these minor differences between isolates from the same trees and outbreaks and greater differences between isolates from elsewhere has not been established, but it is of considerable practical importance. For example, mild strain protection, a control measure suggested by Posnette & Todd (7) from their experience in the New Juaben area of Ghana, is likely to be applicable only in the area from which the mild strain was isolated. Similarly, there is no evidence that varieties which are selected for their resistance or tolerance to infection with viruses from one locality, will show a similar response to viruses from elsewhere.

The effects of cacao swollen shoot viruses on growth and yield

Observations on Mature Trees: Experiments on the behaviour of trees infected with cacao viruses, have been limited by the lack of regularly spaced, uniform trees which could be inoculated in formal trials. Indeed, most of the data have come from observations on the uninterrupted spread of naturally occurring outbreaks in irregularly planted peasant farms. These are variable and have until recently been subject to the complicating effects of other diseases and pests, particularly capsids. Under these conditions virus-infected trees are usually worse than their neighbours and at Koroboto in the crop season 1955-1956, there was a highly significant negative correlation between yield and duration of infection. Similarly at Oluwo in 1958-1959, when recently infected trees gave a mean yield of 18.8 pods per tree, compared with 25.6 from symptomless trees.

Infected trees usually die back and there is a marked deterioration of the canopy, which is accompanied by defoliation, general chlorosis of the foliage and encroachment of grass into the farm. Whole areas have been observed to deteriorate in this way, as virus spreads unchecked and the farms are abandoned and used for food crops or allowed to revert to thicket (2).

This typical sequence of degeneration has not been observed where capsids have been controlled for some years or where these insects are not numerous (8). Under these conditions, virus-infected trees are not obviously worse than their neighbours and it seems that virus infection predisposes trees to capsid attack and hence to subsequent infection with the dieback fungus (*Calonectria rigidiuscula* Berk. & Br.) Sacc. Virus (particularly at the acute stage of infection) seems to increase the probability of dieback occurring and also reduces the ability of the trees to regenerate and maintain their condition. They are, therefore, more likely to deteriorate than healthy trees and frequently pass into a progressive decline often ending in death. The precise details of this postulated interaction between viruses and capsids are now being investigated in experiments on cacao farms and also on recently established seedlings.[1]

1 A preliminary report on the results has been published since the manuscript was received. See. D. Kay, J. F. Longworth and J. M. Thresh. (1960). The Interaction between swollen shoot disease and mirids on cocoa in Nigeria. Proc. VIII Interamerican Cacao Conference, Port-of-Spain, Trinidad. Doc. 18. *(Editor).*

Experiments on Saplings in the Field: Experiments on young cacao under different environmental conditions in the field were started in 1958, and virus supressed flushing, reduced leaf number, leaf area, stem height, stem diameter and root growth. These effects were more marked under exposed conditions than on plots given artificial shade, but the mildest isolates had little effect on growth under any of the conditions.

Experiments with saplings and others with seedlings infected as beans, have shown that the viruses in Nigeria differ in virulence. Typical isolates from some areas cause severe stunting and may be lethal, whereas isolates from elsewhere have intermediate or slight effects. Similar results have been obtained in Ghana, and in both countries the effects on growth are more closely associated with the severity and extent of the leaf symptoms than to the presence or absence or swellings. Indeed, viruses which cause severe leaf symptoms only, have far greater effects than those which cause swellings without conspicuous mosaic.

The insectary experiments have also shown that related isolates from the same outbreaks and localities are not uniform in their effects on growth. For example, one virus from Koroboto reduced stem height and leaf area by 34 per cent, whereas a related mild strain caused an 8 per cent reduction.

The pattern and rate of spread of cacao swollen shoot disease.

The cacao swollen shoot viruses are not known to be seed or soil borne, nor have they been transmitted by sap inoculation. Consequently, spread usually occurs by the movement of the *Pseudococcid* vectors (Figure 4). These may occur on all parts of the tree and can walk through the canopy, although they are usually sedentary and are active only as nymphs, and then predominantly at the first instar. Swollen shoot disease therefore spreads slowly and over short distances compared with viruses which have active winged vectors (11). This has been confirmed at numerous localities in Nigeria, where naturally occurring outbreaks in peasant cacao have been observed for several years.

The Pattern of Virus Spread: At each observation plot most of the new infections appeared alongside existing ones and the probability of spread decreased rapidly with increasing distance from the source. Thus outbreaks tended to spread outwards in an amoeboid manner, although a few scattered infections occurred; presumably caused by wind-borne mealybugs.

The steep gradients of infection around outbreaks of swollen shoot disease have also been demonstrated in a series of coppicing experiments intended to reveal the latent and missed infections around naturally occurring outbreaks (12). The results can be summarised by the equation:

$$\text{Log}_{.10}\ I = a + b.\ x$$

Where I is the intensity of latent and missed infections at distance x from the source. The constant a determines the height of the regression line and increases with outbreak size, whereas the negative constant b determines the slope and was approximately the same for all outbreaks. These results emphasise the importance of local spread by mealybugs moving short distances through the canopy. They also indicate that the spread of swollen shoot disease into new plantings and plots of mature cacao can be checked without difficulty if they are not alongside infected trees and are regularly inspected and rogued.

Figtre 4.—*The mealybug* Pseudococcus nialensis *Laing and attendant. Crematogasterine ants on the surface of a pod which also supports a protective tent built by the ants.*

The Rate of Virus Spread: At each observation plot the number of infected trees increased annually and followed a sigmoid trend with time. Thus at Koroboto and elsewhere, the number of new infections increased for several years until approximately half the trees were diseased and then decreased as infection became complete.

The annual number of new infections was not proportional to the number of existing ones and the ratio between the two decreased with time, suggesting that on this criterion rate of spread decreased as outbreaks increased in size. This in consistent with the available information on the movement of the mealybug vectors, which are unlikely to reach healthy trees from an increasing proportion of the infections.

Rate of spread is difficult to compare between plots because of differences in the spacing, size and condition of the trees. However, the number of infected trees at Offa Igbo increased from 50 to 100 in four months and from 50 to 200 in sixteen. Comparable increases occurred at Koroboto in thirteen and twenty two months, respectively. Virus spread even less rapid'y at Iweke, where the number of infected trees in a two-acre plot increased from 13 to 84 in six years and some of the trees in contact with infected ones did not show symptoms for some years. This situation should be compared with the spread of aphid-borne virus diseases of certain annual crops such as sugar beet, ground-nuts or brassicas, which may become heavily infected in a few months.

The distribution and control of cacao swollen shoot viruses in Nigeria

The cacao necrosis and cacao mottle leaf viruses have a limited distribution in Nigeria and are unimportant. By comparison, the swollen shoot viruses are widespread and an important factor influencing production. They were discovered east of Ibadan and it was thought first that they could be eradicated by the cutting out campaign introduced by the Department of Agriculture in 1946. This involved the destruction of all obviously infected trees, wherever they were found by specially trained survey parties. These control measures were difficult to apply on such a large scale, involved heavy government expenditure on staff and compensation and were unpopular with the farmers. Hence they were modified in 1950, after one and a half million trees had been destroyed (3).

Control measures were abandoned first in a large part of Ibadan Province and later around Ilaro. Inspection continue outside these areas and outbreaks are treated as they are discovered. At first, the obviously infected trees were destroyed together with their neighbours to a distance of thirty yards around all outbreaks. This was introduced as a method of dealing with the latent carriers of infection and also the recently infected trees which were still symptomless. However, these drastic measures involved ten trees which seemed healthy for every one with symptoms. The coppicing experiments showed that this was unnecessary, particularly around the smaller outbreaks (12), and new measures were adopted in 1956. Since that date outbreaks of 1-5, 6-50 and > 50 infected trees have been treated by destroying all the obviously infected trees as before, but their neighbours are now removed to distances of only 5, 10 and 15 yards, respectively.

These changes have resulted in great savings in government expenditure and little loss in the efficiency with which individual outbreaks are eradicated. However, outbreaks are being found at a progressively increasing rate and it seems that virus is spreading more rapidly than hitherto from the abandoned areas. Thus additional efforts will have to be made to maintain the situation and prevent virus from spreading to the healthy areas.

The future outlook in Nigeria

Swollen shoot disease is now so widespread that it is unlikely to be eradicated and it must be considered as a permanent factor influencing the Nigerian cacao crop. This means that cultural methods and agricultural policy must be adjusted to ensure that the losses caused by virus are reduced to a minimum and that annual yields are maintained and even increased. Fortunately, it seems that this can be achieved by the application of existing knowledge. Additional lines of work now being investigated at the West African Cocoa Research Institute may result in still further improvements (9).

Cutting Out Measures: The cutting out measures for controlling swollen shoot disease are costly, unpopular and at best can only maintain the present position without improving production. Their only justification is that they provide a check on the rate at which virus spreads outside the abandoned areas. Thus the measures become equivocal and of doubtful validity unless the survey parties are working with such efficiency that a large proportion of the new outbreaks are discovered at an early stage. This has not always been done and some new outbreaks have been missed and allowed to spread unchecked until they involved more than a thousand infected trees (10). Thus, several additional localities have recently become heavily infected and control measures were abandoned within them.

Further efforts are being made to hold or even retract the present boundaries to the abandoned areas. It seems that most of the cacao in Nigeria can be maintained relatively free from infection and at reasonable cost in relation to the economic value of the crop if this can be done without great increase in expenditure.

Replanting in the Abandoned Areas: Abandoned cacao farms and areas previously used for food crops are still being replanted with cacao in the areas of mass infection. This is done by unsupervised peasant farmers who frequently plant within or alongside existing farms already infected with swollen shoot and other diseases.

Thus the new plantings soon become attacked and maintain the cycle of infection. Losses are minimised if the largest possible blocks are established in compact areas from which all obvious sources of infection have been removed. Barrier crops may also be valuable in further reducing the rate at wich virus spreads into and within such newly planted areas.

Capsid Control in the Abandoned Areas: Experience at Koroboto and elsewhere has shown the value of controlling capsids, even on trees which are infected with swollen shoot disease. Indeed, sprayed infected farms have continued to give an economic yield and show no obvious signs of decline. Similar results could be obtained elsewhere and considerable increases in crop production can be expected from the widespread application of capsid control measures. Farmers in the abandoned areas are now being encouraged to spray and this may halt or even reverse any marked tendency for yields to decline as virus spreads unchecked.

The Use of Insecticides Against Mealybugs: Mealybugs on cacao are difficult to kill and insecticides play no part in the present control measures against swollen shoot disease. However, a cheap safe insecticide which would kill mealybugs without affecting the crop would have widespread application. This justifies further work with some of the newer insecticides, including systemics. These may eventually come into routine use to decrease the general level of mealybug populations and the probability of them spreading virus. This may be partially achieved already by routine capsid control, which must influence mealybug numbers by direct effects and indirect ones on the hosts and the populations of ants they support.

Resistant and Tolerant Varieties: Virus is now spreading in trees of the highly susceptible Amelonado type and there is already evidence that other cacaos resist or tolerate infection. Some of these types are now being tested in the field and improved seed material may soon be available to farmers. This could completely change the present attitude to swollen shoot disease and may lead eventually to modifications of the existing cutting out policy.

Summary

A Nigerian Substation of the West African Cocoa Research Institute was established in 1953. Investigations since that date have demonstrated three distinct viruses of cacao. The cacao necrosis and cacao mottle leaf viruses have a limited distribution and are unimportant. By comparison, the cacao swollen shoot viruses are widespread and occur in numerous strains. These differ greatly in their effects on growth and usually interprotect only if they have been obtained from the same or nearby trees and localities.

Cacao swollen shoot viruses spread slowly and over limited distances compared with viruses transmitted by active winged vectors. This makes them relatively easy ones to control by eradication measures. In Nigeria, these are applied wherever outbreaks are found outside the two abandoned areas of mass infestion. Thus the build up of virus has been checked, although new outbreaks are appearing at an increasing rate. This means that control measures must continue and they may be made more efficient by the use of insecticides, barrier crops and resistant varieties.

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