CAPSIDS AS A FACTOR INFLUENCING THE EFFECT OF SWOLLEN-SHOOT DISEASE ON CACAO IN NIGERIA

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Summary

The unrestricted spread of cacao swollen-shoot disease was followed by monthly observations on naturally occurring outbreaks in the Abeokuta and Ibadan Provinces of Western Nigeria. The condition of the trees was more closely related to the incidence of capsid damage and associated dieback caused by *Calonectria rigidiuscula* (Berk. & Br.) Sacc. than it was to swollen-shoot virus infection. Indeed, where capsid damage was slight or where it was controlled by spraying, the effect of virus was less marked than that due to other factors influencing growth and yield. By comparison, where capsid damage was severe and not controlled, virus infected trees were worse than their neighbours and often died within a few years. These results suggest a new approach to cacao swollen shoot disease and its control, in which the interactions of pests and diseases in their environment are treated as a single ecological problem.

In Ghana the most virulent strains of cacao swollen-shoot virus drastically affect the growth and yield of cacao trees and there are many records of death within a few years [1, 2, 3]. The situation in Nigeria is similar but the differences between healthy and infected trees are not so great and infected trees do not always die.

In both Ghana and Nigeria the deterioration of diseased trees has usually been attributed solely to the effects of virus, but most observations were made before capsids could be adequately controlled. These insects and the fungi associated with their feeding punctures are so widespread in cacao that they must have already damaged most trees before virus infection occurred. Furthermore, Williams [4] showed that capsids and associated fungi and possibly thrips could build up and seriously damage trees already weakened by virus. Experience also shows that infected trees survive longer under favourable conditions than elsewhere. These observations suggest that the effects of virus infection in cacao are considerably influenced by other diseases and pests and also by the environment.

This thesis can now be tested in the field, since chemicals and apparatus for insect control have recently become available; the results of preliminary experiments are presented here. Typical strains of the cacao swollen-shoot viruses in Nigeria had lethal effects only when the infected trees were also attacked by capsids and fungi and particularly where they were growing under unfavourable conditions. Indeed, where capsids were not numerous or where they were controlled by routine sprays, virus infection became just another debilitating factor, of less importance than others influencing growth and yield. These results suggest a new approach to cacao swollen-shoot disease and its control in

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West Africa, in which the interaction of pests and diseases and the environment is treated as an ecological problem.

Methods

Until recently it has been impossible to obtain uniform plots of healthy trees for inoculation in formal experimental designs. Consequently, work has been restricted to observations on naturally occurring outbreaks in irregularly spaced Amelonado cacao in the Ibadan and Abeokuta Provinces of Western Nigeria.

All the outbreaks were found during routine survey operations. At each plot the trees were numbered and inspected monthly, when the presence or absence of leaf symptoms and swellings was noted by the same observer. The plots had been neglected by their owners, so that routine maintenance operations had to be carried out. Trees on certain plots were also harvested regularly and sprayed with copper fungicide and gamma B.H.C. These were applied as mists by knapsack machines, and black pod disease and the major insect pests, including capsids and thrips, were virtually eliminated.

Outbreaks were observed at Iweke, near Ilaro, in Abeokuta Province and at the following villages in Ibadan Province:

Offa-Igbo:	30 miles north-east of Ibadan, off the Iwo road.
Koroboto:	16 miles east of Ibadan, off the Ife road.
Ajia:	18 miles ,, ,, ,,
Oluwa:	14 miles ,, ,, ,,
Ajule:	15 miles ,, ,, ,,
Abuku:	18 miles south of Ibadan, off the Shagamu road.
Araromi:	18 miles ,, ,,

The Effect of Virus on Growth and Yield

Observation Plots where Capsids were not Controlled

Offa-Igbo. Capsid damage and associated dieback caused by *Calonectria rigidiucula* (Berk. & Br.) Sacc. [5, 6] were already obvious on many trees when observations commenced in 1953. Most of the virus-infected trees were more severely affected than their neighbours, but all the trees were in poor condition and had begun to decline before they became infected with virus. The canopy of fan branches was almost completely destroyed by 1956, when virus infection was almost complete and an extensive ground vegetation of grasses and herbaceous weeds had invaded the plot. This was then abandoned and in September 1958, 258 of the 296 trees were dead or moribund.

Abuku. Most of the twenty-six infected trees in this small outbreak were moribund in 1958 and no longer bore pods. However, adjacent trees were in a similar condition and the whole farm had been so severely attacked by capsids and dieback that it had been abandoned and an extensive ground vegetation allowed to develop. Elsewhere in the area, unsprayed cacao without virus was in similarly bad condition and of the few trees which were bearing pods in the 1958 main-crop season most

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Koroboto I. This plot and the one immediately alongside (Koroboto II) were in a similar condition in 1956, when most of the trees were attacked by capsids and showed dieback. Many trees were dead or moribund by 1958 and most of the survivors were infected with virus. The canopy of the trees in the open was virtually destroyed and the remaining leaves were chlorotic. Dieback was severe and an extensive ground vegetation had developed. By comparison, infected trees in the shade of kolas and oil palm still retained some of their sparse canopy branches and continued to yield. They had been infected with virulent virus strains for some years and the shade trees had apparently ameliorated the effects of virus.

Iweke. The trees at Iweke were well maintained and vigorous when virus was found there in 1953. By October 1958, 141 of the 1,490 trees had been found with symptoms, but the farm remained in good condition and similar to adjacent ones without virus symptoms. Some trees were chlorotic or showed obvious symptoms of iron deficiency. Furthermore, thrips were numerous on the leaves and pods and apparently caused some defoliation, but capsids were rare and few trees showed signs of recent damage or dieback. Under these conditions there was no obvious difference between the virus-infected trees and their neighbours. Indeed, some trees had shown virus symptoms for several years and continued to yield satisfactorily. For example, one tree which was first found with symptoms in March 1956 produced 137 pods in the 1956–7 crop season and 97 pods the following year, when yields were generally low. The infected trees produced an average of 24·8 pods per tree in the 1956–7 season and 19·5 in 1957–8. By comparison, the symptomless trees produced 21·9 and 11·7 pods per tree in the same periods. The superior performance of the infected trees in both seasons suggests that in the absence of severe capsid damage the effect of virus at Iweke is less than that due to other factors affecting growth.

Observation Plots where Capsids were Controlled

Koroboto II (sprayed since February 1956). The spread of virus has been followed on this plot since 1953, and in January 1956 most of the virus-infected trees were worse than their neighbours. Nevertheless, capsid damage and dieback were obvious on most trees and some had chlorotic leaves, particularly where the canopy had been broken and had allowed ground vegetation to develop. All the trees were subsequently sprayed monthly with gamma B.H.C. at the rate of 4 oz. per acre. Capsid damage has since been completely checked and the few trees that died included some with virus symptoms and others without (Table 1). Similar effects have been noted elsewhere in Nigeria after spraying farms where the cacao was severely damaged but virus-free. The recovery of the surviving trees was striking and most of the dead twigs and branches were lost as the trees made vigorous new growth from their remaining relatively undamaged parts.

TABLE 1. *Yields at the Koroboto II Observation Plot*

Trees first showed symptoms in:	*Mean Number of Pods per Living Tree**				
	1954–5	*1955–6*	*1956–7*	*1957–8*	*1958–9*
1953	**8·8** (49)	**6·8** (46)	**11·7** (45)	**17·7** (44)	**29·4** (43)
1953–4	**11·1** (52)	**11·4** (51)	**22·0** (50)	**20·7** (50)	**35·2** (49)
1954–5	**16·6** (69)	**11·4** (69)	**14·2** (68)	**15·6** (68)	**24·9** (68)
1955–6	20·0 (119)	**21·1** (119)	**20·4** (118)	**19·8** (117)	**28·1** (116)
1956–7	21·8 (113)	17·7 (113)	**27·5** (113)	**19·4** (112)	**21·0** (112)
1957–8	17·3 (137)	12·7 (137)	18·6 (137)	**17·2** (137)	**20·9** (135)
Symptomless	11·2 (285)	10·2 (281)	14·3 (275)	11·2 (272)	19·0 (271)
All trees	15·2 (824)	13·2 (816)	18·1 (806)	16·0 (800)	23·9 (794)

* Yields in heavy type were from trees which were showing symptoms. Twenty pods per tree, on this plot, is equivalent to approximately 720 pounds of dry cocoa per acre. The number of living trees in each category and crop season is given in parentheses.

Yield records have been taken monthly at Koroboto since August 1954 and a preliminary analysis showed that infection had not reduced the bean content of the pods or their weight. Data for the mean number of pods per tree are summarized in Table 1, in which the trees are grouped according to the year in which they were first found with symptoms. Thus, comparisons between the rows of the table are invalid as positional effects are confounded with those caused by virus. Further, there are no valid controls and some of the symptomless trees are latently infected. Others have probably escaped infection, in some instances because of their small size and limited contact with other trees. Nevertheless, the data for each group of trees in successive years indicate yield trends, and spraying against capsids has been associated with a large increase in the yield of the oldest surviving infections. By comparison, the yields of the relatively undamaged trees which were infected recently or not at all have remained relatively stable and merely indicate seasonal fluctuations. Spraying has maintained and even increased yields and checked any further deterioration in condition, even though some trees have been infected for five years and the number of infected trees increased during the spraying period from 24·4 per cent. of the total to 63·7 per cent. in July 1958.

The virus strains occurring at Koroboto vary in virulence and in the symptoms they cause. Typical ones resemble those occurring at other localities in Nigeria. Consequently the results obtained at Koroboto are probably relevant elsewhere in Nigeria, and this has already been substantiated.

Ajia I (sprayed since February 1956) and *Ajia II* (sprayed since November 1957). The virus at these adjacent plots has apparently had mild effects and trees with virus symptoms and others without were in reasonable condition when observations started on Ajia I in 1956 and on Ajia II in 1957. Capsids and dieback were rare in both plots, which were in far better condition than nearby farms without virus. Regular spraying started after the initial observations, and the trees have continued to grow and yield satisfactorily, with no evidence of any deterioration due to the unrestricted spread of virus. Indeed, each of the trees infected by 1957 produced an average of 25·7 pods in the 1956–7 crop season and 30·1 in 1957–8. By comparison, the symptomless trees produced 15·9 and 21·0 pods in the same period; a further indication that the effect of virus on yield is not so important as other factors. The differences between the yields of the trees within quite small areas here and at Koroboto are not unique and similar ones have been noted elsewhere in West Africa [7] and in clonal cacao in the West Indies [8]. They are likely to become increasingly apparent as capsids and virus are controlled and environmental factors become more obvious and important than hitherto.

Ajule (sprayed since November 1957). The farm was unsatisfactory when observations started in 1957, and capsid damage, dieback, and chlorosis were common on most of the trees, which did not form a closed canopy. However, the condition of the trees was not obviously related to the distribution of virus and some of the most severely damaged ones were remote from the nearest infection symptoms. Spraying has now checked any further deterioration and the trees are recovering, although it will be some time before the trees form a closed canopy and are fully restored.

Oluwa (sprayed since August 1958). When observations started at this farm in 1958 there was an apparent association between the condition of the trees and the incidence of virus. This was shown quantitatively using the canopy scoring system previously described [9]. Vigorous trees with a complete canopy were placed in category one, and moribund trees living only at the base, in category five. Most of the trees were in intermediate groups with obvious dieback; trees with virus symptoms were given a mean score of 3·6 compared with 2·4 for the others. However, some infected trees were in good condition and certain symptomless ones were not (Table 2). This suggests that the condition of the trees was not solely due to the presence of virus, which by chance may have largely coincided with an area of severe capsid damage or of unfavourable conditions. Alternatively, virus may have weakened the trees and caused a break in the canopy which allowed capsids to multiply and cause extensive damage [4]. The trees were sprayed first in August 1958 and virtually all trees made extensive new growth at the subsequent flushing period in October. Trees with virus symptoms, and others without, behaved similarly, and it appears that their decline has been arrested and that the farm will be greatly improved if capsid control is maintained by additional sprays applied whenever necessary.

Araromi (sprayed in August and September 1956). The monthly sprays at Koroboto, Ajia, and Ajule were intended to eliminate all complicating effects caused by insects. They were unnecessarily frequent for the control of capsids, and virus-infected trees at Araromi recovered after less drastic and expensive treatments. The 5-acre plot was sprayed with 4 oz. of gamma B.H.C. per acre in August and September 1956, as part of a large-scale capsid-control experiment [10]. Spot treatments were applied subsequently on the few occasions when additional capsids or capsid damage were found. These continued until January 1957 and recovery was followed quantitatively by monthly observation on the condition of 100 marked trees.

TABLE 2. *The Canopy Condition of Trees in an Outbreak of Swollen-shoot Disease at Oluwa*

Category	Canopy Category in July 1958					Total
	1	*2*	*3*	*4*	*5*	
No. of trees with virus symptoms in July 1958	0	8	25	19	7	59
No. of trees without virus symptoms	83	101	90	53	8	335
Total*	83 (0·0)	109 (7·9)	115 (21·7)	72 (26·4)	15 (46·6)	394 (15·0)

Categories defined by Lister and Thresh [9]; ranging from 1—virtually undamaged, to 5—moribund.

* The percentage number of virus infected trees in each canopy category is given in parentheses.

In November 1958 swollen-shoot disease was found in the plot, and infection was so extensive that some trees must have been infected from the outset of the experiment. Nevertheless, the behaviour of the forty-eight marked trees which were found with symptoms in 1958 had been similar to that of the symptomless ones (Table 3). Both groups of trees had been in virtually the same condition in 1956 and had shown a similar recovery after spraying, despite the complicating effects of virus. Indeed, there was no obvious difference between the trees with virus symptoms and the others without, and the condition of both groups was largely determined by their position in the farm. In the shaded portions, virtually all trees had recovered a full canopy of large, fully green leaves. Elsewhere, similar trees had made a less striking recovery and the leaves were small and chlorotic. Trees in the open also bore dead twigs and branches and bare shoots from which the leaves but not the stipules had fallen. This 'leafless twig' condition was not associated with virus infection and was common on unshaded trees in the whole area.

TABLE 3. *Canopy Condition of Trees in an Outbreak of Swollen-shoot Disease at Araromi, which was sprayed in August and September 1956**

Category	Mean canopy condition		
	August 1956	*August 1957*	*November 1958*
Trees with virus symptoms in November 1958 (49)	6·6	7·5	8·9
Trees without virus symptoms in November 1958 (48)	6·7	8·1	9·4

* Assessments of the extent of the canopy were made by the same observer, using the method described by Donald [10]. Trees with 1, ¾, ½, ¼, and 0 of a possible full canopy were given scores of 12, 9, 6, 3, and 0, respectively.

Discussion

The general condition of trees in the observation plots was largely determined by the incidence of capsids and the associated fungus, causing dieback, and only to a lesser extent by virus. This situation is general throughout Nigeria and the Cocoa Survey officers frequently find virus-infected farms in good condition; often similar to or better than others without virus but in the same locality. The general condition of the cacao in the abandoned areas of mass infection is also little different from that outside, where only scattered outbreaks occur. Clearly, the damage initiated by capsids is much more important and widespread than that caused by virus. Indeed, there is no evidence that typical viruses occurring in Nigeria will kill trees in well-maintained farms where capsids are controlled, or where these insects are not numerous. Under these conditions virus merely becomes a further debilitating factor in the general unthrifty condition of cacao in Nigeria.

Spraying against capsids has been introduced only recently in Nigeria and most farms are still infested, at a level which varies with site and with season. Well-maintained trees which are growing vigorously on good soil and in favourable conditions are little damaged and dieback is checked. Elsewhere, the trees may show severe dieback and pass into a progressive decline, as capsids continue to cause damage. This is accentuated by unfavourable climate, particularly when the canopy is broken and weeds invade the farms to compete for nutrients and soil moisture. By weakening the trees, virus apparently increases the probability of a decline and the rate at which this occurs. Thus the combination of virus and capsids is often lethal and has more harmful effects than either alone. The initial acute stage of virus infection when trees infected with the most virulent strains show conspicuous leaf symptoms, defoliation, and dieback, is apparently critical. Trees which are then heavily infested with capsids have less chance of survival than trees which have already passed into the relatively mild chronic phase. Environmental conditions are also important and it is likely that the effect of virus, like that of capsids [11], is partially determined by shade, soil, and other conditions.

The very great benefits to be derived from spraying against capsids are likely to become increasingly obvious in future years as more and more trees are sprayed. Indeed, extensive spraying provides a method of checking and even reversing any decline in production now caused by virus. Thus the present eradication measures against swollen-shoot disease [9, 12] may eventually be modified. However, any decision to do this cannot be taken lightly, since the most virulent strains may be lethal under atypical conditions or may have very serious effects on growth, yield, or longevity. Furthermore, therapeutic methods are not available for curing trees which become virus-infected, and unrestricted spread will inevitably result in unrelated strains occurring together and having cumulative effects.

Clearly, further work must be started to determine the precise conditions under which viruses kill trees. An approach on ecological lines is indicated in which the action and interaction of pests and diseases is considered in relation to environment. Experiments with seedlings have already been started and reasonably uniform regularly planted trees will soon be available for more precise trials.

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