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THE HISTORY AND CONTROL OF COCOA SWOLLEN SHOOT DISEASE IN NIGERIA

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That the swollen shoot condition of cocoa in Ghana is a virus disease was established by Posnette (1940) in 1938. Since then, virus diseases of cocoa have been found in Trinidad (Posnette, 1943a), Nigeria (Murray, 1945), Ivory Coast (Alibert, 1946), and Colombia (Cifferi, 1948), while symptoms probably caused by virus have been found in Venezuela (Posnette and Palma, 1944), Ceylon (Peiris, 1953), and Java (Thung, unpublished information). Cocoa virus diseases have not been found in Liberia, Sierra Leone or the Cameroons, although it has been established in Ghana that some viruses which will infect cocoa occur naturally in related plants and it is thought that cocoa viruses are probably endemic in wild hosts.

Workers in Ghana, Nigeria and the Ivory Coast have isolated a number of viruses or virus strains from diseased cocoa. The isolates are usually referred to as causing cocoa swollen shoot disease, although some of them produce only leaf symptoms and do not induce stem or root swellings. With a few exceptions, for which no vectors have been found, all the isolates are transmitted by one or more species of mealybug. Furthermore, none of the isolates has been transmitted by sap inoculation. Differences between the various isolates have been detected by observations on symptom expression (Posnette, 1947; Meiffren, 1949) and host range (Posnette, Robertson and Todd, 1950); while protection tests (Crowdy and Posnette, 1947) and vector studies have also revealed important differences.

This paper summarises the available information on the occurrence and extent of cocoa swollen shoot disease in Nigeria, and reviews the methods which have been used by the Department of Agriculture in attempts to control the disease. The paper is also intended to provide a general background to the virus research which is now proceeding at the Nigerian Substation of the West African Cocoa Research Institute and which will be reported in detail at a later date.

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THE HISTORY OF COCOA SWOLLEN SHOOT DISEASE IN NIGERIA

The first survey of Nigerian cocoa started in 1944, and it was carried out to determine the extent and location of the cocoa areas, to discover whether swollen shoot disease was present in the country, and also to record the condition of the farms and the incidence of black pod disease and capsid damage. Within a few months of the start of the survey, trees infected with swollen shoot disease were found near the village of Egbeda, 13 miles east of Ibadan. Shortly afterwards the disease was found near Olanla, 26 miles north-east of Ibadan, and many additional outbreaks were found as the survey progressed. The outbreaks were extensive when they were first discovered, and it seemed likely that swollen shoot disease had been present in Nigeria for some years.

Russell (1946) in Nigeria, and workers at the West African Cocoa Research Institute at Tafo, showed that isolates from different outbreaks had different effects on cocoa seedlings. This early work has recently been extended by Lister and Thresh (1956) and most of the isolates have been found to cause both leaf symptoms and swellings on cocoa, but some cause only leaf symptoms or swellings. Of a selection of isolates collected from widely separate areas, and judged to be representative of the range of effects produced by swollen shoot disease in Nigeria, some proved to be quite mild in their effects on seedlings, while others were very severe (Lister and Thresh, 1955). One isolate from a locality near Egbeda will sometimes kill cocoa seedlings infected at the bean stage. However, Nigerian cocoa viruses in general are less severe in their effects on the growth of mature trees than the virus from the New Juaben area of Ghana, although records of individual tree yields for farmers' cocoa near Ibadan indicate that the effects of virus infection are considerable (Lister and Thresh, 1956).

The first survey of Nigerian cocoa was completed in 1949 and the results were assessed by Johns and

Gibberd (1950), who pointed out that the disease was not present in the limited cocoa areas in the Northern and Eastern Regions of the country, and that in the Western Region most of the diseased trees were in what was then the Ibadan Division of Oyo Province. (Ibadan Division later became separated as Ibadan Province.) It was estimated that 245 square miles of cocoa land east of Ibadan were affected, with at least one outbreak of swollen shoot disease on every individual square mile block. Cocoa was not being grown exclusively over the area and individual farms were not usually more than a few acres in extent, but 250 million trees were said to be either infected or in the immediate neighbourhood of infected trees. Outside Oyo Province an isolated outbreak of swollen shoot disease had been found near Ilesha (60 miles east of Ibadan) in 1946. The following year a further isolated outbreak was found near Abeokuta (45 miles south-west of Ibadan). The virus from this locality is of special interest in producing unique leaf symptoms and, unlike all the other Nigerian isolates, it cannot be transmitted by mealybugs (Posnette, 1950). This virus has not been experimentally transmitted by any insect, although spread appears to occur in the field and the virus has recently been found on cocoa at several villages around the original place of discovery. From a detailed comparison of the virus isolates from these villages with the more usually occurring strains of swollen shoot virus, it is considered justifiable to consider the virus from Abeokuta to be completely distinct, and the name cocoa necrosis virus has been proposed (Thresh, 1957).

Since 1950, further assessments have been made annually by the staff of the Western Region Department of Agriculture and these were summarised at the 1951 and 1953 cocoa conferences (Johns and Gibberd, 1951; Allnutt, 1953). Additional centres of infection were found in further inspections. Many of these apparently new outbreaks occurred in the neighbourhood of previously observed centres of infection and it seems likely that at least some of the smaller ones had developed between successive inspections. Others, however, were not obviously related to previous outbreaks, and some were in localities in which swollen shoot had not previously been reported. The isolated outbreak which was found near Ife in 1952 was in a locality 15 miles from the Ilesha outbreak and about 20 miles from the nearest infection in Ibadan Province. The origin of such outbreaks is obscure but some of them were so extensive when first reported that they could not have developed in the interval between successive inspections and they had clearly been missed by previous inspection parties. Near Ilaro, for example, a second and detailed survey in 1952 revealed a large number of scattered outbreaks over an area of about 36 square miles.

TABLE 1

THE NUMBER OF VILLAGES WHERE OUTBREAKS OF COCOA VIRUS HAVE BEEN FOUND IN EACH OF THE MAIN COCOA AREAS OF THE WESTERN REGION OF NIGERIA

Province	*Acreage in production**	*Mean annual production† in tons*	*Number of known centres of*	
			Swollen shoot virus	*Cocoa necrosis virus*
ABEOKUTA	115,489	16,909	6‡	8‡
IBADAN	221,297	29,134	132‡	1‡
IJEBU	30,034	10,502	0	2
LAGOS	4,147	1,956	0	0
ONDO	442,365	22,589	0	0
OYO	140,608	19,242	2	0
TOTAL	953,940	100,332	140	11

* An estimate of the acreage of trees greater than five years old in 1956.

† Based on the yields of dry cocoa recorded during each of the last five full seasons.

‡ Recorded outside the area of mass infection before April, 1957.

It will be seen from the maps that swollen shoot disease has been found in cocoa in four of the Provinces in which it is grown in the Western Region. In Oyo and Ijebu-Ode Provinces only a few scattered outbreaks have been found (Table 1) and the disease is no more than a potential threat in these areas; but in Abeokuta and Ibadan Provinces large areas of infected cocoa occur and the disease is an important factor influencing productivity. In the absence of any detailed information on the present extent of infection in the heavily infected areas and on the effects of virus infection on yield, it is difficult to estimate the financial loss caused by swollen shoot disease in Nigeria. However, this cannot be less than one-third of a million pounds each year. The annual cost of the inspection service alone amounts to some £170,000 and in addition, during each of the last five years, an average total of £11,000 has been paid to the farmers as compensation for the loss of trees removed in applying the routine control measures to be discussed in later sections of this paper. Furthermore, if virus reduces the overall yield of the cocoa in Ibadan and Abeokuta Provinces by only 1% each

year, this amounts to some 500 tons of dry cocoa (Table 1) worth approximately £100,000 at present prices.

THE CONTROL OF SWOLLEN SHOOT DISEASE IN NIGERIA

Resistant or tolerant varieties, mild strains of virus, biological control and insecticides may all be used in the future, but at the present time the general method of controlling swollen shoot disease is to remove all the infected trees as they are discovered, and in this way try to stop spread by eliminating the obvious sources of infection. The difficulties in applying this method in West Africa are very great, as it is necessary to have a large and adequately supervised staff who are familiar with the various symptoms of swollen shoot disease and are able to make thorough inspections of all the cocoa areas at regular intervals. Despite these difficulties, the cutting out of diseased trees has been the basic method of control adopted at the Central Cocoa Research Station (Posnette, 1943b), the West African Cocoa Research Station (Benstead, 1953), and on a large scale by the Departments of Agriculture in Ghana (Moss, 1953), and Nigeria (Johns and Gibberd, 1951). The work in Nigeria can conveniently be discussed in three phases:—

(1) The period from February, 1946, to June, 1950, when the policy was to remove only the infected trees, and sometimes also the apparently healthy ones in contact with them or immediately adjacent.

(2) The period from June, 1950, to March, 1955, when in addition to the infected trees all apparently healthy trees were cut out to a distance of thirty yards from the nearest infection.

(3) The period from March, 1955, during which time the treatments have been carried out in close association with the staff of the W.A.C.R.I. Substation and have usually involved the removal of all obviously infected trees and the coppicing of all apparently healthy trees to a distance of thirty yards from the nearest infection.

The Period from February, 1946, to June, 1950

The cutting out of infected trees started soon after the discovery of cocoa swollen shoot virus in Nigeria, and between February, 1946, and June, 1950, 1½ million trees were destroyed in an attempt to eradicate the disease. All outbreaks were treated as soon as possible after they had been discovered, and the policy initially adopted was to cut out only trees with symptoms, despite the fact that some of the adjacent apparently healthy trees were likely to be infected. No compensation for the loss of diseased trees was being paid at the time, however, and it was considered undesirable to antagonise the farmers by removing trees on which no symptoms could be found. After the initial treatment the trees surrounding a cut-out area were re-inspected every three months and additional infections were cut out as they were discovered. Only the smallest outbreaks were controlled by the initial treatment and usually additional infected trees were found during one or more of the re-inspections. Nevertheless, from the available data it is apparent that the number of trees cut out in the retreatment of outbreaks was very small compared with the number removed at the outset (Table 2).

The cutting-out campaign progressed on an increasing scale until 1948, and until that time all the known and isolated outbreaks were treated as discovered, while in the heavily infected localities particular attention was given to the main centres of infection, round which the cutting-out groups were concentrated. The intention was to check the outward spread of the disease and advance into the main centres of infection until these had been eliminated. It was estimated that 200,000 infected trees remained to be destroyed in 1948 (Roberts, 1948), when in May of that year work in the main swollen shoot areas was stopped, because of the opposition of the farmers to the cutting-out campaign. Opposition had been building up for some months, despite the fact that compensation was then being paid for the loss of diseased trees.

When the inspection and cutting-out parties returned to the infected parts of Ibadan Province in February, 1949, it was soon realised that the situation had deteriorated and that far more than the estimated 200,000 trees remained to be cut out. Additional infected trees were found in the vicinity of many outbreaks which had previously been treated. Furthermore, many new outbreaks were found, some of them in parts of the Province which appeared to be clear of infection at the time of the first survey. It seemed likely that some of the newly discovered outbreaks had developed since this first inspection. Others had probably been missed, as they were found in previously unrecorded farms and were extensive when first detected. Some of the difficulties experienced by the cocoa survey parties have been described by

TABLE 2

SUMMARY OF THE CUTTING-OUT TREATMENTS CARRIED OUT IN NIGERIA FROM FEBRUARY 1946 TO JUNE 1950

Period	*Initial treatments*		*Retreatments*		*All treatments*	
	Farms involved	*Infected trees cut out*	*Farms involved*	*Infected trees cut out*	*Farms involved*	*Infected trees cut out*
January—March 1946	17	4,563	0	0	17	4,563
April —June 1946	*	*	*	*	*	4,571
July —September 1946	*	*	*	*	44	4,975
October—December 1946	45	*	18	*	63	7,459
January—March 1947	78	19,448	73	701	151	20,149
April —June 1947	106	47,344	106	2,963	212	50,307
July —September 1947	131	57,538	155	2,016	286	59,554
October—December 1947	110	65,225	233	4,035	343	69,260
January—March 1948	133	123,432	293	2,979	326	126,411
April —June 1948†	*	146,590	*	4,272	*	150,862
July —September 1948†	*	26,524	*	297	*	26,821
October—December 1948†	*	*	*	*	*	33
January—March 1949	*	*	*	*	*	95,892
April —June 1949	*	*	*	*	*	183,630
July —September 1949	*	*	*	*	*	257,064
October—December 1949	*	*	*	*	*	175,065
January—March 1950	*	*	*	*	*	180,307
April —June 1950	*	*	*	*	*	96,515
Total	*	*	*	*	*	**1,513,438**

* Data not available.

† Cutting-out operations abandoned in certain areas due to opposition.

Hadland (1951), and it was hardly surprising that infected trees and even large outbreaks were missed. At the outset of the work there were no detailed maps of the cocoa-growing areas, and the survey staff received little co-operation from the farmers in their attempts to locate and inspect the farms, which were often small and dispersed over large areas of difficult country.

Efforts to bring swollen shoot disease under control were intensified in 1949 and additional survey and supervisory staff were employed. The survey system was reorganised and the survey staff began operating in groups instead of individually, moving through the cocoa areas locality by locality and ignoring individual farm boundaries. Previously, the survey staff had inspected the cocoa areas farm by farm, and spent a

good deal of time tracing ownership and farm boundaries. It was possible to keep the survey parties under close supervision when they were working under this new "block survey" system and there was a corresponding increase in efficiency. It also became possible to cut out the apparently healthy trees adjacent to the infected ones. These changes made the control measures more efficient, but the cutting-out parties were still unable to deal with all the new virus outbreaks as they were discovered, and as a result the re-inspections and retreatments were also delayed. It soon became obvious that the complete eradication of swollen shoot disease from Nigeria would be an even greater undertaking than had been anticipated and would involve further increases in staff and the payment of very large sums of money in compensation to the farmers for loss of diseased trees.

After a full review of the situation in February, 1950, Johns and Gibberd (1950) proposed that no further efforts should be made to control swollen shoot disease in the heavily infected parts of Ibadan Province, but that, instead, efforts should be concentrated on keeping the remaining cocoa-growing areas free from the disease. It was realised that the uninterrupted spread of swollen shoot disease in an extensive part of Ibadan Province was likely to lead to a progressive decline in yields in that area and also that many infected trees would remain as sources of infection for some years. However, it seemed from experience in Ghana (West, 1950) that in heavily infected areas swollen shoot disease could only be controlled by the virtual elimination of all the cocoa. This would obviously be an unpopular measure with the Nigerian farmers. Moreover, it would be costly and difficult to carry out, and would cause grave economic crises in the many villages around Ibadan which relied on cocoa to provide their main source of income. For these and other reasons the new proposals were accepted, and in June, 1950, activities were abandoned in the heavily infected parts of Ibadan Province, which became known as the "area of mass infection."

The Period from July, 1950, to March, 1955

The revised measures for the control of swollen shoot disease were introduced in July, 1950, and at the same time the survey system was completely reorganised. Once the precise limits of the area of mass infection had been established, no regular surveys of the farms in this area were carried out, but the adjacent cocoa was inspected at intervals of six months and the more remote cocoa every year. Outbreaks of swollen shoot disease found outside the area of mass infection were treated immediately, and a new cutting-out policy was adopted in an effort to confine the disease to the abandoned area. Not only the infected trees were cut out but also all the apparently healthy ones within a distance of thirty yards from the nearest infection. It was hoped that this more drastic treatment would deal with the latent and missed infections which are inevitably left behind at many outbreaks when only those trees found with symptoms are cut out. The standing cocoa around the sites of treated outbreaks was re-inspected at three-monthly intervals and any additional infections were treated as new outbreaks, so that further apparently healthy trees were destroyed.

The area of mass infection as established in 1951 was about 479,000 acres in extent. The proportion of this land under cocoa ranged from less than 5% in certain localities to more than 60% in others, and all the cocoa was either infected or in the neighbourhood of infected trees. At the time the provisional boundaries were made it was hoped that the amount of abandoned cocoa would be progressively reduced by gradually moving into the heavily infected area and treating outbreaks as they were encountered. With this end in view it was intended that the cocoa immediately within the boundary of the area of mass infection should be inspected from time to time and control measures applied wherever this was practicable. Furthermore, it was thought that the cocoa on 100,000 acres of land north and east of Ibadan was less heavily infected than the other parts of the area of mass infection and the possibility of bringing the disease under control in this area was also considered. However, a detailed inspection which was completed in 1952 showed that infection was heavier than expected, and it became clear that any reduction in the area of mass infection would be difficult to achieve. Not only was it found necessary to abandon control measures in the area north and east of Ibadan, but minor boundary adjustments had to be made which actually increased the area of mass infection.

The belt of cocoa round the perimeter of the area of mass infection was inspected at six-monthly intervals and became known as the area of intensive survey (sometimes referred to as the "cordon sanitaire"). It was hoped that the application of control measures in this belt would check the spread of virus into the more remote and hitherto healthy cocoa. The depth of the area of intensive survey varied according to the importance of the cocoa it was intended to protect. East of the area of mass infection the protective belt was several miles wide, as it adjoined the extensive cocoa-growing areas around Ife, Ilesha and Ondo, while to the north an area of intensive survey

was unnecessary, as little cocoa was to be found beyond the heavily infected area, the boundary of which closely followed that of the lowland rain forest. As far as possible the boundaries to the area of mass infection and the area of intensive survey followed easily recognisable features such as roads, railways, rivers and the margins of forest reserves (Plates XXV and XXVI).

At the time the area of intensive survey was established in 1950, outbreaks of cocoa swollen shoot disease had already been found in the cocoa around three of the villages which were included in the area, and in 1950, virus outbreaks were found in the cocoa around six additional villages. Nevertheless, little difficulty was anticipated in confining the disease to the abandoned area and it was not expected that the drastic cutting-out treatment would have to be applied on any extensive scale.

These expectations were not realised and each year since 1950 apparently new virus outbreaks have been found at additional villages in the area of intensive survey and in some instances outside it. Furthermore, re-inspection of the cocoa around villages where swollen shoot disease had already been found often revealed further infection which necessitated additional cutting-out treatments. The present known distribution of cocoa viruses in the Western Region of Nigeria is shown in Plates XXIV-XXVI, which should be compared with maps prepared for previous conferences (Johns and Gibberd, 1950; Johns and Gibberd, 1951; Allnutt, 1953).

The progressively increasing scale of the cutting-out operations is shown in Table 3 and also in Plate XXVII which gives the number of so-called initial treatments and retreatments carried out each year since 1947 in the cocoa outside the abandoned areas. The term " initial treatment " indicates the first cutting-out operation carried out in the cocoa around a village, whereas the term " retreatment " refers to additional cutting-out operations near a village where infected trees have already been detected and removed. It is apparent from Plate XXVII that the number of villages in which swollen shoot has been known to occur has increased markedly in recent years, despite the fact that the cocoa around them has been under continuous routine inspection for almost ten years. This indicates that new outbreaks continue to arise, presumably as a result of the movement of mealybugs from distant sources of infection or perhaps from wild hosts. However, the true rate of increase of infection in the areas of intensive survey is difficult to estimate and probably differs from the apparent one, because the survey parties cannot detect all outbreaks of swollen shoot disease while these are still at an early stage of development.

Between 1947 and 1956, 126 initial treatments were carried out and the large numbers of infected trees present in some of the newly discovered outbreaks indicate that many of them had been missed for some years. This conclusion is substantiated by the data summarised in Plate XXVIII, which gives the frequency distribution of the number of infected trees involved in the initial treatments and retreatments carried out between 1947 and 1956. It will be seen that 30% of all the initial treatments involved more than 100 infected trees at each village and some of them involved more than 1,000 infected trees and must have been missed for many years. By comparison, only 8% of the retreatments involved more than 100 infected trees at each centre and most of them involved less than 11. This big difference in the efficiency with which infected trees are detected is largely due to the method of survey, as once an outbreak has been found and treated, the surrounding cocoa is examined every three months by special survey groups. These are under the close supervision of senior staff and are additional to those responsible for the routine survey every six months. Thus further outbreaks on the edge of ones which have already been treated are more likely to be detected than outbreaks of comparable size in areas where swollen shoot disease has not been reported. It seems certain, therefore, that if all the cocoa areas were thoroughly inspected by experienced and closely supervised survey parties, additional virus outbreaks would be discovered, although the repeated failure to detect virus in certain areas does indicate that virus is not present in them.

The difficulties experienced by the survey parties in detecting virus outbreaks are illustrated by the events leading to the establishment of the area of mass infection in the Egbado Division of Abeokuta Province. As a result of the first survey carried out in this area, it was believed to be free from infection and a subsequent report of the presence of virus was not confirmed. Yet a second survey of the Division completed in 1953 revealed that infection was widespread over an area of approximately 36 square miles and it seemed likely that infection had been present but undetected for at least five years. A detailed assessment revealed that infected trees were scattered throughout the affected area and it was estimated that about 2% of the trees were showing symptoms. As the infected trees were in good cocoa and it was found that the local farmers were uncooperative, a decision was made not to carry on with the usual cutting-out treatments and a second area of mass infection was established in 1953 (Plates XXIV and XXVI).

This decision to abandon a second area of cocoa

MAP OF THE SOUTH WESTERN PROVINCES OF NIGERIA SHOWING THE KNOWN DISTRIBUTION OF COCOA VIRUSES IN MARCH 1957

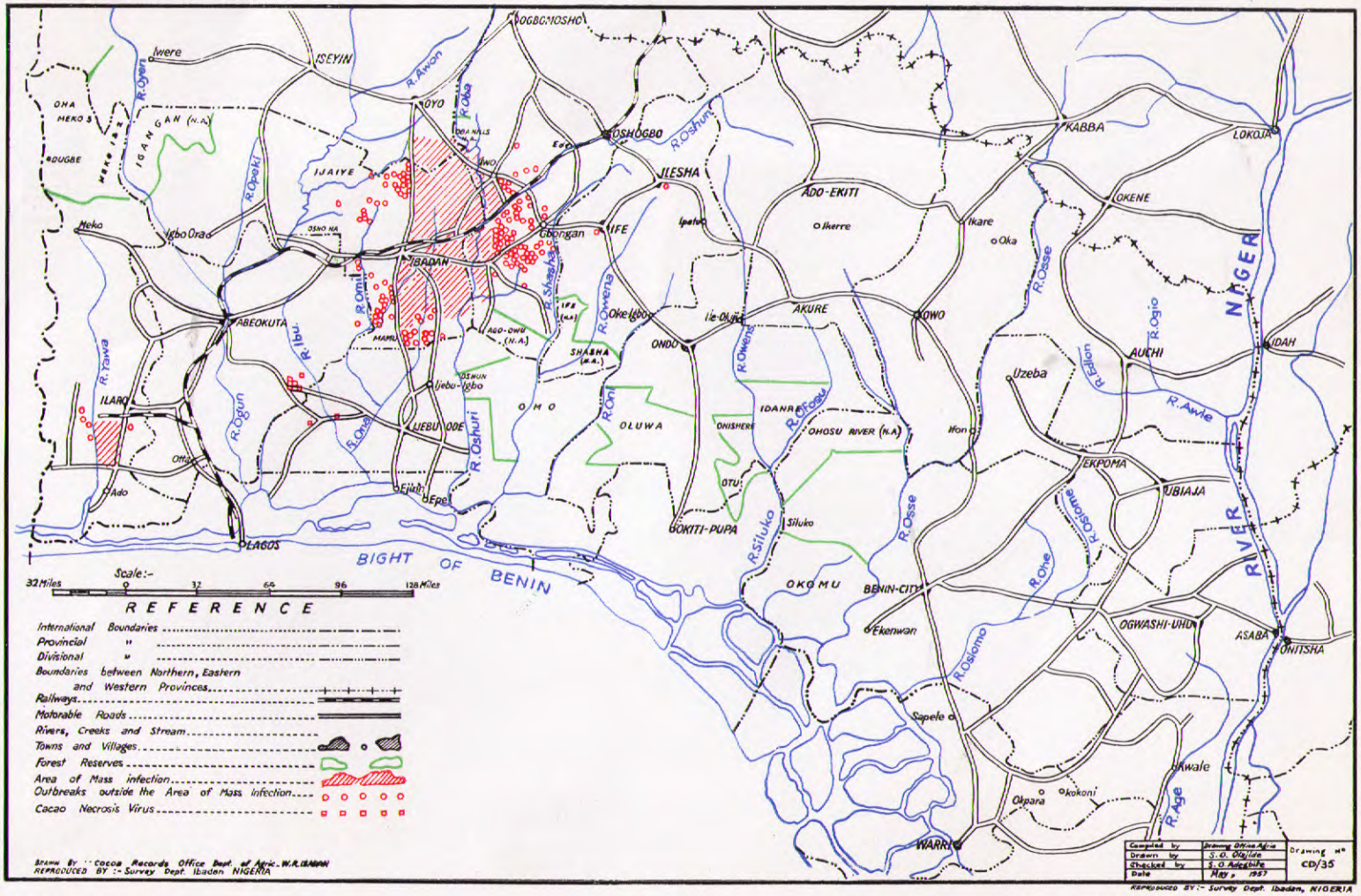

Plate XXIV

Paper by Mr. R. M. Lister and Mr. J. M. Thresh

MAP OF IBADAN AND OYO PROVINCES SHOWING THE DISTRIBUTION OF COCOA VIRUSES AND THE IBADAN AREA OF MASS INFECTION

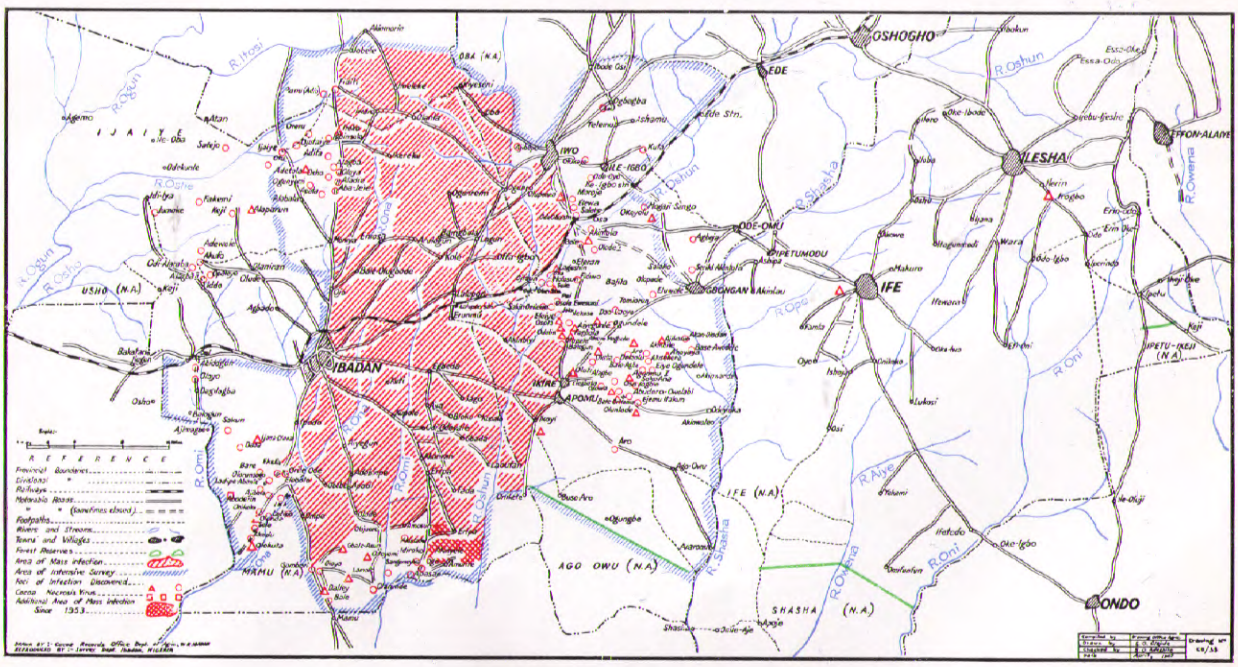

Plate XXV

Paper by Mr. R. M. Lister and Mr. J. M. Thresh

MAP OF ABEOKUTA AND IJEBU PROVINCES SHOWING THE DISTRIBUTION OF COCOA VIRUSES AND THE ILARO AREA OF MASS INFECTION

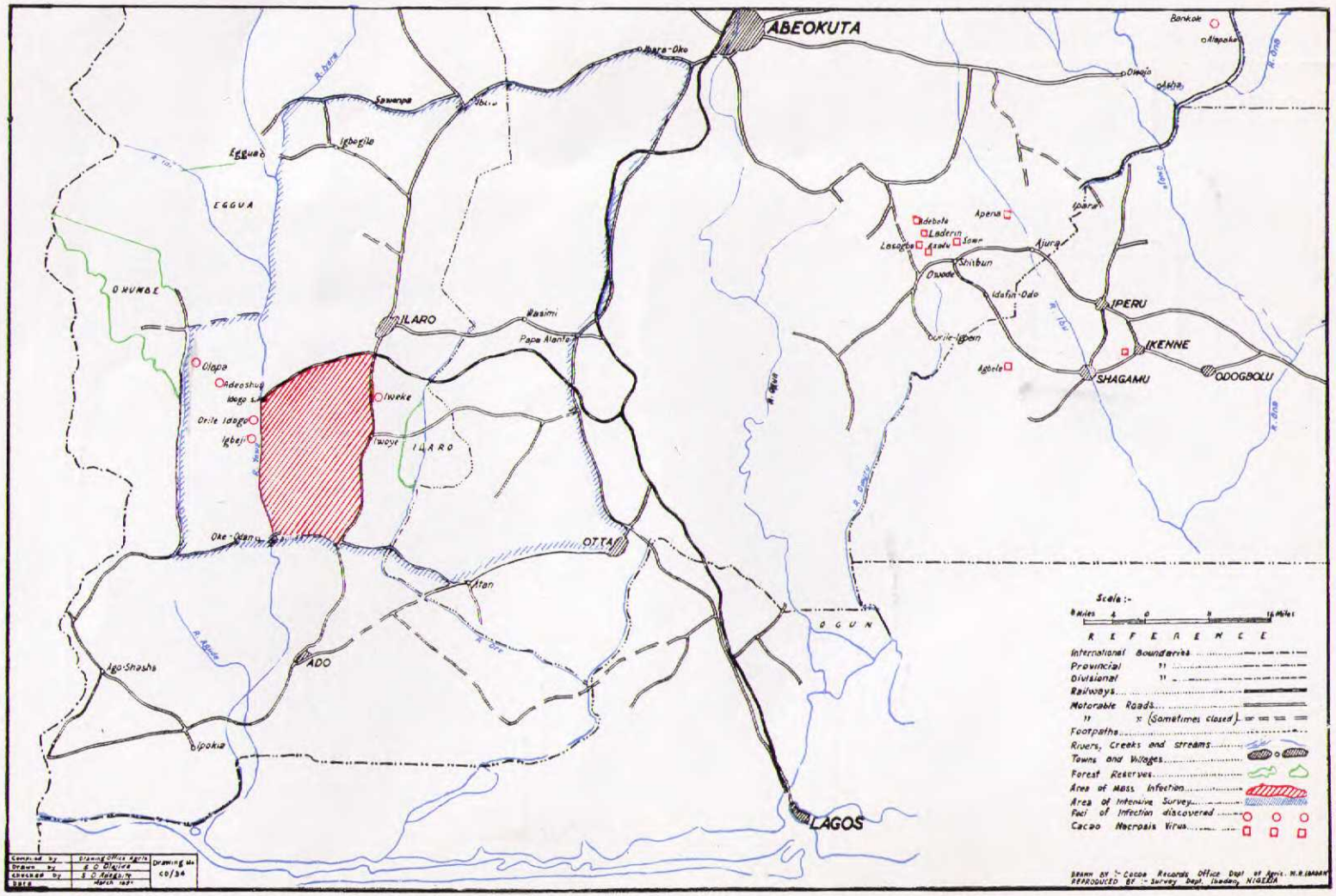

Plate XXVI

Paper by Mr. R. M. Lister and Mr. J. M. Thresh

SWOLLEN SHOOT DISEASE IN NIGERIA

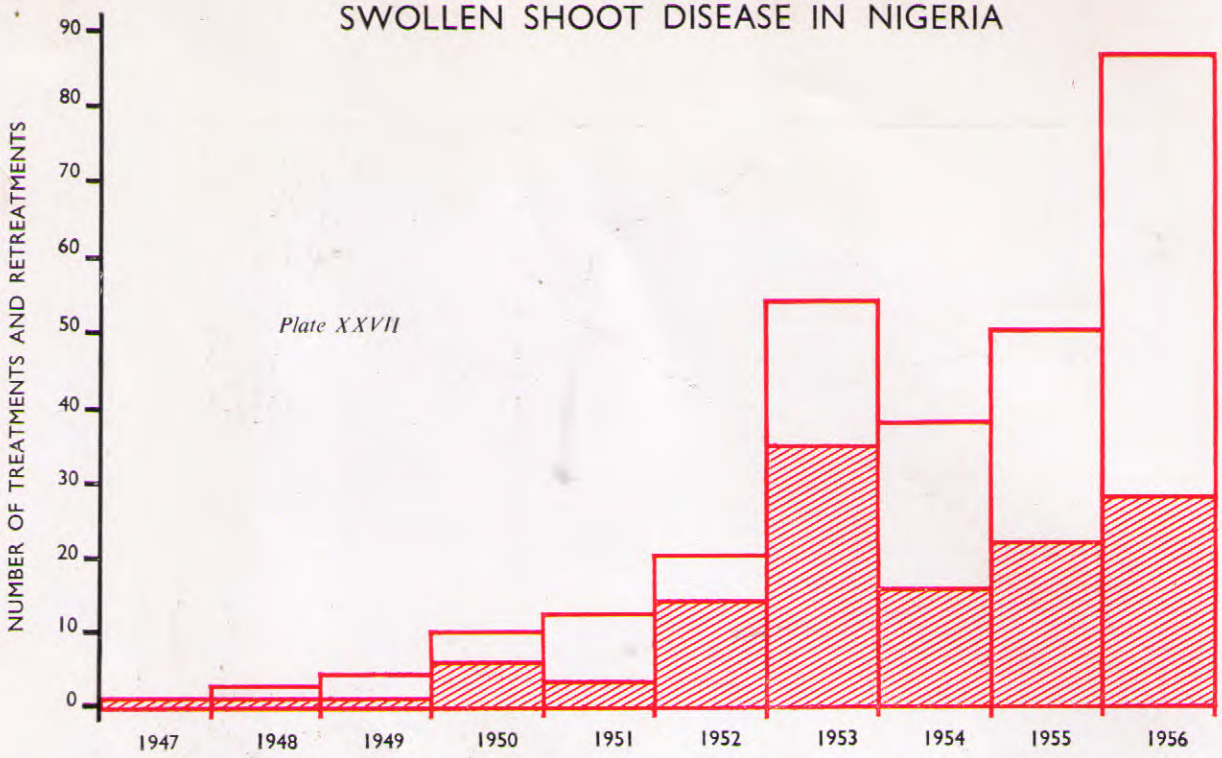

Plate XXVII

HISTOGRAM SHOWING THE TOTAL NUMBER OF INITIAL TREATMENTS AND RETREATMENTS CARRIED OUT OUTSIDE THE AREAS OF MASS INFECTION EACH YEAR SINCE 1947

(Number of initial treatments shown by cross hatching)

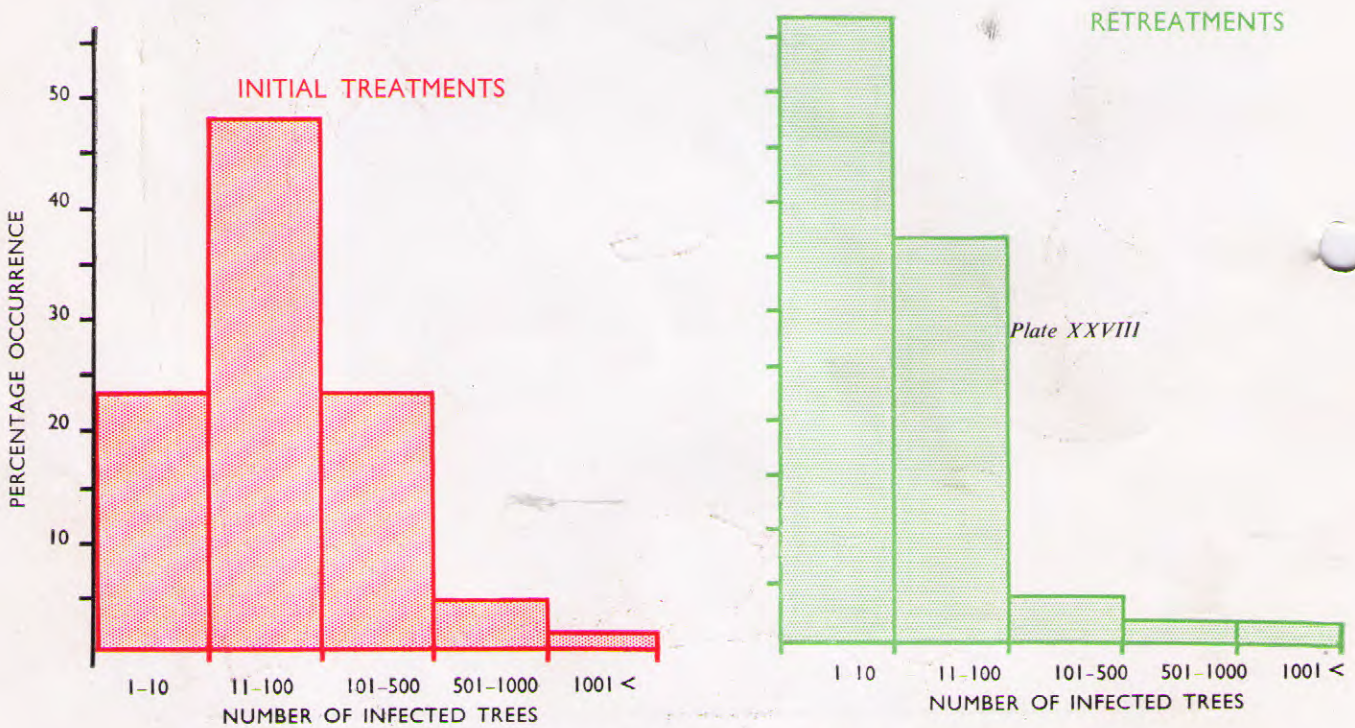

Plate XXVIII

FREQUENCY DISTRIBUTION OF THE NUMBER OF INFECTED TREES INVOLVED IN THE 126 INITIAL TREATMENTS AND 155 RETREATMENTS CARRIED OUT OUTSIDE THE AREAS OF MASS INFECTION SINCE 1946

Paper by Mr. R. M. Lister and Mr. J. M. Thresh

TABLE 3

SUMMARY OF THE CUTTING-OUT TREATMENTS CARRIED OUT OUTSIDE THE AREAS OF MASS INFECTION, 1947-1956

Year	*Initial treatments*					*Retreatment*					*All treatments*				
	Infected trees grubbed	*Apparently healthy trees*			*Total cut*	*Infected trees grubbed*	*Apparently healthy trees*			*Total cut*	*Infected trees grubbed*	*Apparently healthy trees*			*Total cut*
		Grubbed	*Coppiced*	*Total*			*Grubbed*	*Coppiced*	*Total*			*Grubbed*	*Coppiced*	*Total*	
1947	15	130	0	130	145	0	0	0	0	0	15	130	0	130	145
1948	11	93	0	93	104	3	6	0	6	9	14	99	0	99	113
1949	3	48	0	48	51	171	1,706	0	1,706	1,877	174	1,754	0	1,754	1,928
1950	292	3,419	0	3,419	3,711	184	1,853	0	1,853	2,037	476	5,272	0	5,272	5,748
1951	1,688	10,867	0	10,867	12,555	99	6,072	0	6,072	6,171	1,787	16,939	0	16,939	18,726
1952	1,887	24,783	0	24,783	26,670	140	8,196	0	8,196	8,336	2,027	32,979	0	32,979	35,006
1953	2,677	24,991	0	24,991	27,668	943	22,849	0	22,849	23,792	3,620	47,840	0	47,840	51,460
1954	1,218	16,481	2,927	19,408	20,626	1,788	19,685	4,201	23,886	25,674	3,006	36,166	7,128	43,294	46,300
1955	2,325	8,935	11,851	20,786	23,111	2,678	5,948	25,185	31,133	33,811	5,003	14,883	37,036	51,919	56,922
1956	8,552	9,022	31,003	40,025	48,577	3,851	8,565	28,110	36,675	40,526	12,403	17,587	59,113	76,700	89,103
Total	18,668	98,769	45,781	144,550	163,218	9,857	74,880	57,496	132,376	142,233	28,525	173,649	103,277	276,926	305,451

and the discovery of virus at 98 additional villages in the five years after the first area of mass infection was established indicate that the control measures introduced in 1950 have not been entirely successful in preventing the spread of virus into the areas which were originally free from infection. This deterioration in the position is only partly due to the discovery of outbreaks which had been missed during previous surveys and it is difficult to avoid the conclusion that virus is spreading at an increasing rate into the areas of intensive survey from the heavily infected cocoa in the localities in which control measures have been abandoned. That spread occurs in this way is indicated by the grouping of newly discovered outbreaks around the areas of mass infection, and as mealybugs are known to be carried and dispersed by wind currents (Strickland, 1950; Cornwell, 1956) this provides an obvious explanation of the way in which this type of spread takes place. Virus has spread without check in the areas of mass infection and in recent years infection has become increasingly obvious, so that the source of inoculum and number of mealybugs likely to be carrying virus has increased progressively. (In one observation plot in the area of mass infection near Ibadan, the proportion of trees with symptoms increased steadily from about 6% in 1953 to nearly 100% in 1955.) Moreover, the cycle of infection in the abandoned areas is being continued by the farmers who continue to plant available areas with cocoa, which is often near or even alongside mature cocoa already infected with virus. This means that, unless a new policy of dealing with the areas of mass infection is introduced, they will continue to act as dangerous sources of virus and increasing difficulty will be experienced in maintaining the adjacent cocoa free or relatively free from infection.

The efficiency with which the cutting-out measures have checked the spread and build-up of virus in the areas of intensive survey is difficult to evaluate, as there is little indication of the extent to which the disease would have spread if no control measures had been practised. However, it seems certain that further large acreages of cocoa would have become heavily infected if the 28,525 infected trees found outside the areas of mass infection by the end of 1956 had been allowed to remain and act as additional foci of infection. An analysis of the records kept by the Department of Agriculture also shows that the cutting-out measures have achieved considerable success and have resulted in the elimination of disease at many localities where it has been found. Of the 76 villages where outbreaks were treated (and where necessary retreated) in the areas of intensive survey between 1947 and 1954, virus appears to have been completely eliminated from the cocoa around 43 of them, as no additional infected trees were found in 1955 or 1956. Infected trees have not been found at 11 other villages since 1955 and virus also seems to have been eliminated from these localities. At the remaining 22 villages infected trees have been found within the last year, so the control measures have not yet been successful. It may be that at some of these 22 villages the originally treated outbreaks were eliminated in the early cutting-out operations and the apparent failure of the measures was due to the subsequent formation of completely separate outbreaks by spread, not from the original centre, but from an outside source.

The policy of treating outbreaks by removing infected trees and the apparently healthy ones to a distance of thirty yards meant that the partial success of the control measures was only achieved at the expense of large numbers of apparently healthy trees. This is shown by the data summarised in Tables 3 and 4, which give details of treatments carried out between 1947 and 1956, when an average of ten apparently healthy trees were destroyed for every one found with symptoms. As might be expected, this ratio was at a maximum for treatments involving small numbers of infected trees and at a minimum for treatments involving the largest outbreaks (Table 4). The ratio of apparently healthy trees to those found with symptoms was also higher for retreatments than it was for initial treatments, due to the smaller number of infected trees involved in the former.

TABLE 4

RATIO OF APPARENTLY HEALTHY TREES CUT OUT TO THE NUMBER INFECTED ON TREATING OUTBREAKS OF SWOLLEN SHOOT DISEASE OF DIFFERENT SIZE*

Number of infected trees in outbreak	*Number of outbreaks treated*	*Total number of*		*Ratio of apparently healthy to infected*
		Infected trees cut out	*Apparently healthy trees cut out*	
1– 10	116	444	26,432	59 : 1
11– 100	116	3,811	88,096	23 : 1
101–1,000	44	14,338	121,072	8 : 1
1,001–	5	9,932	41,326	4 : 1
TOTAL	281	28,525	276,926	10 : 1

*An analysis of the data presented in Table 3 for all treatments and retreatments carried out outside the areas of mass infection between 1947 and 1956.

At the time the revised control measures were introduced in 1950, there was little evidence to indicate whether the removal of large numbers of apparently healthy trees was justified in treating Nigerian outbreaks of swollen shoot disease. The decision to treat outbreaks of all sizes to a distance of thirty yards was therefore largely an arbitrary one. In 1953, however, the West African Cocoa Research Institute Substation was established in Nigeria and the following year a series of coppicing experiments was started to determine whether the thirty-yard cut-outs were necessary, or whether a similar degree of control could be obtained by less drastic methods. The results of the first experiments have already been reported (Lister and Thresh, 1956) and show that relatively few of the apparently healthy trees were found to have been infected at the time they were coppiced. This immediately suggested that less drastic cutting-out treatments could be adopted. However, it was concluded that the data was insufficient to justify a complete change in the control measures and it was decided that the coppicing experiments should be continued and extended on a large scale. After March, 1955, therefore, all the apparently healthy trees involved in swollen shoot treatments were coppiced and not cut out as in the previous system. The results obtained in this phase of the control operations are described in the following section.

The Period since March, 1955

In March, 1955, coppicing was accepted as a routine part of the control measures against swollen shoot disease and by August, 1956, a total of 123 areas had been coppiced by the Department of Agriculture in treating outbreaks totalling 7,810 infected trees. All the obviously infected trees involved in these treatments were cut out and the adjacent apparently healthy trees were coppiced to the usual distance of thirty yards. Most of the treatments involved less than 100 infected trees and an average of 24 apparently healthy trees were coppiced for every tree found with symptoms.

The new growth from the coppiced stumps was inspected every three months and all the infections which were found were uprooted and a record made of their number and distribution in relation to the infected trees which had been detected and uprooted at the time of coppicing. The number of stumps which failed to regenerate varied from site to site, but most of them produced rapidly growing chupons which usually showed very obvious symptoms if the trees had been infected at the time they were cut back. By February, 1957, chupons with symptoms had been found on 1,200 of the 187,979 coppiced stumps. This figure was lower than expected due to the complete failure of some of the infected stumps to regenerate and also to the fact that some of the re-inspection data were incomplete. However, it seemed clear that most of the coppiced trees were free from virus and the provisional results were in agreement with those of the preliminary experiments started in 1954.

In August, 1956, it was decided to revise the treatment methods and for a trial period these were made less drastic. Discrete outbreaks of from 1 to 10 infected trees were treated to a distance of five yards from the nearest infection, outbreaks of from 11 to 50 infected trees were treated to fifteen yards and the larger outbreaks were treated to thirty yards. By the end of December, 1956, 46 treatments had been carried out using the revised methods and 21,168 apparently healthy trees were coppiced in treating outbreaks totalling 4,418 infected trees. It is estimated that an additional 12,180 apparently healthy trees would have been cut out if the former treatment methods had been employed. This represents a saving in only four months of approximately £2,500 in compensation at the usual rate of 4s. per tree and there were also considerable savings in the time and ease with which the marking and cutting operations were carried out.

In a detailed analysis of the results of the coppicing experiments it has recently been established that virtually all the infected stumps occurred within five yards of the original infection, where this had consisted of from 1 to 10 trees. By comparison, about two-thirds of the infected stumps occurred within five yards of the original infected trees where these numbered from 11 to 50 infected trees; while around the larger outbreaks only about half the infected stumps occurred within five yards. It seems clear, therefore, that not only do latent and missed infections occur in greater numbers around large outbreaks but they also occur to a greater distance from the original infection. This result is consistent with observations made in Ghana and in Nigeria that small outbreaks are more readily controlled than large ones. It also gives some justification for the policy of treating outbreaks according to their size. Nevertheless, even around the largest outbreaks the probability of apparently healthy trees being infected is very low if they occur more than fifteen yards away from the original infection, and it seems that further changes are justified to make the control measures still less drastic.

The changes which have been proposed will not

involve the treatment of the smallest outbreaks, but those consisting of from 11 to 50 infected trees will be treated to 10 yards instead of 15 and the larger outbreaks will be treated to 15 yards instead of 30. In the treatment of an outbreak the number of apparently healthy trees involved tends to increase as the square of the distance to which they are cut. This means that if the new proposals are adopted by the Department of Agriculture there will be further and very considerable savings in carrying out the routine control measures against swollen shoot disease. Virus outbreaks will be controlled less readily by the proposed methods and it seems that infection will be encountered with some frequency amongst the standing trees on the edge of treated areas. However, the results of the coppicing experiments indicate that any retreatments which are necessary are unlikely to involve more than a small proportion of the perimeter trees and there seems little justification for continuing to include all these in the drastic initial cutting-out treatments involving the destruction of all apparently healthy trees to a distance of 30 yards. It follows that using the W.A.C.R.I. recommendations individual outbreaks are likely to be controlled more economically than at present. Nevertheless, the overall success of the control measures will largely depend on the efficiency of the survey parties in detecting new outbreaks and on the policy adopted for dealing with the abandoned cocoa in the areas of mass infection.

SUMMARY

Swollen shoot disease was first found in Nigeria in 1944, soon after the start of the first survey of the cocoa areas. The disease has not yet been found in the limited cocoa grown in the Eastern and Northern Regions of the country and infection appears to be confined to the Western Region, where outbreaks are known to occur in four of the Provinces in which cocoa is grown. Only scattered outbreaks have been found in two of these Provinces, but around Ilaro and Ibadan the disease is widespread and there are large areas of heavily infected cocoa.

The removal of infected trees has been the basic method of control adopted in Nigeria from the outset, and between 1946 and 1950, 1½ million infected trees were destroyed in an unsuccessful effort to eradicate swollen shoot disease from the country. It was then realised that complete eradication of the disease would be impossible, and control measures were abandoned in one heavily infected area in 1950 and in a second in 1953. Outbreaks occurring in the cocoa outside these abandoned areas were treated as they were discovered by uprooting all the obviously infected trees and also the surrounding area of apparently healthy trees to a distance of thirty yards from the nearest infection. Increasing difficulty is being experienced in restricting the disease to the abandoned cocoa and it appears that virus is spreading into the surrounding areas of healthy cocoa at an increasing rate. Nevertheless, the control measures have achieved some success and the cocoa outside the areas of mass infection is still relatively free of virus.

This success has been achieved at the expense of large numbers of apparently healthy trees and an average of ten have been destroyed for every tree found with symptoms. However, recent coppicing experiments have shown that the policy of treating outbreaks of all sizes to a distance of thirty yards can be made much less drastic with little loss in efficiency. It has been recommended that in future all obviously infected trees should be removed and also the adjacent apparently healthy trees—to a distance of five yards where an outbreak consists of a discrete group of 1 to 10 infected trees, to a distance of ten yards where an outbreak consists of from 11 to 50 infected trees, and to fifteen yards around the larger outbreaks. It is anticipated that these modifications will result in considerable savings, although the success of the control measures will continue to depend largely on the efficiency with which new outbreaks are spotted by the survey parties.

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