The Control of Cacao Swollen Shoot Disease in Nigeria

J. M. THRESH

West African Cocoa Research Institute, Nigerian Substation, Moor Plantation, Ibadan, Nigeria

Swollen shoot disease was first discovered in Nigeria in 1944, during the first survey of the cacao-growing areas in the Western Region, where it is now known to be widespread in Ibadan and Abeokuta Provinces. The removal of infected trees was the only possible method of control (THRESH, 1958a) and between January 1946 and June 1950 one and a half million infected trees were destroyed by the Department of Agriculture in an unsuccessful attempt to eradicate the disease completely. It was then realized that this would be costly, difficult and unpopular, and control measures were abandoned in heavily infected parts of Ibadan and Abeokuta Provinces in 1950 and 1953. Elsewhere the cacao has been inspected regularly and new outbreaks treated immediately. This policy achieved limited success in restricting the build-up of virus in the cacao outside the abandoned areas, but increasing difficulty is being experienced in maintaining the situation, and the number of infected trees which were found and cut out increased from 476 in 1950 to 12 403 in 1956.

A review of the history and control of cacao swollen shoot disease in Nigeria was presented by LISTER and THRESH (1957a). The present paper discusses certain aspects of this work in detail and is based on observations by the survey parties responsible for the routine eradication control measures and by the staff of the Nigerian Substation of the West African Cocoa Research Institute.

THE AREAS OF MASS INFECTION

The present situation in the areas of mass infection

The abandoned areas of mass infection contain some of the best available cacao soils in the Western Region and involve approximately half the 225 000 acres of mature cacao in Ibadan Province, and approximately 17 000 of the 120 000 acres in Abeokuta Province. Thus virus is spreading unchecked in almost one seventh of the 989 000 acres of cacao recorded in the Western Region and the decision to abandon first one and then a second major growing area was a significant one which has influenced developments in the areas of mass infection and outside them.

When the two areas of mass infection were abandoned they contained a large number of infected trees, but there had been no detailed assessment of the extent of infection. However, at least 30 per cent of the trees were infected in densely planted areas east of Ibadan and numerous scattered outbreaks occurred elsewhere. Similarly, in the Ilaro area of Abeokuta Province the cacao around half the 104 villages contained diseased trees in 1953 and at

least 300 acres of mature cacao was infected. Observations made on naturally occurring outbreaks in Ibadan and Abeokuta Provinces give some indication of the recent rate of virus spread (THRESH, 1958b). Moreover, infection has become increasingly obvious to members of the survey staff traversing the cacao areas around Ilaro and Ibadan, where infection is now widespread. Indeed, HADLAND (unpublished information) has recently suggested that at least 5 000 000 trees are infected in Ibadan Province alone.

Significance of areas of mass infection

Inadequate information on the incidence of infection in Ibadan and Abeokuta Provinces and on the effect of virus on yield make it impossible to estimate the loss in crop caused by cacao viruses. Moreover, the amount of cacao handled annually by the grading stations gives only an approximate indication of production trends, as the internal movement of cacao varies between years. However, yields are apparently declining in the Ibadan area of mass infection, although they are increasing elsewhere in the province (HADLAND, unpublished information). Furthermore, yield records taken at selected sites indicate that the effect of virus depends on the growing conditions and on the length of time the trees have been infected (LISTER and THRESH, 1957b).

Clearly swollen shoot disease is an important factor reducing yields and the loss in crop increases annually, as more trees become infected and deteriorate. Precise experiments are now in progress to determine the effect of a range of Nigerian viruses on yield and the information obtained, together with the results of a proposed survey of the areas of mass infection, should eventually facilitate a more definite estimate of crop losses.

A further consequence of the uninterrupted spread of virus in the abandoned areas is that these are becoming increasingly dangerous foci of infection, which is spreading to the surrounding cacao. The precise significance of the abandoned areas is difficult to evaluate as naturally infected wild hosts may act as additional virus sources (THRESH, 1958b). Nevertheless, the movement of windborne mealybugs from the abandoned cacao probably accounts for the occurrence of many of the new outbreaks now being found elsewhere (LISTER and THRESH, 1957a). Consequently it is hardly surprising that the cutting-out parties are experiencing difficulty in restricting the spread of swollen shoot disease and that the number of newly discovered outbreaks has increased almost every year since 1947. This indicates that increasing difficulty will be experienced in the future, particularly as there is no practical method of checking the movement of windborne mealybugs which may be carried over large distances and probably for miles (STRICKLAND, 1950; CORNWELL, 1955).

Policy of the Department of Agriculture in areas of mass infection

The policy of the Department of Agriculture in the areas of mass infection has been to encourage the growing of crops other than cacao. Cacao seedlings are not available to farmers for planting within these areas and most of the trees cut out before 1950 are being replaced by citrus or oil palms. However, numerous small plots of cacao have been established by the farmers on their own initiative. These plots are frequently near infected trees and this un-

controlled replanting maintains the infection cycle. Consequently plans are being made by the Department of Agriculture for the rehabilitation of the cacao on more orderly lines and the best available planting material will be used on selected soils and brought under regular inspection. Obviously it would also be advantageous to plant the largest possible blocks and to remove all infected cacao trees and possible wild hosts of cacao viruses from within and around the farms. Under these conditions losses caused by swollen shoot disease are likely to be small (BENSTEAD, 1951 and 1953; THRESH, 1958b).

The best cacao immediately available for planting in the areas of mass infection will be from selected Amelonado or Amazon types. However, resistant or tolerant material may eventually be introduced. Alternatively, planting material may be protected from the effects of severe virus by mild strains. These possibilities and the use of barrier crops and insecticides for controlling the mealybug vectors of swollen shoot disease are being investigated by the W.A.C.R.I. (THRESH, 1958a), and the chances of successfully rehabilitating cacao in the areas of mass infection will probably be increased and the present downward trend in production reversed. Any reduction in the extent of the abandoned areas will increase the likelihood of controlling virus spread. Moreover, cutting out followed by replanting provides an opportunity of changing the present cultivation system, and yields per acre may be increased above their present unsatisfactory level.

DISCOVERY OF NEW OUTBREAKS

Large acreages of infected cacao are likely to remain in the areas of mass infection for some years and it will be essential to maintain a regular survey of the remaining cacao areas and to eradicate any outbreaks of virus found. Thus the amount of virus spread will largely depend on the efficiency with which new outbreaks are detected.

At present the only practical method of detecting field infections is by routine inspection for symptoms. Chemical methods of diagnosis have been evolved (HANCOCK, 1949; TINSLEY and USHER, 1954) but are not suitable for extensive use. Consequently the discovery of new outbreaks depends on the routine survey staff, who must detect trees with symptoms by inspection from ground level. Cacao in localities adjacent to the areas of mass infection is inspected every six months and the more remote cacao every year. These inspections are carried out by 20 to 22 Field Overseers under a headman and supervised by the Provincial Agricultural Officer. Inspection parties are based at the major cacao towns and villages and each party examines approximately 160 acres of cacao each working day. The annual cost of the inspection service is £170 000 and eight survey groups are in operation in Ibadan Province alone.

At the outset of the survey work the cacao buying stations were known, but there was little information on the distribution of the growing areas. These were often in remote or difficult country and the survey parties were greatly hampered by the lack of maps and access roads (HADLAND, 1951). Furthermore, virus symptoms are not always easy to find on infected trees. For example at Koroboto up to 10 per cent of the known infections may be symptomless when examined (THRESH, 1958c). Symptoms tend to be

inconspicuous during the dry season, when branches defoliate and swellings are destroyed by capsid attack or dieback. Similarly, symptoms are also difficult to find during the cool cloudy conditions in the rains, when trees grow slowly. These seasonal variations influence the efficiency of the routine surveys and partly explain why most new outbreaks are found at the beginning and end of the rains, when the trees grow vigorously and show conspicuous symptoms. Moreover, the likelihood of finding outbreaks is at a minimum in areas receiving their annual inspection during the dry season or at the height of the rains.

Thus it is hardly surprising that many outbreaks are missed by the survey parties for years until they involve more than 100 infected trees (LISTER and THRESH, 1957a). However, the survey parties have been working since 1946 and they should have gradually increased in efficiency, particularly as the cacao areas are now known and maps are available. There is no indication of this and each of the 65 new outbreaks found between 1954 and 1956, contained an average of 186 trees, compared with an average of 108 infected trees found in each of the 61 outbreaks discovered between 1947 and 1953 (*Figure 1*).

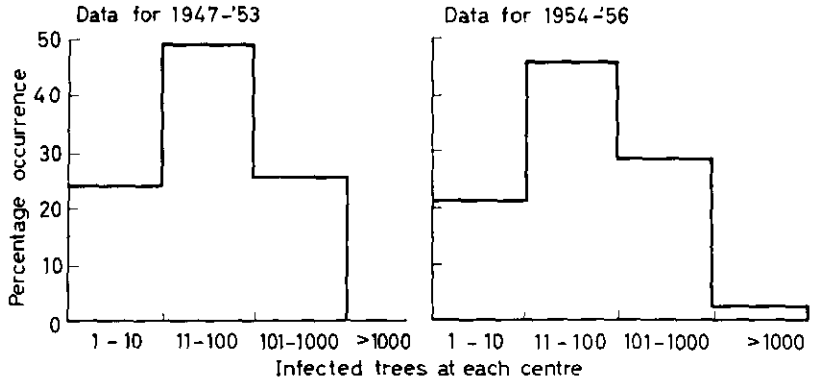

Figure 1. Frequency distribution of number of infected trees originally found at 61 new centres of infection discovered 1947–53 and at 65 centres discovered 1954–56

Ideally, outbreaks should be detected at an early stage when they can be eradicated easily and before they have become important secondary foci of infection. This has been achieved on a small scale (POSNETTE, 1943), although a similar inspection service operating throughout Nigerian cacao would be prohibitively expensive. Nevertheless, efforts are being made by the Department of Agriculture to increase the efficiency of the survey. Each member of the survey staff will in future be allocated an area of cacao, to examine for virus symptoms every six months. The work will be checked at irregular intervals by two specially supervised survey groups and some increase in efficiency is expected, particularly as more detailed maps are being prepared, using aerial photographs.

TREATMENT OF OUTBREAKS ON DISCOVERY

Eradication measures against swollen shoot disease have changed twice since 1946. At the outset only obviously infected trees were removed, but

the routine measures we
apparently healthy trees
were cut out as well. F
evolve a more rational e
tated an assessment of the

Difficulties experienced in
methods

A cutting-out policy i
trees is usually an ine
(POSNETTE, 1943; ANON
coppicing experiments.
controlled 18 of the 32
infected trees, but only o
the apparently healthy
outbreaks containing less
46 larger ones.

Table 1. Comparative efficiency

Size of outbreak (No. of infected trees	
>50	
11–50	
6–10	
1– 5	
Total ..	

*In addition to the trees found wi
†The fraction indicates the num

The frequent failure of
of the survey parties to d
One method of dealing
they are found with sy
This was the practice ad
(HAMMOND, 1957). How
survey parties to keep on
over, the method is funda
latent and missed infect
and subsequent ones. I
gerous sources of virus,
than severely affected t
trees (CORNWELL, 1956).

The infected trees w
several types, viz.:

(*1*) Trees with sympt

(*2*) Recently infected

the routine measures were then changed and between 1950 and 1955 the apparently healthy trees occurring within 30 yards of each treated outbreak were cut out as well. Recently a coppicing technique has been used to evolve a more rational eradication policy. The coppicing work also facilitated an assessment of the efficiency of the earlier measures.

Difficulties experienced in attempts to control swollen shoot disease by eradication methods

A cutting-out policy involving only the removal of obviously infected trees is usually an inefficient method of eradicating virus outbreaks (POSNETTE, 1943; ANON., 1945). For example in the recent Nigerian coppicing experiments, removing obviously infected trees would have controlled 18 of the 32 outbreaks which contained less than six obviously infected trees, but only one of the 48 larger outbreaks (*Table 1*). Removing the apparently healthy ' contact ' trees would have controlled 12 of the 16 outbreaks containing less than six obviously infected trees and 16 of the 46 larger ones.

Table 1. Comparative efficiency of two cutting-out treatments for eradication of outbreaks of cacao swollen shoot virus

Size of outbreak (No. of infected trees)	*No contacts cut**		*Immediate contacts cut**	
	Outbreaks eradicated†	*% eradicated*	*Outbreaks eradicated†*	*% eradicated*
>50	0/17	0·0	2/20	10·0
11–50	1/19	5·3	10/19	52·6
6–10	0/12	0·0	4/7	57·1
1– 5	18/32	56·2	12/16	75·0
Total ..	19/80	23·7	28/62	45·2

*In addition to the trees found with symptoms by a routine inspection of the standing trees from ground level.
†The fraction indicates the number of outbreaks successfully eradicated out of the total number treated.

The frequent failure of simple cutting-out measures is due to the inability of the survey parties to detect the latent and almost symptomless infections. One method of dealing with these missed infections is to cut them out as they are found with symptoms when treated outbreaks are reinspected. This was the practice adopted at first in Nigeria and is still used in Ghana (HAMMOND, 1957). However, it is time-consuming and inconvenient for the survey parties to keep on returning to the sites of treated outbreaks. Moreover, the method is fundamentally inefficient as virus may spread from the latent and missed infections in the interval between the initial treatment and subsequent ones. Indeed, latent infections may be particularly dangerous sources of virus, as they often support higher mealybug populations than severely affected trees and mealybugs may move from deteriorating trees (CORNWELL, 1956).

The infected trees which remain after an eradication treatment are of several types, viz.:

(*1*) Trees with symptoms which are difficult to spot

(*2*) Recently infected symptomless trees

(*3*) Virtually symptomless trees infected with very mild strains of virus
(*4*) Tolerant trees with inconspicuous symptoms.

Trees in the first category were detected by experienced spotters climbing into the canopy or by examining the branches and foliage when apparently healthy trees were felled. Tolerant trees were discovered by transmitting severe virus from infected trees with consistently mild symptoms. The remaining trees were detected by cutting them back to ground level and keeping the regeneration growth under regular inspection. Infected trees usually produce shoots with conspicuous symptoms and this coppicing technique is probably the most crucial of the available tests for demonstrating virus.

The relative distribution of latent and missed infections into the four categories has not been investigated in detail, but at Koroboto less than 10 per cent of all the infected trees were tolerant or infected with mild viruses. However, the distribution probably varies widely between outbreaks and seasons. Thus at three outbreaks found in Ibadan Province in 1954 and 1955 (*Table 2*), there was wide variation in the ratio of the number of infected trees detected before felling, to the number found subsequently. There was also considerable variation in the ratio of missed to latent infections and the greatest proportion of missed trees was at Adifa, where the farms were badly damaged by capsid attack and dieback and showed conspicuous symptoms of iron and nitrogen deficiency; additional evidence that virus symptoms are often inconspicuous on moribund trees.

Table 2. Results of experiments in Nigeria in coppicing outbreaks of cacao swollen shoot virus

Virus outbreak	*Total number of apparently healthy trees coppiced*	*No. of infections*		
		*Observed before felling**	*Additional revealed on felling†*	*Additional revealed by coppicing‡*
Ina Farm	274	20	4	7
Alagbe	764	70	11	6
Adifa	998	25	14	9

*By a routine inspection of the standing trees.
†By a thorough inspection of suspected trees at ground level.
‡By a regular inspection of the growth made after coppicing all the trees on which no symptom could be found.

Treatment of virus outbreaks between 1950 and 1955

Few outbreaks were expected to appear outside the areas of mass infection. Nevertheless, to increase the chances of eradicating any outbreaks of virus which did occur, the obviously infected trees were removed and also the adjacent apparently healthy trees occurring within 30 yards. There was some justification for cutting out the apparently healthy trees in contact with those found with symptoms (POSNETTE, 1943; ANON., 1945) and the recent coppicing experiments have confirmed this, but there was no evidence to warrant such drastic measures. However, the 30-yard treatments were continued, even though an increasing number of outbreaks were being found annually and the original intention of reducing the areas of mass infection was abandoned.

Between July 1950 and
cacao around 98 villages
control outbreaks involvi
distance of 200 yards aro
every three months and
infected trees were found
with the adjacent appare

The Department of Ag
of mass infection are com
keep separate records for
the cacao around a village
cut-outs are referred to as
they are done. This simpl
since 1950. Nevertheless,
trees found in the cacao a
is not always true and a
although it involves a co
the original one and some
the number of infected tr
compared with the numbe
similar to the value of
infected trees were cut ou
not follow that the Ghana
the ratios are not strictly
are only referred to as re-
outbreak.

The number of villages
increasing annually (*Tabl*
relation to the extent of t
as sugar beet yellows, whi
British Isles in a single sea
the type defined by VAN D
in considerable amount.

Table 3. The number of swollen s
si

Year of initial treatment	*Centres*
	in year of discovery
1950	0
1951	3
1952	8
1953	22
1954	7
1955	5
1956	—
1957	—

* Virus is considered to have been
found in 1956 and 1957.
† The fraction indicates the numb
number treated.

Between July 1950 and December 1955, virus outbreaks were found in the cacao around 98 villages and 114 341 trees were cut out in attempts to control outbreaks involving 10 087 obviously infected trees. The cacao to a distance of 200 yards around the cut-out areas was subsequently inspected every three months and the remaining cacao every six. A further 6 006 infected trees were found during these re-inspections and cut out, together with the adjacent apparently healthy trees occurring within 30 yards.

The Department of Agriculture records for treatments outside the areas of mass infection are compiled on a village basis and no attempt is made to keep separate records for individual outbreaks. Thus the first treatment in the cacao around a village is referred to as the initial one and all subsequent cut-outs are referred to as re-treatments, irrespective of the date on which they are done. This simple and convenient system has been used consistently since 1950. Nevertheless, it is misleading and implies that all the infected trees found in the cacao around a village belong to the same outbreak. This is not always true and a treatment may be recorded as a re-treatment, although it involves a completely new outbreak found many months after the original one and some distance from it. Thus the ratio of 1:1·7 between the number of infected trees cut out during the re-treatment of outbreaks, compared with the number removed at the outset, is unexpectedly high and similar to the value of 1:2·1 recorded in Ghana, where only obviously infected trees were cut out until 1957 (HAMMOND, 1957). However, it does not follow that the Ghana and Nigerian treatments are equally efficient, as the ratios are not strictly comparable and cutting-out treatments in Ghana are only referred to as re-treatments if they are within 30 yards of a treated outbreak.

The number of villages where outbreaks were found for the first time is increasing annually (*Table 3*), although the build-up is remarkably slow in relation to the extent of the abandoned areas and the spread of viruses such as sugar beet yellows, which may infect virtually the whole root crop in the British Isles in a single season. Clearly swollen shoot is a ' crowd ' disease of the type defined by VAN DER PLANK (1948) as one which does not spread far in considerable amount.

Table 3. The number of swollen shoot centres where eradication measures have been applied each year since 1950 and the control achieved

Year of initial treatment	*Centres eradicated by initial and re-treatments**						*Centres definitely eradicated†*
	in year of discovery	*within 1 year*	*within 2 years*	*within 3 years*	*within 4 years*	*within 5 years*	
1950	0	2	0	1	0	0	3/6
1951	3	0	0	0	0	—	3/3
1952	8	2	1	2	—	—	13/14
1953	22	1	2	—	—	—	25/35
1954	7	3	—	—	—	—	10/15
1955	5	—	—	—	—	—	5/22
1956	—	—	—	—	—	—	0/28
1957	—	—	—	—	—	—	0/21

* Virus is considered to have been eradicated from treated centres of infection where infected trees were not found in 1956 and 1957.

† The fraction indicates the number of centres where outbreaks were successfully eradicated out of the total number treated.

The latent period of infection in trees is usually less than one year but may be up to two (POSNETTE, 1947; CROWDY and POSNETTE, 1947; LISTER and THRESH, 1955). Thus missed infections may still be found around outbreaks treated in 1956 and 1957 and outbreaks are not considered to have been eradicated unless infected trees were not found in each of these years. On this criterion virus has already been eradicated from the cacao around 59 of the 95 village centres of infection treated before 1956. At 39 centres no re-treatments were necessary and at five others they were only necessary the year the original outbreaks were discovered. Centres readily eradicated in this way were usually small and contained an average of 77 infected trees, compared with an average of 123 infected trees elsewhere.

Failure of the eradication measures was sometimes due to the appearance of a relatively small number of infected trees on or near the edge of the treated areas. These outlying infections usually appeared within three years of the initial treatments and had probably been infected by spread from the originally treated centres. They were readily controlled by one or more re-treatments involving only a small proportion of the perimeter trees.

In the cacao around 37 villages, virus has not been eradicated, or has only been eradicated after re-treatments carried out for more than three years, and new outbreaks are being started by mealybugs coming in from outside sources of infection. Thus new and remote outbreaks appear in the cacao around villages where no virus has been found for several years after earlier treatments. Furthermore, several of the village centres requiring numerous re-treatments are close to the abandoned areas and virus is clearly spreading into the cacao from outside, so that the cutting out measures are merely reducing the amount and extent of secondary spread.

Virus is considered to have been eradicated from farms in Ghana where no infected trees are found during 24 consecutive monthly inspections of the cacao in or within 30 yards of a treated farm. On this criterion virus has been eradicated from two per cent of the treated farms (HAMMOND, 1957) compared with 61 per cent of the village centres in Nigeria which have remained free from infection for at least two years. Clearly the Nigerian 30-yard treatments are very much more effective, although they involve large numbers of apparently healthy trees and an average of 10 were destroyed for every one found with symptoms (LISTER and THRESH, 1957a).

Recent experiments on control of swollen shoot disease by eradication methods

In 1954 a series of coppicing experiments was started to investigate whether the large scale destruction of apparently healthy trees in the 30-yard cutting-out treatments was justified, or whether comparable results could be achieved less drastically. Many outbreaks were selected and the obviously infected trees uprooted. All the apparently healthy trees within 30 yards of the obvious infections were then indexed by coppicing them and keeping the regeneration growth under regular symptom observation. Records were kept of the number of infected stumps found around each outbreak at each inspection. Around 48 of the outbreaks detailed observations were also made on the distribution of the infected trees in relation to those removed at the outset.

Detailed results of the coppicing experiments will be presented elsewhere, but a preliminary analysis shows great variation in the number of infected stumps found, even around outbreaks of similar size. More infected stumps were usually found around large outbreaks than around small ones and this is to be expected from the available information on spread (THRESH, 1958b). Of the infected stumps occurring within 30 yards of the cut-out trees, 51 per cent occurred within 5 yards, 35 per cent occurred between 5 and 10 yards, 8 per cent occurred between 10 and 15 yards and the remaining 6 per cent occurred between 15 and 30 yards; and the distribution was similar around outbreaks of all sizes. However, the intensity of latent infection is highest around the largest outbreaks, which explains why small ones are readily eradicated and justifies the use of cutting out measures based on the size of outbreak treated (*Table 1*).

When estimating the most efficient and economical cutting-out measures to be adopted for treating outbreaks, the additional latent and missed infections eradicated by a more drastic treatment must be balanced against the increased number of healthy trees involved. The coppicing experiments clearly show that the policy of treating the apparently healthy trees around all outbreaks to a uniform distance of 30 yards was unnecessarily severe, particularly around the smallest outbreaks. It is now recommended that apparently healthy trees should be removed to distances of 5, 10 and 15 yards around outbreaks of less than 6, 6 to 50 and 50 to 200 infected trees, respectively. The intensity of latent and missed infection in the apparently healthy trees remaining outside the cut-out areas will then be usually less than 5 per cent, which is not sufficiently high to justify the adoption of more drastic measures. However, the standing trees around each cut-out area must be inspected at regular intervals to ensure that the missed infections are detected soon after they produce obvious symptoms. Infected trees found during these re-inspections should be treated as new outbreaks and eradication measures applied according to the number of infections found.

The latest proposals will result in considerable economies, compared with the original cutting-out policy. Provisional changes were adopted in 1956 and until the end of 1957 the apparently healthy trees around outbreaks involving 1 to 10, 11 to 50 and >50 obviously infected trees were treated to 5, 15 and 30 yards respectively. The number of apparently healthy trees cut out in the treatment of 126 outbreaks totalling 10 379 infected trees was reduced from an estimated 90 947 (which would have been cut out if the 30-yard treatments had been applied) to 55 451; a saving of 35 596 on which the sum of £7 119 would have been paid out in compensation if the trees had been destroyed. If the latest recommendations had been adopted only 24 822 trees would have been cut out; a further saving of 30 529 trees and £6 106.

SUMMARY

An account and analysis is presented of the work of the Nigerian Department of Agriculture in attempts to control cacao swollen shoot disease. The decision to abandon eradication measures in two heavily infected areas is partly responsible for the deterioration in the position in recent years. Virus is spreading without check and causing a progressive decline in yield

in two abandoned areas, which are acting as dangerous foci of infection. The present situation in the abandoned areas is assessed and an outline given of possible development within them.

The present survey system is described and some of the difficulties experienced by the inspection parties discussed. Details are also given of proposals intended to increase the efficiency of the inspection service, which partly determines the build-up of infection outside the abandoned areas.

The routine measures used in attempts to eradicate virus from infected farms are described and their efficiency assessed. Until 1950 only trees found with symptoms were cut out, and only the smallest outbreaks were eradicated efficiently. Since 1950 the trees found with symptoms were cut out, together with the adjacent apparently healthy trees within 30 yards and virus was eradicated from the cacao around approximately two thirds of the treated villages. However, large numbers of apparently healthy trees were involved and coppicing experiments indicate that comparable success could have been achieved less drastically by treating outbreaks according to their size.

(Received August 1958)

REFERENCES

ANON. (1945). 'Swollen shoot of cacao. How to recognize and control.' *Memor. W. Afr. Cocoa Res. Inst.* West African Cocoa Research Institute, Tafo, Ghana

BENSTEAD, R. J. (1951). 'Cocoa re-establishment.' *Proceedings of the Cocoa Conference, London*, p 111

BENSTEAD (1953). 'Swollen shoot disease.' *W.A.C.R.I. Paper No. 18. Proceedings of the West African International Cacao Research Conference*, p 25

CORNWELL, P. B. (1955). 'Mealybug studies.' *Rep. W. Afr. Cocoa Res. Inst.* (1954–55) 45

CORNWELL, P. B. (1956). 'Some aspects of mealybug behaviour in relation to the efficiency of measures for the control of virus diseases of cacao on the Gold Coast.' *Bull. ent. Res.* **47,** 137

CROWDY, S. H. and POSNETTE, A. F. (1947). 'Virus diseases of cacao in West Africa. II. Cross-immunity experiments with viruses 1A, 1B, 1C and 1D.' *Ann. appl. Biol.* **34,** 403

HADLAND, J. R. G. (1951). 'The methods and functions of the Nigerian cocoa survey.' *Proceedings of the Cocoa Conference, London*, p 143

HAMMOND, P. S. (1957). 'Notes on the progress of pest and disease control in Ghana.' *Proceedings of the Cocoa Conference, London.* In press

HANCOCK, B. L. (1949). 'A laboratory colour test for the diagnosis of swollen shoot of *Theobroma cacao*.' *Trop. Agriculture, Trin.* **26,** 54

LISTER, R. M. and THRESH, J. M. (1955). 'Virus research.' *Rep. W. Afr. Cocoa Res. Inst.* (1954–55) 93

LISTER, R. M. and THRESH, J. M. (1957a). 'The history and control of cocoa swollen shoot virus in Nigeria.' *Proceedings of the Cocoa Conference, London.* In press

LISTER, R. M. and THRESH, J. M. (1957b). 'Virus research.' *Rep. W. Afr. Cocoa Res. Inst.* (1955–56) 80

POSNETTE, A. F. (1943). 'Control measures against swollen shoot virus disease of cacao.' *Trop. Agriculture, Trin.* **20,** 116

POSNETTE, A. F. (1947). 'Virus diseases of cacao in West Africa. I. Cacao viruses 1A, 1B, 1C and 1D.' *Ann. appl. Biol.* **34,** 388

STRICKLAND, A. H. (1950). 'The dispersal of Pseudococcidae (Hemiptera Homoptera) by air currents on the Gold Coast.' *Proc. R. ent. Soc. Lond. A*, **25,** 1

THRESH, J. M. (1958a). 'The control of cacao swollen shoot disease in West Africa. A review of the present situation.' *Tech. Bull. No. 4.* West African Cocoa Research Institute

THRESH, J. M. (1958b). 'The spread of virus disease in cacao.' *Tech. Bull. No. 5.* West African Cocoa Research Institute

THRESH, J. M. (1958c). 'Virus research.' *Rep. W. Afr. Cocoa Res. Inst.* (1956–57) 71

TINSLEY, T. W. and USHER, G. (1954). 'A colour test for detecting swollen shoot in Gold Coast cacao.' *Nature, Lond.* **174,** 87

VAN DER PLANK, J. E. (1948). 'The relation between size of fields and the spread of plant disease into them. I. Crowd diseases.' *Emp. J. exp. Agric.* **63,** 134